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## Physiological Profile of Male Competitive and Recreational Surfers

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1 **MANUSCRIPT TITLE: THE PHYSIOLOGICAL PROFILE OF MALE**

2 **COMPETITIVE AND RECREATIONAL SURFERS**

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4 **RUNNING HEAD: PHYSIOLOGICAL PROFILE OF SURFING**

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18 **ABSTRACT**

19 Surfing consists of both high and low intensity paddling of varying durations, utilizing both  
20 the aerobic and anaerobic systems. Surf specific physiological studies lack adequate group  
21 sample sizes and  $VO_{2peak}$  values are yet to determine differences between competitive and  
22 recreational surfers. The purpose of this study was therefore to provide a comprehensive  
23 physiological profile of both recreational and competitive surfers. This multi-site study  
24 involved 62 male surfers, recreational ( $n = 47$ ) and competitive ( $n = 15$ ). Anthropometric  
25 measurements were conducted followed by DEXA, anaerobic testing and finally aerobic  
26 testing.  $VO_{2peak}$  was significantly greater in competitive compared to recreational surfers ( $M$   
27  $= 40.71 \pm 3.28$  vs.  $31.25 \pm 6.31$  ml/kg/min,  $p < .001$ ). This was also paralleled for anaerobic  
28 power ( $M = 303.93$  vs.  $264.58$  W) for competitive surfers. Arm span and lean total muscle  
29 mass was significantly ( $p \leq .01$ ) correlated with key performance variables ( $VO_{2peak}$  and  
30 anaerobic power). No significant ( $p \geq .05$ ) correlations were revealed between season rank  
31 and each of the variables of interest ( $VO_{2peak}$  and anaerobic power). Key performance  
32 variables ( $VO_{2peak}$  and anaerobic power) are significantly higher in competitive surfers  
33 indicating this is both an adaptation and requirement in this cohort. This battery of  
34 physiological tests could be used as a screening tool to identify an athlete's weaknesses or  
35 strengths. Coaches and clinicians could then select appropriate training regimes to address  
36 weaknesses.

37 Key words: Surfing, Aerobic, Anaerobic, Assessment, Screening

38

## 39 INTRODUCTION

40 The basic physiological requirements of surfing has remained unchanged for over a 1,000  
41 years in that a surfer paddles a board out to the waves, then rides it back to shore (22).  
42 Through the use of time motion analysis, the sport can be further broken down into periods of  
43 repetitive upper body movement during paddling and prolonged periods of sitting,  
44 interspersed with intermittent explosive lower body and trunk movements (20). Several  
45 studies have revealed that paddling is the predominant aspect of surfing and encompasses  
46 approximately 50% of a surfing session or competitive heat (9, 19, 26, 30). The activity  
47 requirements of a 20 minute heat in young competitive surfers using global positioning  
48 system (GPS) technology has previously been analyzed. Results revealed that 54% of the  
49 total time involved paddling with a mean heart rate of  $140 \pm 11.6$  beats/min (9). The majority  
50 of these paddling bouts (60%) were only 1 to 20 seconds long; highlighting the importance of  
51 short intense paddling. The activity requirements for young recreational surfers revealed  
52 similar results with paddling encompassing 42.6 to 44% of the total time and mean heart rates  
53 ranging between  $128 \pm 13$  to  $135 \pm 6.9$  beats/min (19, 26).

54 It is apparent that both forms of surfing are intermittent in nature, and clearly utilize the  
55 aerobic and anaerobic energy systems. It could be suggested that surfers must possess a  
56 highly developed capacity to physiologically recover in short rest periods before  
57 recommencing high intensity paddling bouts. Aerobic ( $VO_{2peak}$ ) and anaerobic (peak watts)  
58 physiological testing through paddling assessment have previously been assessed in several  
59 studies (8, 15, 16, 19, 21).

60 Loveless and Minahan (15) conducted the only study which compared competitive and  
61 recreational surfers and revealed no significant differences between the groups for  $VO_{2peak}$

62 values. Mendez-Villanueva et al. (21) also revealed no difference in  $\text{VO}_{2\text{peak}}$  scores when  
63 European level surfers were compared against regional level surfers. Only two studies (8, 15)  
64 have assessed peak power output using ergometers; discrepancies in mean peak power out  
65 values are evident between studies. Competitive surfers have been shown to possess  
66 significantly ( $p < .05$ ) greater peak power outputs (8, 15) and season rank has been  
67 significantly ( $p < .05$ ) correlated with peak power output (8).

