Differences in $\dot{V}O_2$peak of Surfers When Paddling in Water vs. on a Swimbench Ergometer

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Abstract

Furr, HN, Warner, ME, Copeland, TL, Robles-Rodríguez, C, Ponce-González, JG, Nessler, JA, and Newcomer, SC. Differences in $\dot{V}O_2$peak of surfers when paddling in water vs. on a swimbench ergometer. *J Strength Cond Res* 33(4): 1095–1101, 2019—The purpose of this study was to test the hypothesis that surfers would achieve a higher $\dot{V}O_2$peak when tested in a swim flume vs. on a swimbench ergometer. Forty-eight surfers (male: 38, female: 10) aged 18–45 years participated in the study. Protocol 1 and 2 both measured heart rate, oxygen consumption ($\dot{V}O_2$), and respiratory exchange ratio while subjects performed an incremental paddling test both on a swimbench ergometer and in a swim flume. Protocol 2 additionally measured muscle activity and changes in skin temperature. $\dot{V}O_2$peak was significantly higher in the swim flume (33.03 ± 1.04 ml·kg^{-1}·min^{-1}) vs. on the swimbench ergometer (29.86 ± 1.08 ml·kg^{-1}·min^{-1}) (p value < 0.001). There were also significant differences in muscle activation and changes in skin temperature between the flume and ergometer (p-value < 0.05). Surfers significantly increased their $\dot{V}O_2$peak in the water suggesting previous reports of $\dot{V}O_2$peak likely underestimated surfer's aerobic fitness when measured on a swimbench ergometer. Future research investigating the aerobic fitness of surfers should be conducted while paddling in water or account for the 11% difference in $\dot{V}O_2$peak when tested on a swimbench ergometer.

Key Words surfing, aerobic fitness, testing

Introduction

The number of surfers worldwide has increased from approximately 21 million in 2001 to 35 million in 2011 with 2.4 million American surfers alone. Surfing is characterized as an activity that consists of intermittent exercise bouts of varying intensities, durations, and recovery periods using both the upper and lower body (19,21). Surfers first paddle out through the breakers to the take-off area, then use powerful strokes to increase speed and catch a wave, followed by a quick stand-up on the board where they perform maneuvers (21). Field studies performed in competitive and recreational surfers have reported that surfing consists of paddling, sitting or lying stationary, wave riding, and miscellaneous activities (e.g., diving under waves, wading, and swimming) at approximately 48, 39, 4, and 9% of the total time spent surfing, respectively (5,9,17,21,22,24). Based on these data, it is clear that paddling compromises the greatest portion of time surfing. Heart rate (HR) responses when paddling out through the surf have been characterized as aerobic in nature and are consistent with the recommendations for cardiovascular fitness and health set by the American College of Sports Medicine and the Center for Disease Control and Prevention (5,9,16,17,21–23,29). Given this information, it is not surprising that peak oxygen consumption ($\dot{V}O_2$peak) of competitive and recreational surfers during simulated paddling on a swim bench or arm ergometer has been reported to be between 38 and 55 ml·kg^{-1}·min^{-1} (17,19,20,22). These values are similar to an average $\dot{V}O_2$peak of 45.7 ± 5.8 ml·kg^{-1}·min^{-1} reported in competitive swimmers (15). It is important to note that these similarities in $\dot{V}O_2$peak between swimmers and surfers may be somewhat misleading because $\dot{V}O_2$peak values obtained during upper-body exercise (e.g., paddling) can be 20–30% lower than $\dot{V}O_2$peak values obtained during full-body exercise (e.g., swimming) (4).

