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ASSOCIATIONS OF POWER AT $\dot{V}O_{2peak}$ AND ANAEROBIC THRESHOLD WITH RANK IN BRITISH HIGH PERFORMANCE JUNIOR SURFERS

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ABSTRACT

Purpose. The objective of this study was to determine the relationships of peak oxygen uptake ($\dot{V}O_{2peak}$), power at $\dot{V}O_{2peak}$ and power at the anaerobic threshold (AT) with national ranking in a sample of British high performance junior surfers. **Methods.** Eighteen male surfers (aged 15.4 ± 1.4 years) from the British Junior Surfing team were tested for $\dot{V}O_{2peak}$ and AT using an adapted kayak ergometer; national ranking was used to indicate performance level. The AT was identified as the point at which $\dot{V}E/\dot{V}O_2$ started to rise without a concomitant increase in $\dot{V}E/\dot{V}CO_2$. Spearman's rank (r_s) and partial correlations (r_p) controlling for age were used to identify the relationships between the physiological variables and national ranking. **Results.** Mean $\dot{V}O_{2peak}$ was 3.1 ± 0.5 l · min^{-1} (47.7 ± 7.2 ml · kg^{-1} · min^{-1}) and mean AT occurred at 48.1 ± 12.2 W. There were significant correlations between national ranking and power at $\dot{V}O_{2peak}$ ($r_s = -0.549$, p = 0.028), power at AT ($r_s = -0.646$, $p = 0.009$), and age ($r_s = -0.579$, $p = 0.012$). Significant partial correlations were established controlling for age between national ranking and power at $\dot{V}O_{2peak}$ ($r_p = -0.839$, $p = 0.000$) and power at AT ($r_p = -0.541$, $p < 0.046$). **Conclusions.** The power outputs associated with $\dot{V}O_{2peak}$ and AT were significantly related to surfer ranking in this sample. However, due to the low coefficient of determination associated with the AT/ranking relationship, AT does not discriminate well between the ranking of surfers. These findings support the inclusion of power at $\dot{V}O_{2peak}$ in assessment batteries for junior competitive surfers.

Key words: physiology, sport, surfer, fitness, testing

Introduction

Competitive surfing is increasing in popularity worldwide and, concurrently, interest is growing in surf-related sport science such as in determining key performance predictors of success in this sport. While success at any level within surfing requires a high level of skill execution and technical ability [1], it is possible that physiological attributes may also be important at higher levels of performance [2]. The activity profile and the physiological demand of surfing have been previously reported [2–5]. These analyses have determined that a typical surfing session combines repeated intense anaerobic activity interspersed with aerobic exercise [3, 5]. Investigations of surfing have found that various physiological and anthropometrical parameters can be used to predict performance in groups of surfers with varying levels of ability or discriminate between groups of surfers that differ in ability [6–11]. Loveless and Minahan [12] identified that swim bench ergometry is a useful and reliable method for assessing aerobic fitness in surfers, and it has been a widely adopted tool in assessing surfers [3, 7–10, 13]. Mean peak oxygen uptake ($\dot{V}O_{2peak}$) of adult surfers during upper body ergometry has been found to be 3.3 L · min^{-1} (46.84 ml · kg^{-1} · min^{-1}) [1, 2, 4, 10, 14], whereas junior recreational and competitive surfers were found to average 2.5 ± 0.5 l · min^{-1} and 2.7 ± 0.35 l · min^{-1}, respectively. The differences between adult and junior surfers were explained by maturational factors [9]. Thus far, the use of $\dot{V}O_{2peak}$ as a measure to differentiate groups of surfers has been unsuccessful, where no significant associations were found with competitive ranking. However, power output associated with $\dot{V}O_{2peak}$ was found to significantly correlate with ranking [10].

Various studies have suggested that power output associated with various levels of blood lactate accumulation could be used to differentiate the ability and rank of both adult and junior surfers [8, 10]. However, blood sampling for lactate is not always possible due to the availability of equipment or the lack of participant consent. According to Whipp [15], anaerobic threshold (AT) testing can serve as a non-invasive alternative of assessing the lactate threshold (LT). Of the number of ways AT can be measured, the $\dot{V}E/\dot{V}O_2$ method [16, 17] has been described as the easiest to administer and shows good test–retest validity [18]. As mentioned previously, lactate thresholds have been able to discriminate between groups competing at higher and lower levels in surfing. However, no study has yet evaluated whether AT can discriminate between ranks of surfers.

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As the first to do so, this study aimed to evaluate whether any associations exist between $\dot{V}O_{2peak}$, power at $\dot{V}O_{2peak}$ and power at the AT with national ranking.

