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Author

Minahan, Clare L, Pirera, Danielle J, Sheehan, Beth, MacDonald, Luke, Bellinger, Phillip M

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Author's names and affiliations

Clare L Minahan^a, Danielle J Pirera^b, Beth Sheehan^a, Luke MacDonald^{a,c}, and Phillip M Bellinger^a,

- a. Griffith University Sports Science, School of Allied Health Sciences, Griffith University, Gold Coast, Australia.
- b. Surfing Australia High Performance Centre, Casuarina Beach, Australia.
- c. Centre of Excellence for Applied Sport Science Research, Queensland Academy of Sport, Department of National Parks, Sport and Racing, Level 1 Queensland Sport & Athletics Centre, 468 Kessels Rd, Nathan, Queensland 4111, Australia.

Correspondence

P. Bellinger, Griffith University Sports Science, School of Allied Health Sciences, Griffith University, QLD 4222, Australia. Email: p.bellinger@griffith.edu.au

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Tables 2

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Abstract

This study compared determinants of a 30-s all-out paddling effort (30-s sprint-paddling test) between junior surfboard riders (surfers) of varying ability. Eight competitive (COMP) and eight recreational (REC) junior male surfers performed a 30-s sprint-paddling test for the determination of peak power output and the accumulated O₂ deficit. Surfers also performed an incremental-paddling test for the determination of the O₂ uptake-power output relationship that was subsequently used to calculate the accumulated O₂ deficit for the 30-s sprint-paddling test. Peak power output (404 ± 98 vs. 292 ± 56 W, respectively; $p = 0.01$) and the accumulated O₂ deficit (1.60 ± 0.31 vs. 1.14 ± 0.38 L, respectively; $p = 0.02$) were greater in COMP compared to REC surfers whereas peak O₂ uptake measured during the incremental paddling test was not different (2.7 ± 0.1 vs. 2.5 ± 0.2 L/min, respectively; $p = 0.11$). Surfing experience was positively associated with peak power output and the accumulated O₂ deficit ($p < 0.05$). A higher peak power output and a larger accumulated O₂ deficit observed in COMP compared to REC surfers during a 30-s sprint paddling test suggests that surfboard riding promotes the development of the anaerobic energy systems. Furthermore, peak power output determined during 30-s of sprint paddling may be considered as a sensitive measure of surfing ability or experience in junior male surfers.

Key words: Surfboard riding; Surfing; Peak power output; Upper-body exercise; Anaerobic power and capacity

Introduction

When an athlete dominates a sport across several events (e.g., Michael Phelps – swimming), or for a long period of time (e.g., Kelly Slater – surfboard riding), it prompts questions about the unique physiological characteristics of these athletes that underpins their successful performance. The physiological characteristics of swimmers (Gullstrand & Holmer, 1983; Lätt, Jürimäe, Mäestu, Purge, Rämson, Haljaste, Keskinen, Rodriguez, & Jürimäe, 2010; Vaccaro, Clarke, & Morris, 1980), runners (Barnes, McGuigan, & Kilding, 2014; Maresh, Sheckley, Allen, Camaione, & Sinatra, 1991; Rabadán*, Díaz*, Calderón, Benito, Peinado, & Maffulli, 2011), rowers (Bourgois, Steyaert, & Boone, 2014; Hagerman, 1984; Mahler, Nelson, & Hagerman, 1984), and cyclists (Lucía, Pardo, Durántez, Hoyos, & Chicharro, 1998; Moseley, Achten, Martin, & Jeukendrup, 2004; Mujika & Padilla, 2001) have been well documented. In contrast, few previous studies have examined the physiological characteristics of surfboard riders (surfers) (Farley, Harris, & Kilding, 2012a; Loveless & Minahan, 2010; Lowdon, Bedi, & Horvath, 1989; Mendez-Villanueva & Bishop, 2005; Méndez-Villanueva, Perez-Landaluce, Bishop, Fernandez-García, Ortolano, Leibar, & Terrados, 2005) despite the emerging profile of surfboard riding (surfing) as one of the world's most popular and competitive professional sports (Booth, 2005). Determination of the physiological characteristics of competitive athletes, and the comparison of physiological characteristics among surfers of varying ability, provide important information for talent identification and the prescription of specific training programs. In order for coaches to create and implement specific physical training programs and/or identify talent, they must first have access to fundamental information concerning the relative contribution of energy metabolism and other physiological factors that contribute to the performance specialty.