To date, $\dot{V}O_2$peak during paddling of both competitive and recreational surfers has been primarily assessed using swimbench ergometry as an attempt to simulate the paddling motion used by surfers in the water. However, despite research that strongly supports the importance of specificity

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during testing (1), no study has tested the $\dot{V}O_2$peak of surfers in the water (10,26). Interestingly, predicted $\dot{V}O_2$peak in swimmers has been reported to be significantly higher when tested in a flume vs. an ergometer, which is consistent with the specificity of exercise concept (25). These results suggest that the current physiological profile of surfers as determined by swimbench ergometry may be an underestimation of their paddling aerobic capacity because of differences between the mode of testing and the athletes' training. The purpose of this study was to determine whether $\dot{V}O_2$peak values obtained during simulated paddling on a swimbench ergometer differed from those obtained during actual paddling in a swim flume. It was hypothesized that surfers would achieve a higher $\dot{V}O_2$peak when tested in the swim flume vs. on the swimbench ergometer. It was also hypothesized that these differences in $\dot{V}O_2$peak would likely be attributable to differences in muscle recruitment and thermoregulation between the exercise paradigms.

Methods

Experimental Approach to Problem

The aerobic fitness of surfers has previously been assessed using simulated swimbench ergometry; however, there have been no previous studies investigating the aerobic fitness of surfers while paddling in the water. In this study, surfers performed 2 incremental paddling tests to assess and compare $\dot{V}O_2$peak values achieved in the water to those achieved during swimbench ergometry. In addition, peak upper-body muscle activity and changes in skin temperature were measured and compared between the 2 testing paradigms.

Subjects

Forty-eight proficient male and female surfers aged 18–45 years participated in this study. Before participation, subjects were informed of the risks and benefits of the investigation and asked to provide informed written consent. All procedures were approved by the institutional review board at California State University, San Marcos (IRB# 743280). Participants also completed a 1-page surfing history form, which included questions pertaining to their current surf activity, competency (15), and health. Inclusion criteria for the study were a minimum of 5 years of surfing experience and currently participating in surfing at least 2–3 times per week. Exclusion criteria from the study included subjects with any underlying health risks or that not meet the surf experience requirements. Participants were asked to refrain from exercise 24 hours before testing and not eat a heavy meal or drink caffeine up to 3 hours before testing. Subjects' height and body mass were measured using a Health O Meter professional beam scale (Health o meter Professional, McCook, IL, USA). Subject characteristics (age, height, body mass, surfing frequency, and surfing experience) are described in Table 1.

Procedures

Protocol 1. Swim Flume: For the current study, each subject performed 2 incremental paddling tests to assess and compare $\dot{V}O_2$peak. Subjects performed 1 test in a swim flume (Endless Pools, Aston, PA, USA) where they were asked to paddle against an increasing current until they reached volitional fatigue or could no longer keep up with the speed of the current (Figure 1). Intensity represented as speed ($m \cdot s^{-1}$) for the flume test was controlled by the researcher, and pilot studies were performed to determine speeds that would elicit volitional fatigue at similar time points as the swimbench ergometer protocols used in previous research testing $\dot{V}O_2$peak in competitive and recreational surfers (9,11,16–18). The water current started at a speed of 0.6 $m \cdot s^{-1}$ and increased by 0.1 $m \cdot s^{-1}$ everyminute. The dimensions of the surfboard used in this protocol were 5′10″ × 18″ × 2¼" in. This board size fits within the size constraints of the flume and assured that subjects achieved $\dot{V}O_2$peak before the flume reaching its maximal water speed (2.2 $m \cdot s^{-1}$) capacity.

The primary measure in this study was oxygen consumption. Oxygen consumption and respiratory exchange ratio (RER) were measured using a Parvo Medics metabolic cart (TrueOne 2400; Parvo Medics, Sandy, UT, USA). A Hans Rudolph $\dot{V}O_2$ mask and 1-way breathing valve (Hans Rudolph, Inc., Shawnee, KS, USA) were secured to the subjects' head. Two 15-foot tubes were connected to the 1-way valve, 1 on the inhalation side and 1 on the exhalation side leading to the metabolic cart. Calibrations were performed before testing using standard procedures. Heart rate was recorded using a Polar RCX 5 HR watch and Polar T31 coded

Table 1. Subject characteristics.