68 A key theme in these physiological studies is the variation in  $\text{VO}_{2\text{peak}}$  values ( $M = 37.8$  to  
69  $54.2$  ml/kg/min) and peak power outputs ( $M = 205$  to  $348$  W). An explanation for the  
70 variations may be due to differences in equipment and testing protocols used. In addition,  
71 there appears to be no difference in  $\text{VO}_{2\text{peak}}$  scores between recreational and competitive  
72 surfers, despite this being a common finding in most other sports. It should be noted that all  
73 of these studies investigating  $\text{VO}_{2\text{peak}}$  lack adequate group sample sizes ( $n < 10$ ). This limits  
74 the ability to reveal meaningful mean differences between groups and generalize results to  
75 surfing cohorts.

76 In conjunction with physiological assessment, several studies have also assessed body  
77 composition in both recreational and competitive surfers. Surfers have generally been  
78 considered to possess moderate levels of body fat ranging from 10.5 to 22% (10, 17, 20).  
79 Only one study has revealed significant differences between body composition between  
80 surfing cohorts (29). The interpretation of these results is limited given that body composition  
81 was assessed through skinfolds. It has been shown that varying the skinfold site by as little as  
82 1 cm produces significantly different results when experienced practitioners measure the  
83 same subject (1). Dual energy x-ray absorptiometry (DEXA) has been shown to be extremely  
84 reliable in estimating body composition (6) and has yet to be used in a surfing population.

85 It is apparent that further physiological testing is needed in a larger sample size comparing  
86 recreational and competitive surfers. Therefore, the aims of this study were; 1) to provide the  
87 aerobic and anaerobic profile for competitive and recreational surfers and determine if  
88 differences exist between groups; 2) to provide the body composition and anthropometric  
89 comparisons for competitive and recreational surfing cohorts and; 3) to determine if  
90 physiological testing could be used in a surf specific screen to assist with discriminating in  
91 performance. It is hypothesized that competitive cohorts will have increased anaerobic and  
92 aerobic power and decreased body fat compared with recreational surfers.

93

## 94 **METHODS**

### 95 *Experimental Approach to the Problem*

96 Physiological variables ( $\text{VO}_{2\text{peak}}$  and anaerobic power), anthropometrics and body  
97 composition measurements were determined at multiple study sites on both competitive and  
98 recreational surfers. A comparative analysis was conducted between key performance  
99 variables ( $\text{VO}_{2\text{peak}}$ , relative anaerobic power and peak anaerobic power) of both competitive  
100 and recreational groups to determine significant differences.

### 101 *Subjects*

102 This was a multi-site study that involved a total of 62 male surfers, recreational ( $n = 47$ ; age  
103  $26.50 \pm 5.28$  years; mass  $77.42 \pm 10.69$  kg; height  $180.13 \pm 7.54$  cm) and competitive ( $n =$   
104  $15$ ; age  $26.73 \pm 4.68$  years; mass  $77.83 \pm 6.62$  kg; height  $179.44 \pm 3.96$  cm). The 15  
105 competitive surfers were competing on the World Qualifying Series (WQS) or world  
106 championship tour (WCT) (surfing experience  $18.86 \pm 5.46$  years; surfing frequency  $13.23 \pm$   
107  $4.54$  hours per week; dry land training  $4.5 \pm 2.35$  hours per week) all remaining surfers were

108 classified as recreational (surfing experience  $13.22 \pm 6.93$  years; surfing frequency  $7.56 \pm$   
109  $4.91$  hours per week; dry land training  $2.57 \pm 2.93$  hours per week). To be classified as a  
110 recreational surfer, subjects were to have at least one year experience, currently be surfing  
111 and not compete higher than local club level. A total of 34 (54.8%) were tested at one  
112 Australian University and the remaining 28 were tested at an American University; where  
113 only aerobic testing was conducted. Subjects were tested following their normal routine of  
114 sleep, nutrition and hydration levels prior to testing. Being a multi-site study ethics was  
115 granted through the University Human Research Ethics Committee (RO1610) and through  
116 the Institutional Review Board for the Protection of Human Subjects (IRB, 2013-118) prior to  
117 commencement. Participants were informed of the risks and benefits of the investigation  
118 prior to signing an informed consent form.

