PHYSIOLOGICAL PROFILE OF MALE COMPETITIVE AND RECREATIONAL SURFERS

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ABSTRACT

Furness, J, Hing, W, Sheppard, JM, Newcomer, S, Schram, B, and Climstein, M. Physiological profile of male competitive and recreational surfers. *J Strength Cond Res* 32(2): 372–378, 2018—Surfing consists of both high- and low-intensity paddling of varying durations, using both the aerobic and anaerobic systems. Surf-specific physiological studies lack adequate group sample sizes, and $\dot{V}O_2$peak values are yet to determine the differences between competitive and recreational surfers. The purpose of this study was therefore to provide a comprehensive physiological profile of both recreational and competitive surfers. This multisite study involved 62 male surfers, recreational ($n = 47$) and competitive ($n = 15$). Anthropometric measurements were conducted followed by dual-energy x-ray absorptiometry, anaerobic testing and finally aerobic testing. $\dot{V}O_2$peak was significantly greater in competitive surfers than in recreational surfers ($M = 40.71 \pm 3.28$ vs. 31.25 ± 6.31 ml·kg^{-1}·min^{-1}, $p < 0.001$). This was also paralleled for anaerobic power ($M = 303.93$ vs. 264.58 W) for competitive surfers. Arm span and lean total muscle mass was significantly ($p \leq 0.01$) correlated with key performance variables ($\dot{V}O_2$peak and anaerobic power). No significant ($p \geq 0.05$) correlations were revealed between season rank and each of the variables of interest ($\dot{V}O_2$peak and anaerobic power). Key performance variables ($\dot{V}O_2$peak and anaerobic power) are significantly higher in competitive surfers, indicating that this is both an adaptation and requirement in this cohort. This battery of physiological tests could be used as a screening tool to identify an athlete's weaknesses or strengths. Coaches and clinicians could then select appropriate training regimes to address weaknesses.

KEY WORDS surfing, aerobic, anaerobic, assessment, screening

INTRODUCTION

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

It is apparent that both forms of surfing are intermittent in nature and clearly use the aerobic and anaerobic energy systems. It could be suggested that surfers must possess a highly developed capacity to physiologically recover in short rest periods before recommencing high-intensity paddling bouts. Aerobic ($\dot{V}O_2$peak) and anaerobic (peak watts) physiological testing through paddling assessments have previously been assessed in several studies (8,15,16,19,21).

Loveless and Minahan (15) conducted the only study which compared competitive and recreational surfers and revealed no significant differences between the groups for $\dot{V}O_2$peak values. Mendez-Villanueva et al. (21) also revealed no difference in $\dot{V}O_2$peak scores when European level surfers were compared against regional level surfers. Only 2 studies (8,15) have assessed peak power output using ergometers; discrepancies in mean peak power output values are evident

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between studies. Competitive surfers have been shown to possess significantly ($p \leq 0.05$) greater peak power outputs (8,15), and season rank has been significantly ($p \leq 0.05$) correlated with peak power output (8).

A key theme in these physiological studies is the variation in $\dot{V}O_2$peak values ($M = 37.8$–54.2 ml·kg^{-1}·min^{-1}) and peak power outputs ($M = 205$–348 W). An explanation for the variations may be due to differences in equipment and testing protocols used. In addition, there appears to be no difference in $\dot{V}O_2$peak scores between recreational and competitive surfers, despite this being a common finding in most other sports. It should be noted that all of these studies investigating $\dot{V}O_2$peak using paddling ergometers lack adequate sample sizes ($n < 10$). This limits the ability to reveal meaningful mean differences between groups and generalize results to surfing cohorts.

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

It is apparent that further physiological testing is needed in a larger sample size comparing recreational and competitive surfers. Therefore, the aims of this study were (a) to provide the aerobic and anaerobic profile for competitive and recreational surfers and determine whether differences exist between groups; (b) to provide the body composition and anthropometric comparisons for competitive and recreational surfing cohorts and; (c) to determine whether physiological testing could be used in a surf-specific screen to assist with discriminating in performance. It is hypothesized that competitive cohorts will have increased anaerobic and aerobic power and decreased body fat compared with recreational surfers.