Sex	N	Age (yrs)	Height (cm)	Body mass (kg)	$h \cdot wk^{-1}$	Years surfed	Competency (1–10)
Male	38	26.8 ± 1.28	177.62 ± 1.15	74.70 ± 1.30	8.42 ± 1.00	11.74 ± 1.33	6.41 ± 0.25
Female	10	24.8 ± 1.94	165.61 ± 2.16	56.97 ± 2.03	5.70 ± 1.33	11.20 ± 2.19	6.10 ± 0.57
Total	48	26.4 ± 1.09	175.13 ± 1.23	71.01 ± 1.52	7.85 ± 0.85	11.63 ± 1.13	6.34 ± 0.23

Figure 1. Experimental setup in the swim flume for experiments from protocols 1 and 2.

transmitter strap (Polar Electro, Inc., Kempele, Finland). The transmitter strap was placed securely around the subjects' chest with the transmitter centered at the base of the sternum. Height and body mass were entered into the HR watch and placed on the subjects' wrist. $\dot{V}O_2$peak, RER, and maximum HR were collected at 15-second intervals and reported for this portion of the study.

Swimbench Ergometry: The other portion of protocol 1 was performed on a Vasa swimbench ergometer (Vasa, Inc., Essex Junction, VT, USA). Swimbench ergometry has been used historically and believed to be valid and reliable in testing the aerobic fitness of recreational and competitive surfers (9,11,16–18). $\dot{V}O_2$peak, RER, and maximum HR were collected at 15-second intervals using procedures identical to those used in the swim flume. Intensity for the ergometry test was represented in watts (W) and was self-regulated by the subject (not controlled by the researcher). During the first work stage, paddling began at 10 W and increased by 10 W every minute following. This protocol has previously been used in describing the physiological profile (11) and characterizing the activity and cardiovascular response of male recreational and competitive surfers (17). Power output (W) was recorded using simulANT (Dynastream Innovations, Inc., Alberta, CA, USA). A GoPro Hero 4 (GoPro, Inc., San Mateo, CA, USA) was used to display wattage from the output display screen on the ergometer to a Google tablet (ASUS Computer, Inc., Taipei, TW) secured at the nose of the board. This provided subjects with visual feedback of their power output while paddling. The order of the swim flume and swimbench ergometer experiments was randomized for every subject and performed no longer than 1 week apart at the same time of day ($n = 36$). Subjects were naive to both swimbench ergometer and flume, and there was no familiarization on either piece of equipment before testing. Air temperature, humidity, and barometric pressure were measured using Davis Vantage Vue weather systems (Davis Instruments Corporation, Hayward, CA, USA). Water temperature and speed were measured using a flow watch flowmeter (JDC Electronics, Yverdonles-Bains, Switzerland) and recorded for the flume protocol.

Protocol 2. Because of the results of protocol 1, a second protocol was developed to investigate potential mechanisms underlying the differences observed in $\dot{V}O_2$peak between the swim flume and ergometer. Twelve additional subjects performed both the flume and ergometer incremental paddling tests following the same procedures as protocol 1. In addition to $\dot{V}O_2$peak, HR, and RER, muscle activity of the upper body and changes in skin temperature between the flume and ergometer were also measured and compared. However, for this protocol, subjects performed both incremental paddling tests on the same day in a random order, with a 90-minute recovery period between tests. This discrepancy between protocols 1 and 2 was necessary to ensure that electromyography (EMG) sensors did not have to be removed and therefore remained in the exact same anatomical location for both the flume and ergometer ($n = 12$).

Muscle activity data were collected through 10 wireless Delsys Trigno EMG sensors (Delsys, Inc., Natick, MA, USA). Electromyography sensors were secured with transparent tegaderm patches (NexcareTM TegadermTM, St. Paul, MN) on the skin of the upper trapezius, middle trapezius, posterior deltoid, medial deltoid, and latissimus dorsi bilaterally. Before testing, the signal for each electrode was tested, and the electrode was repositioned to ensure a quality signal. A Dell laptop (Dell, Inc., Round Rock, TX, USA) was used to collect data from the Delsys Trigno EMG system during the last 15 seconds of each incremental work stage for both the flume and ergometer tests.