119 Prior to undertaking analysis between the competitive and recreational groups, data collected  
120 between both testing sites needed to be analyzed to ensure there were no differences in  
121  $VO_{2peak}$ , mass and age. Only aerobic testing was conducted at the American University and  
122 therefore only key variables that could influence  $VO_{2peak}$  scores were analyzed. No significant  
123 differences were seen between the two sites for age ( $27.19 \pm 4.24$  vs.  $26.03 \pm 5.91$  years;  $p$   
124  $= .47$ ), weight ( $M = 74.82 \pm 8.66$  vs.  $79.20 \pm 11.70$  kg;  $p = .17$ ), and  $VO_{2peak}$  ( $32.75 \pm 5.24$  vs.  
125  $30.25 \pm 6.85$  ml/kg/min;  $p = .19$ ). Therefore data was pooled together to provide a  
126 recreational group of 47 surfers.

127

## 128 ***Procedures***

129 Testing at the Australian University was conducted by a physiotherapist with additional  
130 training in exercise testing and an accredited exercise physiologist with over 20 years'

131 experience. Testing at the American University was conducted under the direct supervision of  
132 an exercise physiologist with over 15 years of experience. Initially, anthropometric  
133 measurements were conducted followed by DEXA then anaerobic testing and finally aerobic  
134 testing. All subjects were tested in a University setting and underwent the exact same order of  
135 testing on the same day; however testing conducted at the American University involved  
136 aerobic testing only.

### 137 *Anthropometrics and Body composition*

138 Anthropometric measurements included height, mass and arm span. Height was initially  
139 measured to the nearest 0.1 cm and body mass was measured with minimal clothing using a  
140 standard medical balance scale (Seca, 700, Hamburg, Germany). Arm span was measured to  
141 the nearest 0.1 cm according to standard recommendations (23). Arm span was divided by  
142 height to determine “Ape Index”; a ratio commonly used with sports such as rock climbing  
143 and swimming where larger ratios favour the competing athlete (31).

144

145 A DEXA scanner (General Electric, Prodigy Pro (Madison, Wisconsin, USA)) was utilized  
146 for all body composition testing. Encore software provided an output of segmental body  
147 composition for each surfer (right & left arms, legs and trunk). All scans were completed  
148 according to the standardized DEXA operational protocol (24). Surfers were centrally  
149 positioned where by both feet were placed on a foam block and foam pads were placed on  
150 each hand to help determine tissue differences between arms and trunk (foam is transparent  
151 under DEXA). Using a foam block and pads, a constant distance between feet (15cm) and  
152 between hands and trunk (3cm) was maintained. According to standardized baseline  
153 conditions (24) subjects are required to be overnight fasted on the morning of measurements.  
154 Unfortunately the DEXA occurred prior to anaerobic and aerobic testing and therefore



155 overnight fasting was not appropriate. To ensure standardized conditions, subjects were  
156 required to fast for at least 2 hours prior to testing.

### 157 *Anaerobic power output testing*

158 Both aerobic and anaerobic testing was completed on a wind-braked swim bench ergometer  
159 (Vasa, Inc., Essex Junction, VT, USA) with the addition of a surfboard mounted on top of the  
160 bench. A new display unit with interoperability (ANT+) technology was used to gather all  
161 data on the display unit of the swim bench ergometer. This allowed for total peak power, left  
162 and right peak power, total distance covered and velocity to be calculated and captured.

163 Total peak power was defined as the highest sample of left plus right watts (W).

164 The resistance unit on the swim bench ergometer provided seven airflow resistance settings.

165 The highest setting was used in this study, as previous research by Loveless and Minahan

166 (16) revealed the maximum power output was achieved at the highest resistance. Anaerobic

167 power output was measured during a 10-second sprint on the swim bench ergometer at

168 maximal effort (completed prior to aerobic testing). The surfer was initially familiarized with

169 the equipment and given standardized instructions on the testing procedures. This was

170 followed by a three-minute warm up at 30 watts and then three 5-second maximal effort

171 sprints with each sprint separated by a 20-second rest period. Following the completion of the

172 warm up the surfer had a 10-minute rest before completing the 10-second sprint at maximal

173 effort. A 10 minute rest period was selected as complete resynthesis of adenosine

174 triphosphate (ATP) occurs within three to five minutes, and complete creatine phosphate

175 resynthesis can occur within eight minutes (4, 11, 13). This protocol was based on previous

176 anaerobic testing conducted on a competitive surfing cohort (8, 16). As previously discussed

177 the inclusion of ANT+ software allows for data on the display unit to be capture and

178 wirelessly transmitted. Peak power, mean power, left and right power outputs, peak velocity  
179 and total distance were all calculated.