Material and methods

This observational study received research ethics committee approval and was conducted in accordance with the Declaration of Helsinki. Eighteen high performance male (mean age 15.4 ± 1.4 years) surfers were recruited from the British Junior Surfing team. All participants were highly trained surfers, regularly competing in national- and international-level competitions. All participants provided written informed consent to participate in the research after parent or guardian approval was obtained.

After recording resting heart rate, blood pressure was measured using a Dekomet mercury sphygmanometer (Accosan, UK) and Classic II S.E. stethoscope (Littman, Germany). Cut-off values for participation in the exercise test were a resting heart rate of 100 bpm or above, systolic blood pressure of 140 mmHg or above, and a diastolic blood pressure of 90 mmHg, as these values would indicate mild hypertension [19].

Peak oxygen uptake ($\dot{V}O_{2peak}$) was predicted on the basis of a sub-maximal test as institutional ethical protocol prevented maximal effort testing of adolescents. The test involved paddling on an adapted K1 kayak ergometer (Australian Sports Commission, Australia) in 3 min stages starting at 20 W and increased by 10 W every 3 min. Heart rate (HR) was monitored throughout the test via a Polar S810i heart rate monitor (Polar Electro, Finland) and recorded on a second by second basis. The exercise test was ended when the participant achieved a HR of 85% or greater of age-adjusted maximum HR, calculated using the equation: 208 – (0.7 × age) [20], or due to volitional exhaustion. Gas analysis was obtained via a face mask (Hans Rudolph, USA) using the Metalyzer 3B (Cortex Biophysik, Germany) metabolic system. The system was calibrated with every hour using a 3 L syringe (Hans Rudolph, USA) for the volume tranducer. The gas analyser was calibrated using both ambient air and a calibration gas (18.23% O_2 and 2.07% CO_2). The pressure sensor was calibrated using a digital barometer (Oregon Scientific, USA). All calibrations were performed via a laptop computer (Toshiba Europe, Germany). Fingertip capillary blood samples were examined for blood lactate concentration using an YSI 2300 stat analyser (YSI, USA).

Peak oxygen uptake ($\dot{V}O_{2peak}$) was estimated by extrapolating the linear HR/$\dot{V}O_2$ relationship to age-predicted maximum HR. Power at $\dot{V}O_{2peak}$ was estimated by extrapolating the power/HR relationship in the same manner. The anaerobic threshold was determined by calculating 30 s averages for $\dot{V}O_2$, $\dot{V}E$ and $\dot{V}CO_2$. The AT was identified as the point at which $\dot{V}E/\dot{V}O_2$ started to rise without a concomitant increase in $\dot{V}E/\dot{V}CO_2$ [21]. Power output and $\dot{V}O_2$ at the AT were reported in absolute terms and as a percentage of the maximum predicted at $\dot{V}O_{2peak}$.

The physiological assessment was performed one month before the completion of the competitive year. Rankings were taken from the national junior rankings at the end of the competitive year. Statistical analyses were performed using SPSS ver. 20 (IBM, USA). Spearman's rank correlations were computed between the physiological parameters and the post-season national rankings of the surfers. Further analyses were performed through partial correlations between the post-season national rankings and the physiological parameters controlling for age. Least squares bivariate regressions between the physiological measures and the national ranking were produced using Microsoft Excel 2013 (Microsoft, USA). The significance level was set at $\alpha = 0.05$.

Results

The mean values and standard deviation for each of the physiological variables are presented in Table 1. The individual participant correlations for the HR/$\dot{V}O_2$ relationship ranged between $r = 0.80$ and $r = 0.96$.

Spearman's rank correlations revealed that there were significant correlations between national ranking and power at $\dot{V}O_{2peak}$ ($r_s = -0.549$, $p = 0.028$; Figure 1), national ranking and power at AT ($r_s = -0.646$, $p = 0.009$; Figure 2), and national ranking and age ($r_s = -0.579$, $p = 0.012$). $\dot{V}O_{2peak}$ scores were not significantly correlated with national ranking ($r_s = -0.405$, $p = 0.097$). Partial correlations controlling for age indicated significant relationships between national ranking and power at $\dot{V}O_{2peak}$ ($r_p = -0.839$, $p = 0.000$) and national ranking and power at AT ($r_p = -0.541$, $p < 0.046$).