Skin temperature (°C) was measured before and after both the flume and ergometer protocols. Measurements were taken using an infrared surface thermometer (Infrared

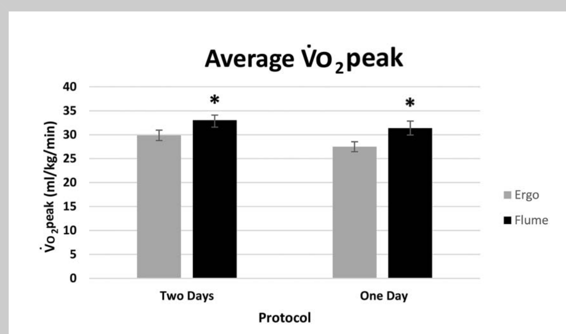

Figure 2. Average $\dot{V}O_2$peak in the swim flume vs. during swimbench ergometry for protocol 1 (2 days) and protocol 2 (1 day). Subjects for protocols 1 and 2 were different. Error bars represent 1 *SE* in the positive and negative direction. Asterisk (*) indicates significance at a p value <0.001.

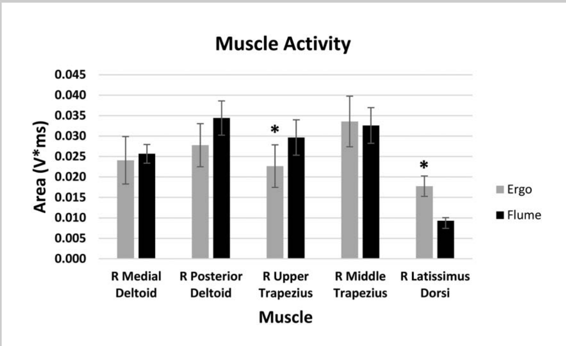

Figure 3. Average muscle activity (V*ms) during the final stage of a $\dot{V}O_2$peak test for the right medial deltoid, posterior deltoid, upper trapezius, middle trapezius, and latissimus dorsi in the flume vs. during swimbench ergometry. "Area" indicates the average area under the curve for the filtered and rectified EMG signal. Error bars represent 1 *SE* in the positive and negative direction. Asterisk (*) indicates significance at a *p* value <0.05. EMG = electromyography.

Thermometer, Fluke USA, Everett, WA). Anterior measurements were made on the right shoulder, chest, thigh, and shin. Posterior measurements were made on the shoulder, upper back, hamstring, and calf. Postmeasurements were made exactly 1 minute after the incremental paddling test ended. Measurements were used to calculate changes in skin temperature that occurred during testing.

Air temperature, humidity, and barometric pressure were measured using Davis Vantage Vue weather systems (Davis Instruments Corporation). Water temperature and speed were measured using a flow watch flowmeter (JDC Electronics) and recorded for the flume protocol.

Statistical Analyses

The 2 highest consecutive 15-second $\dot{V}O_2$ outputs were averaged and reported as $\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$) for each protocol. The 2 RER values that correspond with the 2 highest consecutive $\dot{V}O_2$ values were averaged and reported for maximum RER. Maximum HR was obtained from the subjects' data training file on the RCX5 HR watch. Pre–skin temperature was subtracted from post–skin temperature for each subject and averaged for the sample ($n = 12$) to determine the average change in skin temperature for both the flume and ergometer. Changes in skin temperature were compared between the flume and the ergometer incremental paddling tests. Muscle activation during the final stage of paddling was found by calculating the average area under the curve across all strokes. This value was then averaged across all subjects ($n = 12$) for both the flume and ergometer on the right side only. A paired T-test was used to determine any differences in $\dot{V}O_2$peak, HR, RER, peak muscle activity, and changes in skin temperature between the flume and the ergometer. Significance was set at a p value ≤ 0.05. All data are reported as mean ± *SE*.