METHODS

Experimental Approach to the Problem

Physiological variables ($\dot{V}O_2$peak and anaerobic power), anthropometrics and body composition measurements were determined at multiple study sites on both competitive and recreational surfers. A comparative analysis was conducted between key performance variables ($\dot{V}O_2$peak, relative anaerobic power and peak anaerobic power) of both competitive and recreational groups to determine significant differences.

Subjects

This was a multisite study that involved a total of 62 male surfers, recreational (± SD $n = 47$; age 26.50 ± 5.28 years; mass 77.42 ± 10.69 kg; height 180.13 ± 7.54 cm) and competitive ($n = 15$; age 26.73 ± 4.68 years; mass 77.83 ± 6.62 kg; height 179.44 ± 3.96 cm). Subjects ages ranged from 19 to 36 years old. The 15 competitive surfers were competing on the World Qualifying Series or World Championship Tour (surfing experience 18.86 ± 5.46 years; surfing frequency 13.23 ± 4.54 hours per week; dry land training 4.5 ± 2.35 hours per week) and all remaining surfers were classified as recreational (surfing experience 13.22 ± 6.93 years; surfing frequency 7.56 ± 4.91 hours per week; dry land training 2.57 ± 2.93 hours per week). To be classified as a recreational surfer, subjects were to have at least 1-year experience, currently be surfing and not compete higher than local club level. A total of 34 (54.8%) were tested at one Australian University and the remaining 28 were tested at an American University, where only aerobic testing was conducted. Subjects were tested after their normal routine of sleep, nutrition, and hydration levels before testing. Being a multisite study, ethics was granted through the Bond University Human Research Ethics Committee (RO1610) and through the Institutional Review Board for the Protection of Human Subjects (IRB, 2013-118) before commencement. Participants were informed of the risks and benefits of the investigation before all signing an informed consent form.

Before undertaking analysis between the competitive and recreational groups, data collected between both testing sites needed to be analyzed to ensure there were no differences in $\dot{V}O_2$peak, mass, and age. Only aerobic testing was conducted at the American University and therefore only key variables that could influence $\dot{V}O_2$peak scores were analyzed. No significant differences were seen between the 2 sites for age (27.19 ± 4.24 vs. 26.03 ± 5.91 years; $p = 0.47$), mass ($M = 74.82 \pm 8.66$ vs. 79.20 ± 11.70 kg; $p = 0.17$), and $\dot{V}O_2$peak (32.75 ± 5.24 vs. 30.25 ± 6.85 ml·kg^{-1}·min^{-1}; $p = 0.19$). Therefore, data were pooled together to provide a recreational group of 47 surfers.

Procedures

Testing at the Australian University was conducted by a physiotherapist with additional training in exercise testing and an accredited exercise physiologist with over 20 years of experience. Testing at the American University was conducted under the direct supervision of an exercise physiologist with over 15 years of experience. Initially, anthropometric measurements were conducted followed by DEXA then anaerobic testing and finally aerobic testing. All subjects were tested in a university setting and underwent the exact same order of testing on the same day; however, testing conducted at the American University involved aerobic testing only.

Anthropometrics and Body Composition

Anthropometric measurements included height, mass, and arm span. Height was initially measured to the nearest 0.1

cm and body mass was measured with minimal clothing using a standard medical balance scale (Seca 700, Hamburg, Germany). Arm span was measured to the nearest 0.1 cm according to standard recommendations (23). Arm span was divided by height to determine "Ape Index," a ratio commonly used with sports such as rock climbing and swimming where larger ratios favor the competing athlete (31).

A DEXA scanner (General Electric; Prodigy Pro, Madison, WI, USA) was used for all body composition testing. Encore software provided an output of segmental body composition for each surfer (right and left arms, legs and trunk). All scans were completed according to the standardized DEXA operational protocol (24). Surfers were centrally positioned where by both feet were placed on a foam block and foam pads were placed on each hand to help determine tissue differences between arms and trunk (foam is transparent under DEXA). Using a foam block and pads, a constant distance between feet (15 cm) and between hands and trunk (3 cm) was maintained. According to the standardized baseline conditions (24), subjects are required to be overnight fasted on the morning of measurements. Unfortunately, the DEXA occurred before anaerobic and aerobic testing and therefore overnight fasting was not appropriate. To ensure the standardized conditions, subjects were required to fast for at least 2 hours before testing.