A much larger bivariate coefficient of determination (r^2), which accounted for 79% of the variation between power at $\dot{V}O_{2peak}$ and national ranking (Figure 1), was found when compared with 39% of the variation accounted for between power at AT and national ranking (Figure 2). This is explained by the impact of the protocol used to determine power at AT, where there is a clustering of individual values at 40 W with nearly the

Table 1. Physiological variables of the sample ($n = 18$)

Measure	Mean ± *SD*
Age (years)	15.6 ± 1.3
Stature (cm)	171.0 ± 7.3
Body mass (kg)	64.1 ± 6.6
$\dot{V}O_{2peak}$ (l · min^{-1})	3.1 ± 0.5
$\dot{V}O_{2peak}$ (ml · kg^{-1} · min^{-1})	47.7 ± 7.2
Power output at $\dot{V}O_{2peak}$ (W)	97.6 ± 14.1
$\dot{V}O_2$ at AT (l · min^{-1})	1.6 ± 0.4
Power output at AT (W)	48.1 ± 12.2

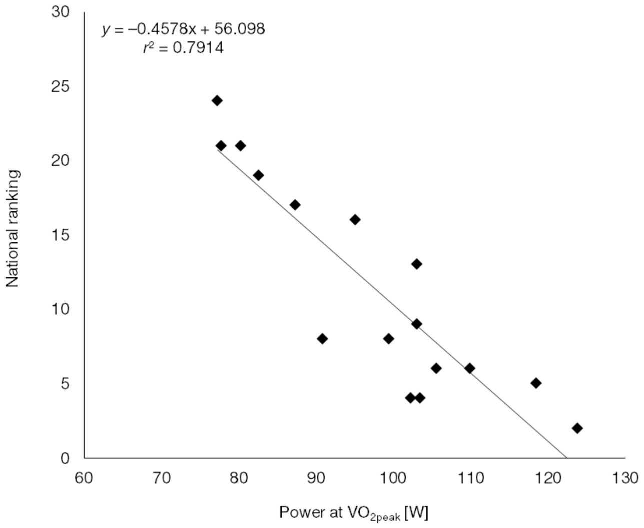

Figure 1. The relationship between national ranking and power at $\dot{V}O_{2peak}$

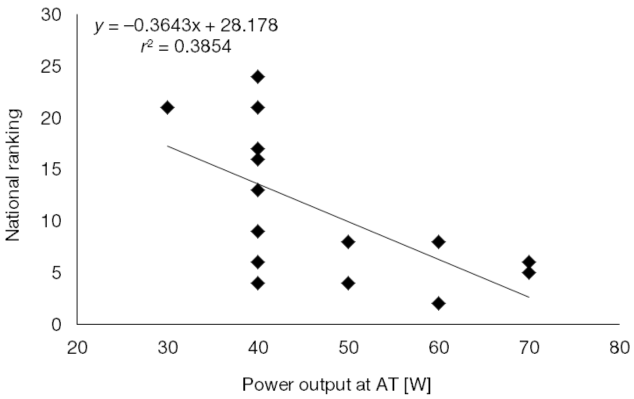

Figure 2. The relationship between national ranking and power at AT

whole range of national rankings represented at this power output. This indicates that power output at AT does not effectively discriminate between national rankings.

Discussion

This is the first study to report the physiological characteristics of young British male surfers. In doing so, we found that the absolute ($l \cdot min^{-1}$) and relative ($ml \cdot kg^{-1} \cdot min^{-1}$) $\dot{V}O_{2peak}$ scores were not significantly correlated with national ranking and considerably lower than that presented by Lowdon and Pateman (70.2 $ml \cdot kg^{-1} \cdot min^{-1}$) [14]. However Lowdon and Pateman's values are considerably higher than those reported by other authors in studies relating to surfers, possibly due to the nature of the employed protocol. The values in the current study are slightly lower than those presented by Mendez-Villanueva et al. [10] for adult surfers competing in top-level European events (3.3 ± 0.3 $l \cdot min^{-1}$ or 50.0 ± 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$) and the absolute oxygen uptake values for regional-level surfers (3.4 ± 0.4 $l \cdot min^{-1}$) but similar to the relative values presented for regional-level surfers (47.9 ± 6.3 $ml \cdot kg^{-1} \cdot min^{-1}$). This comparison suggests that maximal oxygen uptake has little utility in differentiating adult and junior surfers. It should be considered that although the participants in the current study were all part of a national team, only a subset of these would go on to compete at the international level and thus be comparable in performance with the top European surfers in Mendez-Villanueva et al. [10]. The differences in the absolute oxygen uptake values between the junior surfers in the current study and the regional-level surfers [10] are most likely due to differences in body mass of the two groups (mean body mass values of 71.1 ± 2.6 kg and 64.1 ± 6.6 kg, respectively).

Loveless and Minahan [9] measured the peak oxygen uptake of competitive and recreational junior surfers. The competitive surfers were all part of the Australian junior squad and, as such, provide a comparative sample for the participants of the current study, with consideration that the Australian surfers mean age was 18 ± 1 years for the competitive surfers and 18 ± 2 years for the recreational surfers. The peak values for the participants in the present study demonstrated higher values than both the recreational (2.5 ± 0.5 $l \cdot min^{-1}$) and competitive (2.7 ± 0.4 $l \cdot min^{-1}$) groups of Australian surfers who performed a comparable incremental paddling ergometer test.