Results

$\dot{V}O_2$peak, Heart Rate, and Respiratory Exchange Ratio

Surfers achieved a significantly higher $\dot{V}O_2$peak in the swim flume (33.03 ± 1.04 $ml \cdot kg^{-1} \cdot min^{-1}$) than on the swimbench ergometer (29.86 ± 1.08 $ml \cdot kg^{-1} \cdot min^{-1}$) when tested on 2 separate days. Similarly, a significantly higher $\dot{V}O_2$peak was also obtained in the swim flume (31.39 ± 1.46 $ml \cdot kg^{-1} \cdot min^{-1}$) when compared with swimbench ergometry (27.49 ± 1.06 $ml \cdot kg^{-1} \cdot min^{-1}$) in subjects who tested on the same day in protocol 2 (Figure 2). There was no significant difference in average maximal HR between the swim flume (177 ± 2 $b \cdot min^{-1}$) and the swimbench ergometer (176 ± 3 $b \cdot min^{-1}$) in the subjects who were tested on 2 different days. There was also no significant difference in maximal HR between the swim flume (172 ± 4 $b \cdot min^{-1}$) and the swimbench ergometer (171 ± 3 $b \cdot min^{-1}$) when tested on the same day. In addition, there was no significant difference in RER between the swim flume (1.23 ± 0.02) and the swimbench ergometer (1.22 ± 0.02) when testing was completed on 2 separate days. Likewise, there was no difference in RER between the flume (1.28 ± 0.03) and the swimbench ergometer (1.29 ± 0.02) when testing was completed in the same day. No differences were seen in the average time to fatigue between the ergometer (8.33 ± 0.31 minutes) and the flume (8.36 ± 0.33 minutes) in subjects who performed the test on 2 separate days.

Electromyography

Muscle activity during the final stage, as assessed by the maximal area under the curve, was significantly higher in the upper trapezius when paddling in the flume (0.033 ± 0.004 V*ms) vs. during ergometry (0.023 ± 0.005 V*ms). However, latissimus dorsi activity during the final stage was significantly higher during ergometry (0.018 ± 0.002 V*ms) when compared with paddling in the water (0.009 ± 0.002 V*ms). No significant differences in muscle activation during the

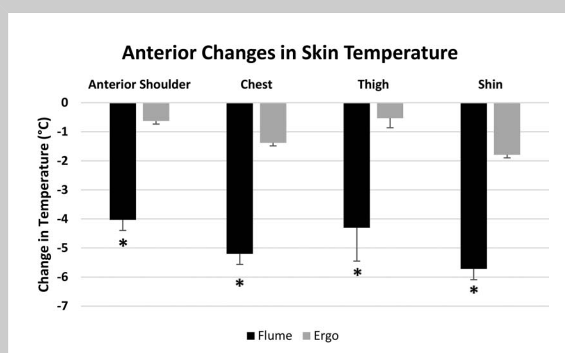

Figure 4. Average changes in anterior skin temperature after completion of an incremental paddling test in the swim flume vs. on a swimbench ergometer. Asterisk (*) indicates a significant difference between the flume and ergometer at a *p* value <0.001. Error bars represent 1 *SE* in the negative direction.

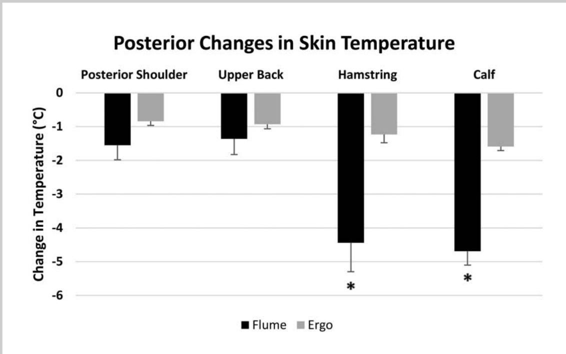

Figure 5. Average changes in posterior skin temperature after completion of an incremental paddling test in the swim flume vs. on a swimbench ergometer. Asterisk (*) indicates a significant difference between the flume and ergometer at a *p* value <0.001. Error bars represent 1 *SE* in the negative direction.

final stage of paddling were found for the medial deltoid, posterior deltoid, or middle trapezius when comparing paddling in the flume with swimbench ergometry (Figure 3).

Skin Temperature

There was a significantly greater decrease in skin temperature of the anterior shoulder, chest, thigh, and shin at the end of testing in the swim flume when compared with ergometry ($p < 0.001$) (Figure 4). On the posterior side of the body, there was a significantly greater decrease in skin temperature over the hamstring and the calf after testing in the swim ($p < 0.001$). There were no significant differences in the change in skin temperature of the posterior shoulder and upper back between the swim flume and swimbench ergometer (Figure 5).