The activity pattern associated with competitive surfing comprises low-intensity paddling, interspersed by high-intensity bouts of all-out paddling with short-recovery periods (Farley, Harris, & Kilding, 2012b; Mendez-Villanueva, Bishop, & Hamer, 2006). Furthermore, despite the proposition that surfers require exceptional cardiorespiratory endurance, peak O₂ uptake cannot

differentiate surfers of varying ability (Loveless & Minahan, 2010; Mendez-Villanueva & Bishop, 2005). In contrast, Farley et al. (Farley et al., 2012a) demonstrated that “season ranking” was associated with peak power output achieved during a 10-s all-out paddling bout in competitive surfers. In addition, superior spring paddling ability has been highlighted in adult surfers when compared to junior surfers (Sheppard, Osborne, Chapman, & Andrews, 2012), as well as surfers of higher competition level (Sheppard, Nimphius, Haff, Tran, Spiteri, Brooks, Slater, & Newton, 2013). This suggests that the capability of a surfer to produce a high rate of energy anaerobically may be better able to differentiate surfers of varying ability when compared to peak aerobic power. Furthermore, it is reasonable to suggest that a larger capacity for anaerobic energy production may be important for successful wave-riding given the intense, prolonged (up to 3 min) paddling that ensues as the surfer paddles back beyond the breaking waves after wave-riding (Farley et al., 2012b). No previous study has measured and compared anaerobic energy production during short-term exercise between competitive and recreational surfers.

A larger accumulated O₂ deficit determined during a 30-s all-out paddling effort would suggest a greater contribution from the anaerobic energy systems and provide some evidence of anaerobic energy system augmentation (e.g., via training). Indeed, Medbo and Burgers (1990) demonstrated significantly higher (30% higher) accumulated O₂ deficit values for sprint-trained athletes when compared to untrained and endurance-trained individuals when measured during a 30-s maximal-cycling effort (Medbø & Burgers, 1990). In the present study, we used a swim-bench ergometer to determine and compare power output and energy provision during a 30-s sprint-paddling test between junior male recreational and competitive surfers. The measurement of peak power output and the relative contribution of energy systems to a 30-s all-out paddling effort in surfers may provide Sport Scientists and coaches with important information for the prescription of exercise training programs and the priorities placed on relevant energy systems in surfers.

Materials and methods

Participants

Eight competitive male surfers (COMP) (18 ± 1 yr) and eight recreational male surfers (REC) (18 ± 2 yr) volunteered to participate as subjects in the present study. Five subjects from each group acted as subjects in a previous study by Loveless and Minahan (Loveless & Minahan, 2010). COMP surfers were members of the Australian Junior National Team and had been competing nationally for a minimum of 2 yr in age-group events. REC surfers had been surfing at least 2 session·wk⁻¹ for a minimum of 4 yr, but had not participated in competitive surfing events, other than their local board-riding events (< 6 event·yr⁻¹). All surfers were not participating in any other organized sport more than 1 session·wk⁻¹ within the last 12 mo. The Griffith University Human Research Ethics Committee approved this study. Written informed consent was obtained from all volunteers, as well as from their parental guardian if they were under 18 yr of age, before they were accepted as a subject.

Experimental design

COMP and REC surfers participated in three separate days of testing (Day 1, Day 2, and Day 3). Familiarization of the testing equipment and procedures was conducted on Day 1 of testing. On Day 2, surfers performed the 30-s sprint-paddling test on the swim-bench ergometer for the determination of peak and mean power output as well as the fatigue index (FI%) and the accumulated O₂ deficit. The peak power output was subsequently used to determine the power outputs used in the incremental-paddling test performed on Day 3. At least 48 h later, on Day 3 of testing, surfers performed an incremental-paddling test to exhaustion on the swim-bench ergometer for the determination of the O₂ uptake-power relationship and peak O₂ uptake for paddling.