180

### 181 *Aerobic $VO_{2peak}$ uptake testing*

182 Subjects'  $VO_{2peak}$  was obtained during an incremental endurance exercise test. Measuring  
183 peak oxygen consumption is considered the gold standard for quantifying aerobic fitness.

184 Swim bench ergometry has previously been shown to be both valid and reliable to test peak  
185 aerobic and anaerobic levels in recreational and competitive surfers (8, 15). All surfers

186 underwent aerobic testing on the swim bench ergometer. Oxygen consumption was analyzed

187 using a Parvo Medics (TrueOne<sup>®</sup>, 2400) automated gas analysis system (O<sub>2</sub> analyser, CO<sub>2</sub>

188 analyser, pneumotach) which was calibrated prior to each test. The expired gas analysis

189 system meets Australian Institute of Sport accreditation standards for precision and accuracy.

190 This provided breath-by-breath measurement of maximum oxygen consumption (L/min), and

191 relative to body weight (ml/kg/min), maximal ventilation, and energy expenditure (kcal).

192 Oxygen uptake was averaged every 30 seconds, with the peak value recorded as the highest

193 value obtained over a 30-second period.

194 The incremental test began at 30 watts, with increments of 10 watts every minute. Testing

195 was terminated if maximum heart rate was exceeded, respiratory exchange ratio (RER)

196 reached greater than 1.5, oxygen consumption did not increase concurrently with power

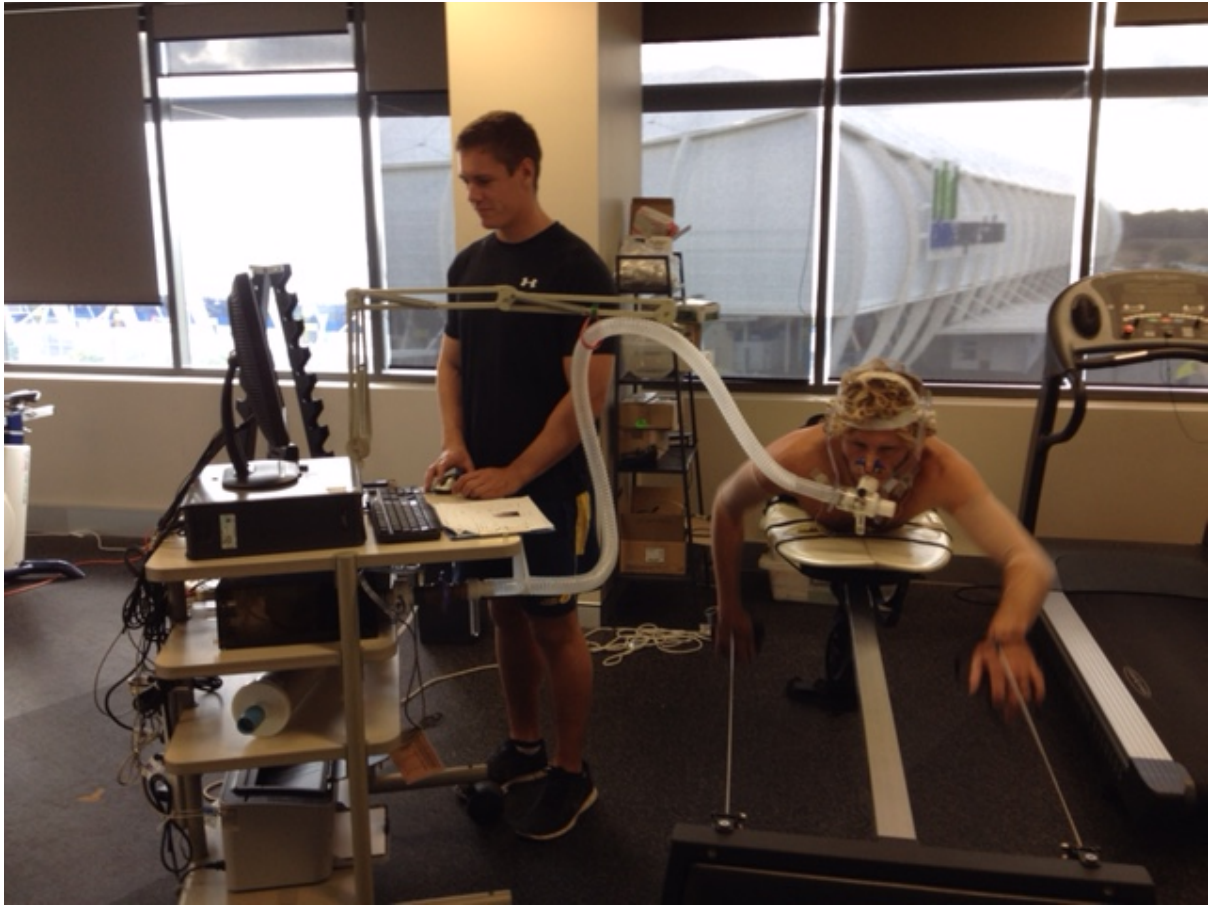
197 output, required power output was not maintained for greater than 10 seconds, volitional