Environmental

Water temperature was maintained between 26 and 28° C for protocol 1 and protocol 2. There was no difference in air temperature between day 1 (21.31 ± 0.87° C) and day 2 (21.67 ± 0.77° C) when tests were completed on 2 separate days.

Discussion

Despite the increased participation in surfing worldwide, the aerobic fitness of recreational and competitive surfers has yet to be studied in the water. To determine whether $\dot{V}O_2$peak values obtained during simulated paddling on a swimbench ergometer differed from those obtained during actual paddling in a swim flume, we assessed the $\dot{V}O_2$peak of surfers in the swim flume and on the swimbench ergometer and compared the 2 values. Results from the current study demonstrate that a significantly higher $\dot{V}O_2$peak was achieved by surfers when tested in the water vs. during simulated paddle ergometry. To identify potential mechanisms underlying these differences in $\dot{V}O_2$peak, we also investigated upper-body muscle recruitment and changes in skin temperature between the flume and ergometer. Significant differences were also observed between the flume and ergometer in peak muscle activity as well as changes in skin temperature. These findings are the first to demonstrate that testing surfers' aerobic capacity during paddling in a flume vs. an ergometer elicits significantly higher $\dot{V}O_2$peak, and that these observed differences are likely at least partially attributable to differences in both thermoregulation and muscle recruitment between these exercise modalities.

Many studies have previously assessed the $\dot{V}O_2$peak of recreational and competitive surfers through simulated paddle ergometry; however, to the best of our knowledge, this is the first study to assess the $\dot{V}O_2$peak of surfers in the water (9,11,16–20,22). Similar to results from the previous research that determined the predicted $\dot{V}O_2$peak of swimmers was significantly higher when tested in a flume, surfers in the current study were able to elicit higher $\dot{V}O_2$peak when tested in a flume vs. an ergometer (25). This result aligns with research that strongly supports the importance of specificity when assessing aerobic fitness (10,26). For example, it has been repeatedly demonstrated that $\dot{V}O_2$max on a cycle ergometer is lower than $\dot{V}O_2$max on a treadmill by as much as 25% in an individual without cycle training (31). Results from our study provide evidence that this is no different when testing the aerobic fitness of surfers who exercise primarily in the water. Our data suggest that $\dot{V}O_2$peak of surfers performing simulated paddling on an ergometer is approximately 11% lower than those achieved while paddling in the water. Therefore, $\dot{V}O_2$peak in surfers is specific to exercise modality, which is consistent with what has been reported previously when assessing the aerobic fitness of other athletes (24). Results from our study seem to suggest how the specificity of a testing environment can influence physiological and biomechanical responses that directly affect the $\dot{V}O_2$peak of surfers.

The precise mechanisms underlying the significant differences in $\dot{V}O_2$peak between exercise modalities are unclear. However, one can speculate that these differences may in part be due to changes in cardiac output that occur during exercise in the water. It is well established that exercising in water increases central venous pressure and decreases the role of gravity on venous pooling (6). These changes that occur in the peripheral circulation, as a result of exercising in the water, have been reported to facilitate increases in end diastolic volume and cardiac output during exercise (6,28,30). The current finding of no significant differences in maximal HR between the swim flume and ergometer is consistent with previous literature and suggests that potential differences in cardiac output between the exercise modalities was attributable to increases in stroke volume while exercising in the water (6).

The impact of temperature on skeletal muscle blood flow is another potential mechanism that may have contributed to an increased $\dot{V}O_2$peak in the flume compared with the ergometer.

As expected during exercise, skin temperature decreased during both the swim flume and ergometer protocols as sweat evaporated and skin blood flow increased dissipating heat away from the body (12). However, it is well established that heat loss occurs 3 to 5 times faster in water than air of the same temperature, which may explain the significantly greater decrease in skin temperature observed in the swim flume (3,13,27,32). One can speculate that these differing rates of heat exchange in water (flume) and air (ergometer) provided a greater thermoregulatory challenge while paddling on the ergometer, which subsequently resulted in an increase in skin blood flow and a reciprocal decreased oxygen delivery to the working skeletal muscle (13,31). Therefore, the greater thermoregulatory stress elicited while exercising on the ergometer in the current study likely significantly lowered $\dot{V}O_2$peak by decreased oxygen delivery to the working skeletal muscle (8).