Experimental equipment

Subjects performed the 30-s sprint-paddling test and the incremental-paddling test to exhaustion on a Vasa Swim Ergometer (Vasa, Inc., Essex Junction, VT, USA). The swim-bench ergometer consisted of hand paddles attached to two pull ropes that induce rotation of the isokinetic resistance device. Two suitably mounted force transducers on each hand pulley measured tensile force, distance and force duration for the calculation of external power output of each separate arm pull. When force is

applied to the hand paddles, the pull rope produces a velocity which ranges up to maximum, termed the maximum pull velocity (MPV). The resistance unit on the swim-bench provided seven MPV settings. Based on previous testing in our lab, the highest MPV setting of 7 was used in all tests, for all surfers. Power output is calculated and continuously fed back to the subject via a digital display unit. The display unit on the ergometer used in the present study had no memory storage, so the duration of the paddling tests were recorded via digital video and played back to obtain 1-s power output values displayed during the trial.

Breath-by-breath pulmonary gas-exchange was measured during the 30-s sprint-paddling test and the incremental-paddling test using a metabolic measurement system (MedGraphics CardiO₂, Cardiopulmonary Diagnostic Systems, St. Paul, MN). Subjects wore a nose clip and breathed through a low-resistance mouthpiece and volume sensor assembly (pneumotachograph). Gases were drawn continuously from the mouthpiece assembly through a capillary line and analyzed for O₂ and carbon dioxide (CO₂) concentrations by fast-response analyzers. The O₂ and CO₂ analyzers and the pneumotachograph were calibrated before and after each test using gases of known concentration and a 3-L syringe, respectively. Breath-by-breath O₂ uptake values were averaged over 30 s for the incremental-paddling test and over 5 s for the 30-s sprint-paddling test. Peak O₂ uptake for the incremental-paddling test was determined as the highest 30-s average O₂ uptake value.

Heart rate (HR) and rhythm were monitored continuously using a modified CM5 electrode configuration and a Lohmeier electrocardiograph (M607, Munchen Germany) with the ECG signal transferred onto a computer for storage using custom designed software. HR values were measured beat-by-beat and then reported every s for the 30-s sprint-paddling test and for every 30-s interval for the incremental-paddling test. Peak HR was taken for both the 30-s sprint-paddling test and the incremental-paddling test as the highest 1-s HR value achieved during the duration of the test.

Blood lactate concentration ([La⁻]) was analyzed at the time of blood collection using an automated hand-held blood lactate analyzer (Lactate Pro, AKA, Japan). The earlobe was cleansed thoroughly using alcohol wipes (Tyco Healthcare Group LP, USA). The earlobe was punctured using a 2.3 mm

disposable lancet (Safe-T-Pro Plus, Accu-Chek, Australia). Approximately 5 mL of blood was collected onto a test strip for the subsequent determination of blood $[La^-]$ immediately before the commencement of the test (i.e., baseline; 10-min following warm up), and at 3-min post the 30-s sprint-paddling test.

Incremental-paddling test and the determination of the O_2 uptake-power output relationship and peak O_2 uptake

The incremental-paddling test was modified from methods developed by Mendez-Villanueva & Bishop (2005) and consisted of four, 3-min work stages followed by a $20\text{ W}\cdot 30\text{s}^{-1}$ increase until volitional exhaustion. The power output of the four, 3-min work stages of the incremental-paddling test was 10%, 15%, 20%, and 25% of peak power output achieved during sprint-paddling. The incremental-paddling test protocol was designed to provide incremental work rates that were appropriate for each individual. The commencement of the test was preceded by 3 min of quiet rest on the swim-bench ergometer. To begin the test, subjects paddled at a self-selected paddling frequency but were required to stay within $\pm 5\text{ W}$ of the predetermined power outputs. The test was terminated when the surfer could no longer maintain the predetermined power output and had already been given two prior warnings to "pick up" the intensity. O_2 uptake, power output, and HR were all continuously monitored throughout the incremental-paddling test using equipment and methods previously discussed. Peak power output was taken as the power output of the final work stage where at least 15 s of the 30-s work stage was completed.

The O_2 uptake and corresponding power values achieved during the four, 3-min constant load work stages, as well as the peak O_2 uptake and peak power of the incremental-paddling test, were used to determine the O_2 uptake-power relationship for each subject. The O_2 uptake for each work stage was taken as the average value of the last 30 s of each work stage. The linear regression of the O_2 uptake-power output relationship was used to calculate the total energy demand (i.e., accumulate O_2 demand) for the 30-s sprint-paddling test.