198 exhaustion was achieved or any symptoms of chest pain were expressed by the surfer. This

199 termination criteria was based upon the ACSM guidelines for exercise testing and

200 prescription (3). The incremental testing protocol was based off previous  $VO_{2peak}$  testing

201 conducted on a competitive and recreational surfing cohort (8, 15). The testing set up with  
202 the surfboard attached to the swim bench is seen in Figure 1.



203

204 *Figure 1: Laboratory setup of  $VO_{2peak}$  testing performed on the swim bench ergometer*

205

206

207 *Statistical Analyses*

208 Data analysis was performed with SPSS version 20.0. Descriptive statistics including means,  
209 standard deviations and ranges were calculated for each measure and for each session. A  
210 Shapiro-Wilks test ( $p > 0.05$ ) (27) and a visual inspection of their frequency histograms,  
211 normal Q-Q plots and box plots showed that all key performance variables ( $VO_{2peak}$ , relative  
212 anaerobic power and peak anaerobic power) were normally distributed for both the  
213 competitive and recreational groups; with the magnitude of skewness and kurtosis being non-  
214 significant (5, 7). Independent *t*-tests were used for comparative analysis between  
215 competitive and recreational groups. Paired *t*-tests were used to determine differences within  
216 groups. A Spearman's rank order correlation was conducted between end of year ranking and  
217 each of the variables of interest ( $VO_{2peak}$ , peak and relative anaerobic power). A Pearson's  
218 correlational analysis was conducted with key physical attributes (arm span and total muscle  
219 mass) and key performance variables ( $VO_{2peak}$ , peak anaerobic power and relative anaerobic  
220 power).

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## 225 RESULTS

### 226 *Reliability analysis*

227 A small pilot study was conducted for both anaerobic ( $n = 7$ ) and DEXA ( $n = 8$ ) assessment.  
228 Whereby, each subject was assessed twice on the same day separated by 2 hours. The same  
229 assessor completed each assessment in order to evaluate intra-rater reliability. ICC scores  
230 were within the excellent range for anaerobic testing and the use of DEXA (ICC .97 and .99  
231 respectively). Reliability of  $\text{VO}_{2\text{peak}}$  testing has been well established with test retest scores  
232 being high ( $r = .95-.99$ ) (2).

233

### 234 *Recreational vs. Competitive*

235 A comparative analysis between the competitive and recreational groups can be seen in Table  
236 1. Independent  $t$ -tests revealed significant differences ( $p \leq .05$ ) between recreational and  
237 competitive groups for key performance variables. Competitive surfers had significantly  
238 greater arm span ( $M = 190.61$  vs.  $182.61$  cm,  $p = .01$ ) compared to recreational surfers.  
239 Consequently competitive surfers revealed significantly higher Ape Index scores (arm span/  
240 height) compared to recreational males ( $M = 1.06$  vs.  $1.03$ ,  $p < .001$ ).  $\text{VO}_{2\text{peak}}$  was and peak  
241 anaerobic power was significantly greater in the competitive surfers compared to recreational  
242 surfers ( $M = 40.71$  vs.  $31.25$  ml/kg/min,  $p < .001$ ;  $M = 303.93$  vs.  $264.58$  W respectively).

### 243 *Physical attributes and key performance variables*

244 Arm span was significantly ( $p \leq .01$ ) correlated with  $\text{VO}_{2\text{peak}}$  ( $r = .55$ ), relative anaerobic  
245 power ( $r = .49$ ) and peak power output ( $r = .72$ ). Total muscle mass was also significantly  
246 correlated ( $p \leq .05$ ) with  $\text{VO}_{2\text{peak}}$  ( $r = .56$ ), relative anaerobic power ( $r = .49$ ) and peak power  
247 output ( $r = .83$ ).