Anaerobic Power Output Testing

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

The resistance unit on the swim bench ergometer provided 7 airflow resistance settings. The highest setting was used in this study, as previous research by Loveless and Minahan (16) revealed that the maximum power output was achieved at the highest resistance. Anaerobic power output was measured during a 10-second sprint on the swim bench ergometer at maximal effort (completed before aerobic testing). The surfer was initially familiarized with the equipment and given standardized instructions on the testing procedures. This was followed by a 3-minute warm-up at 30 watts and then three 5-second maximal effort sprints with each sprint separated by a 20-second rest period. After the completion of the warm-up, the surfer had a 10-minute rest before completing the 10-second sprint at maximal effort. A 10-minute rest period was selected as complete resynthesis of adenosine triphosphate (ATP) occurs within 3 to 5 minutes, and complete creatine phosphate resynthesis can occur within 8 minutes (4,11,13). This protocol was based on previous anaerobic testing conducted on a competitive surfing cohort (8,16). As previously discussed, the inclusion of ANT+ software allows for data on the display unit to be captured and wirelessly transmitted. Peak power, mean power, left and right power outputs, peak velocity, and total distance were all calculated.

Aerobic $\dot{V}O_2$peak Uptake Testing

Subjects' $\dot{V}O_2$peak was obtained during an incremental endurance exercise test. Measuring peak oxygen consumption is considered the gold standard for quantifying aerobic fitness. Swim bench ergometry has previously been shown to be both valid and reliable to test peak aerobic and anaerobic levels in recreational and competitive surfers (8,15). All surfers underwent aerobic testing on the swim bench ergometer. Oxygen consumption was analyzed using a Parvo Medics (TrueOne, 2400) automated gas analysis system (O_2 analyzer, CO_2 analyzer, pneumotach) which was calibrated before each test. The expired gas analysis system meets Australian Institute of Sport accreditation standards for precision and accuracy.

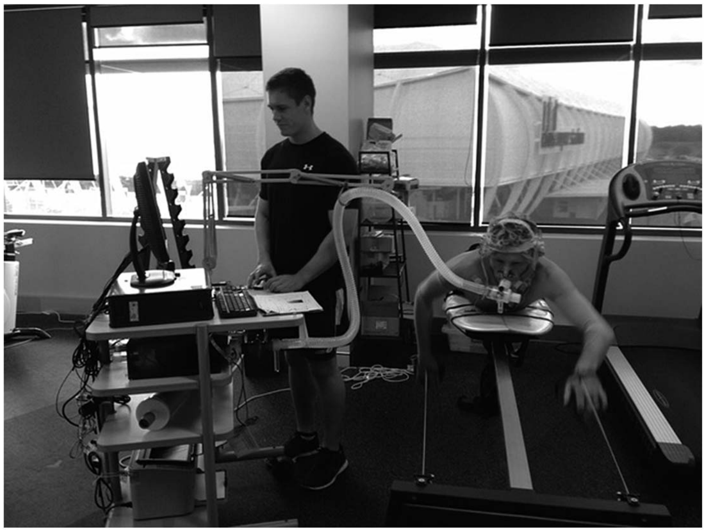

Figure 1. Laboratory setup of $\dot{V}O_2$peak testing performed on the swim bench ergometer.

This provided breath-by-breath measurement of maximum oxygen consumption ($L \cdot min^{-1}$) and relative to body mass ($ml \cdot kg^{-1} \cdot min^{-1}$), maximal ventilation, and energy expenditure (kcals). Oxygen uptake was averaged every 30 seconds, with the peak value recorded as the highest value obtained over a 30-second period.

The incremental test began at 30 W, with increments of 10 W every minute. Testing was terminated if maximum heart rate was exceeded, respiratory exchange ratio reached greater than 1.5, oxygen consumption did not increase concurrently with power output, required power output was not maintained for greater than 10 seconds, volitional exhaustion was achieved or any symptoms of chest pain were expressed by the surfer. These termination criteria were based on the ACSM guidelines for exercise testing and prescription (3). The incremental testing protocol was based on previous $\dot{V}O_2$peak testing conducted on a competitive and recreational surfing cohort (8,15). The testing setup with the surfboard attached to the swim bench is seen in Figure 1.