The 30-s sprint-paddling test

The 30-s sprint-paddling test consisted of 30-s of all-out alternate arm paddling at a self-selected stroke rate. Prior to the test subjects participated in a 5-min warm up comprising 3 min of light-intensity (i.e., $HR < 120 \text{ beat}\cdot\text{min}^{-1}$) continuous paddling followed by three, 5-s all-out paddling efforts; each 5-s effort was separated by a 30-s rest period. Subjects then rested for 10 min before they were asked to resume their position on the swim-bench to commence the test. Each subject was reminded to paddle maximally until they were instructed to stop and advised that they would be given strong verbal encouragement. Subjects commenced the 30-s sprint-paddling test with both arms stretched out in front of their body. The chief investigator then provided a 3-s countdown to 'go!' which triggered the start of the test. Surfers were not informed of the elapsed time and verbal encouragement went for 32 s before the surfers were told to stop in order to prevent them from slowing down too early. Subjects continued to paddle against an MPV setting of 3, at $50 \text{ rev}\cdot\text{min}^{-1}$ for at least 5 min after the 30-s sprint-paddling test.

Peak power, mean power, fatigue index (FI%) and the change in blood $[\text{La}^-]$ from baseline to 3-min post exercise ($\Delta[\text{La}^-]$), were determined as indices of anaerobic energy production (Green & Dawson, 1993; Méndez-Villanueva et al., 2005; Vandewalle, Péérès, & Monod, 1987). Peak power was determined as the highest power output value produced for the duration of the test, whereas mean power was determined as the average power output for the duration of the test (i.e., 30-s). The FI% was calculated as the absolute difference between the highest and the lowest work rate expressed as a percent of the highest work rate.

Calculation of the energy contributions to the 30-s sprint-paddling test

To determine the anaerobic contribution of the 30-s sprint-paddling test, we measured the accumulated O_2 deficit using a modified version of the methods previously described (Medbø & Burgers, 1990). Briefly, the linear regression of the O_2 uptake-power output relationship was extrapolated to estimate the energy demand (in O_2 equivalents) for every 5 s of the 30-s sprint-paddling test. The sum of the six, 5-s segments were used to estimate the accumulated O_2 demand (L) of the 30-s sprint-paddling test. The aerobic contribution (i.e., accumulated O_2 uptake: L) to the 30-s

sprint-paddling test was determined by summing the values of O₂ uptake measured during the six, 5-s segments of the test using open-circuit spirometry. The accumulated O₂ deficit (anaerobic contribution) was then calculated by subtracting the accumulated O₂ uptake from the accumulated O₂ demand.

Data analysis

All group data was reported as mean±SD. Independent t-tests were used to test for group differences in physical characteristics, surfing experience, and participation patterns as well as for peak and mean power output, FI%, HR, Δ[La⁻], and O₂ uptake values determined during the experimental paddling tests. Correlations among several experimental variables (e.g., number of years surfing, peak power output, and the accumulated O₂ deficit) were examined using the Pearson's correlation coefficient (r). Statistical significance was accepted at P < 0.05.

Results

Physical characteristics, surfing history

The physical characteristics and surfing experience of the REC and COMP surfers are presented in Table I (both the t scores and p values are displayed in the table). There were no significant differences in body mass or height between the two groups. Surfing experience was greater in COMP surfers with differences in group mean values of 7 yr longer, 9 session·wk⁻¹ more, and 12 h·wk⁻¹ more when compared to REC surfers. Furthermore, COMP group means for competitive events per year was twenty one more when compared to REC surfers.

Incremental-paddling test for the determination of the O₂ uptake-power relationship and peak O₂ uptake.

Peak O₂ uptake (2.5±0.2 vs. 2.7±0.1 L·min⁻¹, t = -1.69, p = 0.11) and peak HR (193±6 vs. 192±7 beat·min⁻¹, t = 0.26, p = 0.80) for the incremental-paddling test were not different between REC and COMP surfers, respectively. Furthermore, the mean slope of the line for the O₂ uptake-power output

relationship was not different between COMP and REC suggesting that paddling economy was not different between the two groups (0.017 ± 0.007 vs. 0.014 ± 0.003 , respectively; $t = 0.43$, $p = 0.67$).