The values in the current study were also lower than those reported by Meir et al. [4] for recreational surfers, who found maximal oxygen uptake values to be 3.8 ± 0.8 $l \cdot min^{-1}$ or 54.2 ± 10.2 $ml \cdot kg^{-1} \cdot min^{-1}$. The values for the junior surfers in this study were higher than those reported by Lowdon [22] for collegiate surfers in tests involving tethered board paddling (2.9 ± 0.04 $l \cdot min^{-1}$ or 40.4 ± 2.9 $ml \cdot kg^{-1} \cdot min^{-1}$) and hand cranking (3.0 ± 0.4 $l.min^{-1}$ and 41.6 ± 4.0 $ml \cdot kg^{-1} \cdot min^{-1}$). The values in both the current study and Lowden were lower than those reported by Meir et al. [4]. It is surprising that recreational surfers achieved higher values than competitive surfers. However, these differences might be due to the adopted testing protocol, the small sample size as in the study of Meir et al. ($n = 6$) [4] or the comparatively large variation in the maximal oxygen uptake values of that study (± 10.2 $ml \cdot kg^{-1} \cdot min^{-1}$). Moreover, we can assume that competitive surfers focus their sporting activities mainly around surfing, whereas recreational surfers might participate in other sports to a greater extent and thus might present fitness profiles influenced by these other sports.

The power output associated with peak oxygen uptake in the present study was lower than the values reported for national-level adult surfers (205.0 ± 54.2 W) [7], European- (154.7 ± 36.8 W) and regional-level (117.7 ± 27.1 W) adult surfers [10] and recreational (199 ± 24.0 W) and junior (199.0 ± 45.0 W) competitive surfers [9]. This may reflect the younger age of our participants (mean age 15.6 years) compared with those of the above-mentioned studies. The development of muscle mass in young males accelerates throughout late adolescence, with attainment of adult mass by the early twenties. Given that the surfers in the current study were aged 14 to 16 years, growth and maturation will likely influence power output values. The lower values seen in the current study may also be the result of differences in testing equipment. Many of the popular ergometers used to assess surfers are air braked, thus the determined power outputs can vary throughout a protocol.

Unlike a study of male surfers aged 18 years [9], the power output associated with maximal oxygen uptake significantly correlated with the national ranking of the surfers (r_s = –0.549, p = 0.028; r_p = –0.839, p = 0.000). A similar relationship was found by Mendez–Villanueva et al. [10] between national ranking and power output associated with peak oxygen uptake in European-level surfers (r = –0.65, p < 0.01), thus supporting the suggestion that power output associated with peak oxygen uptake is an important predictor of ability in competitive surfers. The significant relationships between power output associated with AT (r_s = –0.646, p = 0.009; r_p = –0.541, p = 0.046) mirror the findings of Fernandez-Lopez et al. [8], who found that the power outputs associated with the lactate threshold and the onset of blood lactate accumulation were significantly correlated with the ranking position of professional junior Basque surfers. This was similar in the case of Mendez-Villanueva et al. [10], who found that the power output associated with a blood lactate concentration of 4 mmol · l^{-1} (LT_4) could differentiate European- and regional-level surfers and predict ranking in a single competition.

The significant relationship found between AT and national ranking (r = 0.54, p = 0.012) suggests that power at AT as measured by expired gas analysis using ventilatory equivalents can provide a useful measure of fitness in the assessment of surfers. However, given the low r^2 value of 0.385, there is little possibility of being able to use AT as a predictor of surfing competitive rank. In contrast, the correlation of power at $\dot{V}O_{2peak}$ with rank, with an r value of 0.549 and r^2 of 0.788, warrants consideration. The results of this study suggest that power at $\dot{V}O_{2peak}$ is a very important physical fitness characteristic that can discriminate the national ranking of surfers.

The results of this study suggest that while aerobic fitness is an important component for surfers, the value of $\dot{V}O_{2peak}$ cannot be used to differentiate between ranks of junior male surfers. However, power output at $\dot{V}O_{2peak}$ is related to the ranking of junior male surfers. Coaches and sports scientists wishing to evaluate the potential performance of surfers need not undertake complex gas analysis measures and can instead utilise simpler measures of peak power during maximal aerobic paddling exercises in order to rank the potential of their participants. If gas analysis is to be used then the use of AT threshold should be considered if participants are reluctant to undertake blood sampling for lactate analysis.

Conclusions

The $\dot{V}O_{2peak}$ values of competitive junior British surfers are similar to those reported elsewhere but are not significantly related to competitive ranking. Instead, power output at $\dot{V}O_{2peak}$ and the anaerobic threshold were significantly related to ranking in this sample and, as such, indicate that upper body aerobic power might be an important determinant for achieving success in competitive surfing in male junior age groups.

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