Statistical Analyses

Data analysis was performed with SPSS version 20.0. Descriptive statistics including means, *SD*s, and ranges were calculated for each measure and for each session. A Shapiro-Wilks test ($p > 0.05$) (27) and a visual inspection of their frequency histograms, normal Q-Q plots and box plots showed that all key performance variables ($\dot{V}O_2$peak, relative anaerobic power, and peak anaerobic power) were normally distributed for both the competitive and recreational groups; with the magnitude of skewness and kurtosis being nonsignificant (5,7). Independent *t*-tests were used for comparative analysis between competitive and recreational groups. Paired *t*-tests were used to determine the differences within groups. A Spearman's rank order correlation was conducted between end of year ranking and each of the variables of interest ($\dot{V}O_2$peak, peak and relative anaerobic power). A Pearson's correlational analysis was conducted with key physical attributes (arm span and total muscle mass) and key performance variables ($\dot{V}O_2$peak, peak anaerobic power, and relative anaerobic power).

RESULTS

Reliability Analysis

A small pilot study was conducted for both anaerobic ($n = 7$) and DEXA ($n = 8$) assessments. Whereby, each subject was assessed twice on the same day separated by 2 hours. The same assessor completed each assessment to evaluate intrarater reliability. Intraclass correlation coefficient (ICC) scores were within the excellent range for anaerobic testing and the use of DEXA (ICC 0.97 and 0.99, respectively). Reliability of $\dot{V}O_2$peak testing has been well established with test-retest scores being high ($r = 0.95–0.99$) (2).

Recreational vs. Competitive

A comparative analysis between the competitive and recreational groups can be seen in Table 1. Independent *t*-tests revealed significant differences ($p \leq 0.05$) between recreational and competitive groups for key performance variables.

TABLE 1. Key physical attributes and performance variables for competitive and recreational surfers ($M \pm SD$).

Measure	Competitive; $n = 15$	Recreational; $n = 47$	p
Anthropometrics and body composition			
Arm span (cm)*	190.61 ± 4.79	182.61 ± 9.28	0.01†
Ape Index*	1.06 ± 0.01	1.03 ± 0.02	<0.001†
Total body fat (%)*	17.11 ± 2.93	18.86 ± 3.33	0.12
Total muscle mass (g)*	61.66 ± 4.02	58.21 ± 6.46	0.81
Aerobic $\dot{V}O_2$peak test			
$\dot{V}O_2$peak ($L \cdot min^{-1}$)	3.14 ± 0.37	2.41 ± 0.53	<0.001†
$\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	40.71 ± 3.28	31.25 ± 6.31	<0.001†
Respiratory exchange ratio	1.10 ± 0.07	1.21 ± 0.08	<0.001†
Peak blood lactate (mmol)	12.01 ± 3.28	12.03 ± 3.37	0.99
Peak heart rate ($b \cdot min^{-1}$)	182.07 ± 5.27	175.58 ± 10.51	0.03†
Age-predicted heart rate max (%)	94.41 ± 4.19	90.80 ± 5.53	0.03†
Peak aerobic power (W)	121.93 ± 9.20	101.26 ± 18.49	<0.001†
Anaerobic 10-s test			
Absolute peak anaerobic power (W)*	303.93 ± 57.99	264.58 ± 46.14	0.04†
Mean anaerobic power (W)*	257.21 ± 47.28	224.04 ± 39.75	0.03†
Relative anaerobic power ($W \cdot kg^{-1}$)*	3.91 ± 0.63	3.53 ± 0.38	0.04†
Peak anaerobic speed ($m \cdot s^{-1}$)*	1.65 ± 0.09	1.54 ± 0.10	<0.001†

*Testing conducted at Bond University only ($n = 34$).
†Statistical significance ($p \leq 0.05$) determined through independent *t*-tests.

Competitive surfers had significantly greater arm span (M = 190.61 vs. 182.61 cm, $p = 0.01$) than recreational surfers. Consequently, competitive surfers revealed significantly higher Ape Index scores (arm span/height) than recreational males ($M = 1.06$ vs. 1.03, $p < 0.001$). $\dot{V}O_2$peak and peak anaerobic power were significantly greater in the competitive surfers than in recreational surfers (M = 40.71 vs. 31.25 $ml \cdot kg^{-1} \cdot min^{-1}$, $p < 0.001$; M = 303.93 vs. 264.58 W, respectively).