30-s sprint-paddling test

Performance values obtained during the 30-s sprint-paddling test are presented in Table II. Peak and mean power output, as well as $\Delta[\text{La}^-]$ achieved during the 30-s sprint-paddling test were greater in COMP compared to REC surfers. There were no differences in FI% or peak HR achieved during the 30-s sprint-paddling test between the two groups. The mean accumulated O_2 demand, accumulated O_2 uptake, and accumulated O_2 deficit for REC and COMP surfers are illustrated in Figure 1. The accumulated O_2 demand for REC surfers (1.82 ± 0.33 L) was less than COMP surfers (2.26 ± 0.32 L; $t = -2.35$, $p = 0.02$). However, the accumulated O_2 uptake was not significantly different between the two groups (REC = 0.68 ± 0.15 L, COMP = 0.66 ± 0.13 L; $t = -0.81$, $p = 0.80$). Accordingly, the accumulated O_2 deficit determined for REC surfers (1.14 ± 0.38 L) was less than the accumulated O_2 deficit determined for COMP surfers (1.60 ± 0.31 L; $t = -2.57$, $p = 0.02$).

Correlations between surfing experience and exercise variables

The results of the correlation analysis are presented in Table III. Surfing experience (number of years surfing and/or number of surfing sessions per week) was significantly correlated with the peak power output and the accumulated O_2 deficit achieved during the 30-s sprint-paddling test, whereas surfing experience was not significantly correlated with peak O_2 uptake or the slope-of-the-line developed during the incremental-paddling test.

Discussion

The present study found that COMP surfers displayed a higher peak power output and a greater accumulated O_2 deficit when compared to REC surfers while peak O_2 uptake measured during the incremental paddling test was not different between the two cohorts of surfers. Furthermore, surfing

experience was positively associated with peak power output and the accumulated O₂ deficit ($p < 0.05$). The higher peak power output and larger accumulated O₂ deficit observed in COMP compared to REC surfers during the 30-s sprint paddling test suggests that surfboard riding promotes the development of the anaerobic energy systems.

Supported by previous research, the results of the present study suggest that no significant difference exists in peak O₂ uptake between junior COMP and REC surfers and that peak aerobic power cannot differentiate surfers of varying ability (Loveless & Minahan, 2010; Méndez-Villanueva et al., 2005). Furthermore, the physiological demands and movement patterns of competitive surf competition suggest a high demand for both anaerobic power (explosive paddling bursts to catch a wave) and total anaerobic energy production (intense prolonged paddling to get back beyond the breaking waves) (Farley et al., 2012a; Mendez-Villanueva et al., 2006) suggesting that anaerobic characteristics might be able to distinguish surfers of varying ability. Thus, recent attention on the physiological characteristics of surfers has been directed towards the peak rate of anaerobic energy production (i.e., anaerobic power/peak power output; (Farley et al., 2012a)) as well as the amount of anaerobic energy produced in a sprint-paddling test (i.e., accumulated O₂ deficit/mean power output) introduced in the present study.

The present study found that peak power output determined during a 30-s sprint-paddling test was greater in COMP surfers when compared to REC surfers. This finding is in agreement with previous research from Sheppard et al. (2013) who reported faster sprint paddle times (0-15 m) and greater sprint paddle velocity in competitively superior junior surfers. The results of the present study, in addition to those of Sheppard et al. (2013), suggest that COMP surfers have the ability to produce a higher rate of energy-output during sprint-paddling when compared to REC surfers. Farley et al. (2012a) reported a significant relationship between surfers' "season ranking" and peak power output achieved during a 10-s maximal-intensity paddling effort. These authors speculated that a larger anaerobic power would allow higher ranked surfers to catch otherwise unattainable waves perhaps leading to a higher score and season ranking. The findings of Farley et al. (2012a) and the present

study suggest that determination of peak power output during sprint-paddling is an important physiological characteristic for competitive surfers and could be useful for distinguishing surfers of varying ability.