248 *Season Ranking*

249 A total of 10 competitive male surfers were utilized in the analysis as all of these surfers  
250 completed an entire year of competition. Key variables of interest were  $\text{VO}_{2\text{peak}}$ , peak  
251 anaerobic power and relative anaerobic power. No significant correlations ( $p \geq .05$ ) were  
252 revealed for each of the variables of interest ( $\text{VO}_{2\text{peak}}$ ,  $r = .33$ ; peak anaerobic power,  $r = .06$ ;  
253 relative anaerobic power,  $r = .09$ ).

254 *Symmetry in power outputs*

255 As power output data was attained during both the anaerobic and aerobic testing,  
256 comparisons between dominant and non-dominant arm outputs were conducted using paired  
257  $t$ -tests. There was no statistical difference ( $p > .05$ ) between mean dominant and non-  
258 dominant arm power outputs for anaerobic (dominant =  $139.14 \pm 34.30$  versus non-dominant  
259 =  $135.62 \pm 2.59$  W) and aerobic testing (dominant =  $31.40 \pm 5.77$  versus non-dominant =  
260  $31.05 \pm 5.53$  W) for all surfers.

261

262

263 **Table 1: Key physical attributes and performance variables for competitive and recreational surfers (M ± SD)**

Measure	Competitive; n = 15	Recreational; n = 47	p value
<i>Anthropometrics and Body Composition</i>			
Arm span (cm)†	190.61 ± 4.79	182.61 ± 9.28	.01*
Ape Index†	1.06 ± 0.01	1.03 ± 0.02	< .001*
Total body fat (%) †	17.11 ± 2.93	18.86 ± 3.33	.12
Total muscle mass (g) †	61.66 ± 4.02	58.21 ± 6.46	.81
<i>Aerobic VO<sub>2peak</sub> test</i>			
VO <sub>2peak</sub> (L/min)	3.14 ± 0.37	2.41 ± 0.53	< .001*
VO <sub>2peak</sub> (ml/kg/min)	40.71 ± 3.28	31.25 ± 6.31	< .001*
Respiratory exchange ratio (RER)	1.10 ± 0.07	1.21 ± 0.08	< .001*
Peak blood lactate (mmol)	12.01 ± 3.28	12.03 ± 3.37	.99
Peak heart rate (b.min <sup>-1</sup> )	182.07 ± 5.27	175.58 ± 10.51	.03*
Age predicted heart rate max (%)	94.41 ± 4.19	90.80 ± 5.53	.03*
Peak aerobic power (W)	121.93 ± 9.20	101.26 ± 18.49	< .001*
<i>Anaerobic 10s test</i>			
Absolute peak anaerobic power (W) †	303.93 ± 57.99	264.58 ± 46.14	.04*
Mean anaerobic power (W) †	257.21 ± 47.28	224.04 ± 39.75	.03*
Relative anaerobic power (W/kg) †	3.91 ± 0.63	3.53 ± 0.38	.04*
Peak anaerobic speed (m/s) †	1.65 ± 0.09	1.54 ± 0.10	< .001*

264 † refers to testing conducted at Bond University only (n = 34); \* refers to statistical significance ( $p \leq 0.05$ ) determined through independent  
 265 *t*-tests; NA refers to “not applicable”.

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## 270 **DISCUSSION**

271 The purpose of this study was to 1) to provide the aerobic and anaerobic profile of  
272 competitive and recreational surfers and determine if differences exist between groups; 2) to  
273 provide the body composition and anthropometric comparisons for competitive and  
274 recreational surfing cohorts and 3) to determine if physiological testing could be used in a  
275 surf specific screen to assist in discriminating performance. Findings from the current study  
276 support our hypothesis that competitive surfers tested on a swim bench ergometer had  
277 significantly higher values for both oxygen consumption and anaerobic power. In contrast to  
278 our hypothesis body composition measured by DEXA did not significantly differ between  
279 competitive and recreational surfers tested in this study.

### 280 *Aerobic Testing*

281 Time motion analysis revealed that upper body paddling represents the largest component of  
282 surfing (20). The competitive group had significantly higher aerobic scores in comparison to  
283 the recreational group. These findings suggest that high levels of aerobic fitness are attributes  
284 associated with competitive surfers. This is logical when considering the activity  
285 requirements of a competitive heat and the associated additional training. Farley et al. (9)  
286 reported that during a 20 minute competitive heat a surfer is required to participate in  
287 repeated high and low intensity paddling bouts (1 to 20 seconds) interspersed with short rest  
288 periods accumulating  $54 \pm 6.3\%$  of the total heat time . This paddling requirement may foster  
289 a high capacity for oxygen uptake in order to allow for sufficient recovery between paddling  
290 bouts. High intensity interval training has previously been shown to increase maximal oxygen  
291 consumption (12). Given that paddling is characterized by a series of short sprints it may be  
292 these demands of competitive surfing that cause increases in maximal oxygen consumption.  
293 Competitive surfers are also generally involved in additional training that is designed to



294 replicate paddling bouts in heats. This is commonly achieved using interval type training  
295 methods (25).