Muscle activity during the final stage of paddling may also have contributed to the reported differences in $\dot{V}O_2$peak between the ergometer and flume. We found that surfers had significantly higher activation of their upper trapezius in the swim flume, while on the ergometer, there was significantly more latissimus dorsi activation during peak performance. These results suggest that there is a difference in paddling mechanics between the swim flume and ergometer, which may have contributed to the differences found in $\dot{V}O_2$peak. It is well established that skeletal muscle mass plays an important role in oxygen consumption during exercise (31). It is possible that the lower $\dot{V}O_2$peak observed on the ergometer was partially a result of muscle fatigue, which can prevent athletes from activating sufficient muscle mass when testing aerobic fitness (14). By contrast, paddling in water is a complex activity where core stability is required for stabilization in the water (2). It is possible that the higher $\dot{V}O_2$peak observed in the swim flume was in part due to recruitment of supplemental muscle groups such as the core to maintain stability while paddling in the water. The existing differences in muscle activity determined by the current data indicate that peak paddling mechanics on the swim bench ergometer are not similar to those in the water and may contribute to an invalid assessment of $\dot{V}O_2$peak in surfers.

A few factors contributed to our selection of subjects and testing protocols for the current study. It has been reported that the population of recreational surfers comprises approximately 90% male surfers and 10% female surfers (7). The current study included a similar ratio of male (80%) to female (20%) surfers as reported in the general population. Ambient air temperature was another factor that may have influences our results. However, by randomizing the order of the 2 testing paradigms, we were able to control for differences in weather as evidenced by the lack of difference in average ambient air temperature (21° C) between day 1 and day 2 of testing. Finally, one of the limitations of the swimbench ergometer was that power output had to be self-regulated by the subject and could not be controlled by the researcher. Analysis of the power output data demonstrated that subjects were able to maintain prescribed workloads of the protocol, and therefore, self-regulated workload likely did not impact our overall result.

This is the first study to assess the aerobic fitness of surfers paddling in the water compared with simulated paddling on a swimbench ergometer. The current findings suggest that previously published data of surfers $\dot{V}O_2$peak, as determined by swimbench ergometry, are likely an underestimation of their true aerobic capacity. The findings from this study also provide evidence that differing $\dot{V}O_2$peak values between the flume and ergometer are likely a result of differences in hemodynamics, thermoregulation, and muscle recruitment (6,31). This information suggests that future research investigating the aerobic fitness of surfers should be performed while paddling in water or account for the 11% difference in $\dot{V}O_2$peak when tested on a swimbench ergometer.

Practical Applications

The sport of surfing is scheduled to make its Summer Olympic debut in 2020, and countries are beginning the process of evaluating, which surfers will take part in these games. One can speculate that coaches and trainers will likely be interested in the aerobic capacity of competitive surfers during paddling, given the fact that it constitutes the greatest percentage of time and is the most metabolically demanding of all surfing activities (5,9,16,17,21–23,29). The finding from the current study suggests that coaches and trainers should make aerobic capacity measurements of surfers during paddling in an aquatic environment such as a flume. Unfortunately, there are currently a limited number of facilities in which these types of physiological measurements can be made in an aquatic environment. The lack of access to these facilities may necessitate surfer's aerobic capacity to be assessed while simulated paddling on an ergometer. The findings from the current study suggest that coaches and trainers should be cognizant that surfer's aerobic capacity during simulated paddling on an ergometer will likely be underestimated by 11%. It is also important for coaches and trainers to note that findings from the current study suggest that there are significant differences in muscle activity during paddling in an aquatic environment vs. simulated paddling on an ergometer. These findings suggest that the outcomes from land-based paddle training on an ergometer may be different from aquatic paddle training. Therefore, coaches and trainers should incorporate aquatic-based paddling over simulated paddling into the surfers training.

Acknowledgments

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