Previous research examining the movement patterns of surfing have agreed that recreational surfing sessions as well as competitive heats contain repeated-bouts of high-intensity paddling (Farley et al., 2012b; Meir, Lowdon, Davie, Geebng, & Victoia, 1991; Mendez-Villanueva & Bishop, 2005). In agreement with these findings, the results from the present study demonstrated that both the accumulated O₂ deficit and $\Delta[\text{La}^-]$ values determined from the 30-s sprint-paddling test were higher in COMP compared to REC surfers suggesting an augmentation of the anaerobic energy systems in COMP when compared to REC surfers. The significant correlations observed between surfing experience (no. of years surfing) and surfing frequency (no. of sessions per week) and measures of anaerobic energy production (e.g., peak power output, accumulated O₂ deficit) support the notion that surfboard riding promotes the development of the anaerobic energy systems. Thus, in agreement with Farley et al. (2012a), our findings suggest that peak power output determined during a 10 or 30-s sprint paddling test may be considered as a sensitive measure of surfing ability or surfing experience in junior male surfers. Furthermore, not only is the peak rate of anaerobic energy production (i.e., peak power output) a key variable that differentiates surfers of varying ability, we confirm that a larger capacity to produce energy anaerobically (i.e., accumulated O₂ deficit) is also an important parameter that distinguishes between COMP and REC surfers.

The larger accumulated O₂ demand suggests that COMP surfers were able to perform more work in 30 s when compared to their recreationally-trained counterparts. Moreover, the similar accumulated O₂ uptake values suggest that the aerobic energy system did not account for the additional work performed by the COMP surfers. Rather, the larger accumulated O₂ deficit observed in the COMP compared to the REC surfers suggests that the anaerobic energy systems provided the extra ATP required to perform the additional work. The larger accumulated O₂ deficit was commensurate with a higher mean power output and a higher $\Delta[\text{La}^-]$ observed in the COMP compared to the REC surfers

in the present study. Indeed, it has been suggested that mean power during sprint-type exercise may provide a reliable prediction of the total amount of energy released anaerobically (Minahan, Chia, & Inbar, 2007).

The improved ability to produce work anaerobically observed in COMP surfers may be due to the greater amount of high-intensity paddling undertaken when compared to REC surfers. Indeed, 60% of all high-intensity bouts of paddling in competitive surfing last between 1 and 20 s (Mendez-Villanueva et al., 2006), suggesting that competitive surfers are required to undertake regular bouts of short-duration, high-intensity paddling during competition.

The AO_2 deficit values reported relative to body mass for COMP ($32.80 \text{ mL}\cdot\text{kg}^{-1}$) and REC surfers ($27.28 \text{ mL}\cdot\text{kg}^{-1}$) in the present study, are both significantly less than AO_2 deficit values for a 30-s wingate cycling test in endurance-trained ($50\text{-}60 \text{ mL}\cdot\text{kg}^{-1}$) and sprint-trained ($65\text{-}75 \text{ mL}\cdot\text{kg}^{-1}$) track cyclists (Calbet, Paz, Garatachea, Vaca, & Chavarren, 2003). The higher AO_2 deficit values in the sprint-trained cyclists when compared to endurance-trained cyclists suggests that the AO_2 deficit is a sensitive measure to identify differences in anaerobic performance and sprinting ability in athletes providing further evidence that the AO_2 deficit measures observed in COMP and REC surfers in the present study is a sensitive measure of a surfers sprinting or maximal-paddling ability and anaerobic power. The differences in the AO_2 deficit measured during a 30-s sprint-paddling test compared to a 30-s cycling wingate test may be associated with the larger amount of work performed and active muscle mass involved in cycling when compared to arm exercises. To the best of our knowledge, the AO_2 deficit achieved during 30-s of maximal paddling has not been previously determined.