296 The findings from the current study have both similarities and inconsistencies with previous  
297 surf specific research (8, 15, 16, 19, 21). The competitive  $VO_{2peak}$  scores are similar to  
298 previous research conducted by Farley, Harris and Kilding (8) and Loveless and Minahan  
299 (15); however the recreational scores appear to be consistently lower than previous research  
300 conducted by Loveless and Minahan (15) and Meir, Lowdon and Davie (19). All of the  
301 aforementioned studies had sample sizes of less than 10, thus limiting the ability to compare  
302 their results with the current study and generalize their results to recreational and competitive  
303 surfing cohorts. The current study revealed significant differences in  $VO_{2peak}$  scores between  
304 recreational and competitive surfers. Previous research (15, 21) had not identified this,  
305 however both of these studies had sample sizes of less than 10 surfers in each group; once  
306 again limiting the ability to generalize the results to a surfing population.

### 307 *Anaerobic Testing*

308 As previously mentioned 60% of paddling bouts were 1 to 20 seconds long, highlighting the  
309 importance of short intense paddling (9). This activity requirement utilizes the anaerobic  
310 energy system and hence the need to attempt to replicate this activity on a swim bench. This  
311 study revealed significantly higher anaerobic scores in competitive surfers compared to  
312 recreational surfers (see Table 1). This is an important attribute to a competitive surfer as it  
313 assists in the ability to catch waves and gain a position advantage over their competitors  
314 during a heat. It may also allow for fast entry into a wave optimizing the execution of  
315 manoeuvres (28). It needs to be highlighted that competitive surfers commonly take part in  
316 additional training to further develop this energy system; therefore higher anaerobic scores in  
317 the competitive group may be due to both the activity requirements of surfing in heats and

318 additional training. Nevertheless, this information adds to the physiological profile of a  
319 competitive and recreational surfer.

320 Only two published studies have conducted anaerobic testing in a surfing cohort using upper  
321 limb ergometers (8, 16). Our results are slightly higher than the study conducted by Farley,  
322 Harris and Kilding (8); however a kayak ergometer was used which differs to the swim bench  
323 ergometer used in the current study. Loveless and Minahan (16), using the same equipment  
324 set-up, revealed slightly higher values for the competitive surfers ( $348 \pm 78$  W) compared  
325 with the results of the current study ( $303.93 \pm 57.99$  W). This inconsistency remains puzzling  
326 considering that the average weight for the study by Loveless and Minahan (16) was  $61.1 \pm$   
327  $9.2$  kg compared to the current study's average weight of  $77.83 \pm 6.62$  kg. The current study  
328 revealed a significant correlation ( $r = .83$ ;  $p < .001$ ) between lean muscle mass and peak  
329 power output; therefore it would be expected that the heavier competitive group would  
330 produce greater peak power output scores. It needs to be noted that Loveless and Minahan  
331 (16) conducted six trials over two days to determine the mean power output of  $348 \pm 78$ . It  
332 could be postulated that a learning effect occurred with subjects becoming more proficient at  
333 the motor pattern required and the demands of the test over the six trials.

### 334 ***Body Composition***

335 This study was the first to utilize DEXA to determine body composition with the variable of  
336 interest being percent body fat. Results revealed competitive surfers have low to moderate  
337 levels of body fat (17%). This is not surprising as surfers are not purely endurance athletes  
338 who tend to reveal lower body fat levels ranging from 8-13% through the use of DEXA (24).  
339 The results of the current study are similar to previous research, which has used skinfold  
340 assessment to estimate body fat with values ranging from 10.5-22% for competitive male and  
341 female surfers (10, 17, 20). It could be postulated that low body fat values do not represent a

342 real advantage from a performance perspective. It has also been suggested that higher body  
343 fat levels are possibly an adaptation to surfing in colder waters as additional body fat  
344 provides greater insulation (18, 20). Once again, this information adds to building the profile  
345 for recreational and competitive surfers using DEXA.