Physical Attributes and Key Performance Variables

Arm span was significantly ($p \leq 0.01$) correlated with $\dot{V}O_2$peak ($r = 0.55$), relative anaerobic power ($r = 0.49$), and peak power output ($r = 0.72$). Total muscle mass was also significantly correlated ($p \leq 0.05$) with $\dot{V}O_2$peak ($r = 0.56$), relative anaerobic power ($r = 0.49$), and peak power output ($r = 0.83$).

Season Ranking

A total of 10 competitive male surfers were used in the analysis as all of these surfers completed an entire year of competition. Key variables of interest were $\dot{V}O_2$peak, peak anaerobic power, and relative anaerobic power. No significant correlations ($p \geq 0.05$) were revealed for each of the variables of interest ($\dot{V}O_2$peak, $r = 0.33$; peak anaerobic power, $r = 0.06$; relative anaerobic power, $r = 0.09$).

Symmetry in Power Outputs

As power output data were attained during both the anaerobic and aerobic testing, comparisons between dominant and nondominant arm outputs were conducted using paired t-tests. There was no statistical difference ($p > 0.05$) between mean dominant and nondominant arm power outputs for anaerobic (dominant = 139.14 ± 34.30 vs. nondominant = 135.62 ± 2.59 W) and aerobic testing (dominant = 31.40 ± 5.77 vs. nondominant = 31.05 ± 5.53 W) for all surfers.

DISCUSSION

The purpose of this study was (a) to provide the aerobic and anaerobic profile of competitive and recreational surfers and determine whether differences exist between groups; (b) to provide the body composition and anthropometric comparisons for competitive and recreational surfing cohorts; and (c) to determine whether physiological testing could be used in a surf-specific screen to assist in discriminating performance. Findings from the current study support our hypothesis that competitive surfers tested on a swim bench ergometer had significantly higher values for both oxygen consumption and anaerobic power. In contrast to our hypothesis, body composition measured by DEXA did not significantly differ between competitive and recreational surfers tested in this study.

Time-motion analysis revealed that upper-body paddling represents the largest component of surfing (20). The competitive group had significantly higher aerobic scores in comparison with the recreational group. These findings suggest that high levels of aerobic fitness are attributes associated with competitive surfers. This is logical when considering the activity requirements of a competitive heat and the associated additional training. Farley et al. (9) reported that during a 20-minute competitive heat, a surfer is required to participate in repeated high- and low-intensity paddling bouts (1–20 seconds) interspersed with short rest periods accumulating 54 ± 6.3% of the total heat time. This paddling requirement may foster a high capacity for oxygen uptake to allow for sufficient recovery between paddling bouts. High-intensity interval training has previously been shown to increase maximal oxygen consumption (12). Given that paddling is characterized by a series of short sprints, competitive surfing may cause increases in maximal oxygen consumption. Competitive surfers are also generally involved in additional training that is designed to replicate paddling bouts in heats. This is commonly achieved using interval-type training methods (25).

The findings from the current study have both similarities and inconsistencies with previous surf-specific research (8,15,16,19,21). The competitive $\dot{V}O_2$peak scores are similar to previous research conducted by Farley et al. (8) and Loveless and Minahan (15); however, the recreational scores appear to be consistently lower than previous research conducted by Loveless and Minahan (15) and Meir et al. (19). All of the aforementioned studies had sample sizes of less than 10, thus limiting the ability to compare their results with the current study and generalize their results to recreational and competitive surfing cohorts. The current study revealed significant differences in $\dot{V}O_2$peak scores between recreational and competitive surfers. Previous research (15,21) had not identified this; however, both of these studies had sample sizes of less than 10 surfers in each group; once again limiting the ability to generalize the results to a surfing population.

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

Only 2 published studies have conducted anaerobic testing in a surfing cohort using upper-limb ergometers (8,16). Our results are slightly higher than the study conducted by Farley et al. (8); however, a kayak ergometer was used which differs from the swim bench ergometer used in the current study. Loveless and Minahan (16), using the same equipment setup, revealed slightly higher values for the competitive surfers (348 ± 78 W) compared with the results of the current study (303.93 ± 57.99 W). This inconsistency remains puzzling, considering that the average weight for the study by Loveless and Minahan (16) was 61.1 ± 9.2 kg compared to the current study's average mass of 77.83 ± 6.62 kg. The current study revealed a significant correlation ($r = 0.83$; $p < 0.001$) between lean muscle mass and peak power output; therefore, it would be expected that the heavier competitive group would produce greater peak power output scores. It needs to be noted that Loveless and Minahan (16) conducted 6 trials over 2 days to determine the mean power output of 348 ± 78 W. It could be postulated that a learning effect occurred with subjects becoming more proficient at the motor pattern required and the demands of the test over the 6 trials.