In the present study, a higher peak power output, AO_2 deficit and $\Delta[\text{La}^-]$ in COMP compared to REC surfers suggests that the anaerobic characteristics of a surfer may be a sensitive measure of surfing ability, or an important physiological characteristic for a competitive surfer. However, such conclusions cannot be drawn from this study alone as significant correlations were found between peak power during the 30-s sprint-paddling test and AO_2 deficit with surfing experience (yr surfing) and surfing participation frequency (surfing $\text{hr}\cdot\text{wk}^{-1}$). Therefore, it may be possible that the higher

anaerobic power, $\dot{V}O_2$ deficit and $\Delta[La^-]$ in COMP surfers may only be associated with greater surfing experience and surfing participation frequency. Further research investigating peak power for paddling, the $\dot{V}O_2$ deficit, and anaerobic capacity in two groups of surfers of different surfing ability but similar surfing experience and frequency (i.e. competitive surfers of different competition standard or ranking) will help determine whether anaerobic performance measures are a sensitive determinant of surfing ability.

The present study found that COMP surfers have a greater peak power output during a 30-s sprint-paddling test on a stationary swim-bench ergometer compared to REC surfers. A greater $\dot{V}O_2$ deficit and $\Delta[La^-]$ in COMP compared to REC surfers suggests that the proportion of extra work produced by COMP was due to a greater anaerobic contribution. Furthermore, peak power and $\dot{V}O_2$ deficit were both correlated with surfing experience and frequency. Collectively, these findings suggest that measures of anaerobic performance provide a sensitive measure for physiological parameters of surfing ability and indicate that highly developed anaerobic systems are necessary to compete successfully in surfing competition.

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Figures

Figure I. Contribution of the aerobic (AO₂ uptake) and anaerobic (AO₂ deficit) energy systems to the total energy demand (AO₂ demand) determined during a 30-s sprint-paddling test in recreational

(REC) and competitive (COMP) junior male surfers. Energy demand is estimated in Liters of oxygen equivalents (L of O₂ Eq). Values presented are the mean±SD. *REC significantly different to COMP (P < 0.05).

Tables

Table I. Physical characteristics, surfing experience, and participation rates of recreational (REC) and competitive (COMP) junior male surfers.

	REC	COMP	t score
	n = 8	n = 8	(p value)
Body mass (kg)	66.7±6.3	68.9±4.7	-0.80 (0.44)
Height (cm)	169.1±10.1	170.0±4.8	-0.45 (0.66)
Surfing experience (yr)	4.5±0.8	11.6±2.1	-6.38 (<0.01)*
Surfing frequency (session·wk ⁻¹)	3±1	13±2	-10.23 (<0.01)*
Surfing duration (h·wk ⁻¹)	4.8±3.4	17.1±6.0	-5.10 (<0.01)*
Participation in competition (events·yr ⁻¹)	2±3	23±3	-14.58 (<0.01)*

Values presented are the mean±SD. *Significance is accepted at P < 0.05.

Table II. Values determined during a 30-s sprint-paddling test in recreational (REC) and competitive (COMP) junior male surfers.

	REC n = 8	COMP n = 8	t score (p value)
Peak power output (W)	292±56	404±98	-2.82 (0.01)*
Mean power output (W)	236±59	335±74	-2.96 (0.01)*
Fatigue index (%)	34±8	28±6	0.28 (0.12)
Peak heart rate (bpm)	180±26	186±11	-0.66 (0.52)
Δ[La ⁻] (mmol/L)	4.9±0.9	7.8±1.2	-5.32 (<0.01)*

Values presented are the mean±SD. *Significance is accepted at P < 0.05.

Note: Δ[La⁻] = change in blood lactate concentration from baseline (10-min post warm up) to 3-min post exercise.

Table III. Pearson's correlation coefficients determined among surfing experience (number of yr surfing) and surfing frequency (sessions per wk) and values obtained during a 30-s sprint-paddling test (anaerobic) and an incremental-paddling test (aerobic).

		30-s sprint-paddling test		Incremental-paddling test	
		Peak power (W)	Accumulated O ₂ deficit (L)	Slope of the line	Peak O ₂ uptake (L)
Surfing experience (yr)	r =	0.57	0.58	-0.35	0.34
	p =	0.02*	0.02*	0.19	0.20
Surfing frequency (session·wk ⁻¹)	r =	0.70	0.59	-0.43	0.43
	p =	<0.01*	0.02*	0.10	0.09

*Significance is accepted at P < 0.05.

Note: Slope of the line was calculated from the O₂ uptake-power output relationship determined from four, 3-min submaximal constant power output stages and the peak exercise values (i.e., peak O₂ uptake and peak power).