346

### 347 *Performance Screening*

348 The final aim of this study was to determine if physiological testing could be used to  
349 discriminate in performance. Significant differences were revealed between competitive and  
350 recreational surfers indicating the ability of the aerobic and anaerobic testing to discriminate  
351 between groups. However, when analysing the competitive cohort separately, no associations  
352 were detected. Whereby a surfers ranking and key performance variables (peak and relative  
353 power and  $VO_{2peak}$ ) were not correlated. This finding suggested that although high anaerobic  
354 and aerobic levels are associated with competitive surfers they do not assist in determining  
355 their individual level of performance. This is logical as a surfer is ranked according to their  
356 ability of actually riding a wave (performing critical manoeuvres) which was not assessed  
357 with these physiological tests. Therefore, although paddling assessment is crucial to  
358 undertake, it does not assist in discriminating the level of performance within a competitive  
359 cohort. It should however be noted that the standard deviations for key performance variables  
360 ( $VO_{2peak}$ , peak and relative power output) were all minimal indicating most results were  
361 closely related. Perhaps a test which resulted in a wide spread data set may have illustrated a  
362 stronger correlation. However, a single study conducted by Farley, Harris and Kilding (8) has  
363 previously shown a correlation between season rank and anaerobic scores achieved during a  
364 10-second paddle sprint.

365 Interestingly a correlational analysis revealed significant ( $p \leq .05$ ) associations between arm  
366 span, lean muscle mass and key performance variables ( $VO_{2peak}$ , peak and relative power  
367 output). These results may suggest that those surfers with longer arms and greater lean  
368 muscle mass produced higher  $VO_{2peak}$  and anaerobic scores. Correlations between arm span  
369 and  $VO_{2peak}$  scores are commonly reported in swimming studies (14, 23). There were no  
370 differences in height between the competitive and recreational group; however, arm span  
371 significantly differed as with the ratio of arm span divided by height, known as “Ape Index”.  
372 This finding is unique as it raises the question as to whether significant increases in arm span  
373 in the competitive group are a result of a physical predisposition for success in the sport.  
374 Further investigation of this variable is warranted to determine the utility of this indices for  
375 assisting in talent identification.

376 Finally, this is the first surf specific study to analyse symmetry of power output during  
377 aerobic and anaerobic paddling tests. No statistical difference was found between the  
378 dominant and non-dominant arms for power outputs during either test. This finding is novel  
379 in itself as it provides information that symmetry of power output is needed during paddling.  
380 This opens up several practical applications; where-by surfers suffering shoulder injuries  
381 could use swim bench ergometers for corrective and feedback purposes. It could also be used  
382 as a screening tool to identify asymmetry or even for rehabilitative purposes.

383 To our knowledge, this study is the largest comparative surf specific study to date that has  
384 comprehensively presented the physiological profile of competitive and recreational surfers.  
385 Key performance variables ( $VO_{2peak}$ , peak and relative power output) are significantly higher  
386 in competitive surfers indicating this is both an adaptation and requirement in this cohort.  
387 Interestingly no significant correlation was identified between key performance variables and  
388 ranking in the competitive cohort. This suggests tests which replicate wave-riding

389 components, may be more appropriate to discriminate performance within a competitive  
390 group. Arm span and ape index were the anthropometric measurements that were  
391 significantly greater in the competitive group; whether this is a result of physical  
392 predisposition is yet to be determined. This comprehensive study adds to the physiological  
393 and physical profile of a recreational and competitive surfer. This battery of physiological  
394 tests could be used as a screening tool to identify an athlete's weaknesses or strengths.  
395 Coaches and clinicians could then select appropriate training regimes to address weaknesses  
396 and therefore place less emphasis on strengths.

397 There is also potential for this research within the surfing industry. Prior to the arrangement  
398 of sponsoring deals, a surfer could undergo physiological screening to provide the company  
399 with additional information. This concept is not foreign to many other sports and may be of  
400 benefit to both the athlete and the company providing the sponsorship. Whereby, the surfer is  
401 provided with a profile of his or her strengths and weakness along with strategies to address  
402 their weaknesses. The company is provided with additional information regarding the state of  
403 the athlete from a physiological point of view.

404

#### 405 **PRACTICAL APPLICATIONS**

406 Key performance variables ( $VO_{2peak}$  and anaerobic power) are significantly higher in  
407 competitive surfers indicating this is both an adaptation and requirement in this cohort. This  
408 battery of physiological tests could be used as a screening tool to identify an athlete's  
409 weaknesses or strengths. Coaches and clinicians could then select appropriate training  
410 regimes to address weaknesses. These findings are limited to the current study and results

411 should not be generalized to female surfing cohorts as further research is needed in this

412 surfing cohort.

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