This study was the first to use DEXA to determine body composition with the variable of interest being percent body fat. Results revealed competitive surfers have low to moderate levels of body fat (17%). This is not surprising as surfers are not purely endurance athletes who tend to reveal lower-body fat levels ranging from 8 to 13% through the use of DEXA (24). The results of the current study are similar to previous research, which has used skinfold assessment to estimate body fat with values ranging from 10.5 to 22% for competitive male and female surfers (10,17,20). It could be postulated that low body fat values do not represent a real advantage from a performance perspective. It has also been suggested that higher body fat levels are possibly an adaptation to surfing in colder waters as additional body fat provides greater insulation (18,20). Once again, this information adds to building the profile for recreational and competitive surfers using DEXA.

The final aim of this study was to determine whether physiological testing could be used to discriminate in performance. Significant differences were revealed between competitive and recreational surfers indicating the ability of the aerobic and anaerobic testing to discriminate between groups. However, when analyzing the competitive cohort separately, no associations were detected. Whereby a surfers ranking and key performance variables (peak and relative power and $\dot{V}O_2$peak) were not correlated. This finding suggested that although high anaerobic and aerobic levels are associated with competitive surfers, they do not assist in determining their individual level of performance. This is logical as a surfer is ranked according to their ability of actually riding a wave (performing critical maneuvers) which was not assessed with these physiological tests. Therefore, although paddling assessment is crucial to undertake, it does not assist in discriminating the level of performance within a competitive cohort. It should however be noted that the *SD*s for key performance variables ($\dot{V}O_2$peak, peak and relative power output) were all minimal, indicating most results were closely related. Perhaps a test which resulted in a wide spread data set may have illustrated a stronger correlation. However, a single study conducted by Farley et al. (8) has previously shown a correlation between season rank and anaerobic scores achieved during a 10-second paddle sprint.

Interestingly a correlational analysis revealed significant ($p \leq 0.05$) associations between arm span, lean muscle mass, and key performance variables ($\dot{V}O_2$peak, peak and relative power output). These results may suggest that those surfers with longer arms and greater lean muscle mass produced higher $\dot{V}O_2$peak and anaerobic scores. Correlations between arm span and $\dot{V}O_2$peak scores are commonly reported in swimming studies (14,23). There were no differences in height between the competitive and recreational group; however, arm span significantly differed as with the ratio of arm span divided by height, known as Ape Index. This finding is unique as it raises the question as to whether significant increases in arm span in the competitive group are a result of a physical predisposition for success in the sport. Further investigation of this variable is warranted to determine the utility of these indices for assisting in talent identification.

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

To our knowledge, this study is the largest comparative surf-specific study to date that has comprehensively presented the physiological profile of competitive and recreational surfers. Key performance variables ($\dot{V}O_2$peak, peak and relative power output) are significantly higher in competitive surfers, indicating that this is both an adaptation and requirement in this cohort. Interestingly, no significant correlation was identified between key performance variables and ranking in the competitive cohort. This suggests that tests which replicate wave-riding components may be more appropriate to discriminate performance within a competitive group. Arm span and Ape Index were the anthropometric measurements that were significantly greater in the competitive group; whether this is a result of physical predisposition is yet to be determined. This comprehensive study adds to the physiological and physical profile of a recreational and competitive surfer. This battery of physiological tests could be used as a screening tool to identify an athlete's weaknesses or strengths. Coaches and clinicians could then select appropriate training regimes to address weaknesses and therefore place less emphasis on strengths.

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

PRACTICAL APPLICATIONS

Key performance variables ($\dot{V}O_2$peak and anaerobic power) are significantly higher in competitive surfers indicating that this is both an adaptation and requirement in this cohort. This battery of physiological tests could be used as a screening tool to identify an athlete's weaknesses or strengths. Coaches and clinicians could then select appropriate training regimes to address weaknesses. These findings are limited to the current study, and results should not be generalized to female surfing cohorts as further research is needed in this surfing cohort.

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