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Graduate Studies

HEART RATE RESPONSE AND ENERGY COST OF STANDUP PADDLEBOARDING

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Clinical Exercise Physiology

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By Jessica B. Andres

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology

The candidate has completed the oral defense of this thesis.

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ABSTRACT

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Standup Paddleboarding (SUP) began in Hawaii as a way to view island scenery and as a way for photographers to get better picture angles of surfers. The purpose of this study was to determine the heart rate (HR) response and energy expenditure of SUP. Sixteen recreational paddleboarders completed a total of three trials at Rating of Perceived Exertion (RPE) levels of 11, 13, and 15. It was found that HR was between 67% and 89% of age-predicted maximal HR and energy expenditure was between 9.00 and 13.9 kcal per minute, depending on the RPE level of the paddleboarder. The results indicate that SUP meets American College of Sports Medicine guidelines for positively affecting body composition and improving cardiorespiratory endurance.

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Thanks to all the participants of my study. Extra thanks for those who had to redo trials due to technical difficulties.

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I would like to thank Chris Dodge and Maria Cress for the innovative backpack design that held the douglas bag and head gear in place during the trials.

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Lastly, I would like to thank Robin Howell, my beautiful mother, for always being encouraging, supportive, and inspiring. She has and always will be my rock. My mom has always done whatever it takes to help me succeed in any endeavor. I thank her for giving me the courage to come to the University of Wisconsin-La Crosse, 600 miles away from my hometown in Kentucky.

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INTRODUCTION

In the 1940's, Hawaiian surf instructors began creating the modern version of standup paddleboarding (SUP). The instructors found that standing up on surfboards allowed for a better view of their student's surf technique and they used a paddle to navigate the waves and change directions. Additionally, surf photographers began standing on their boards to get better picture angles. The popularity of SUP soared in 2003, when SUP racing became an event at a world-renowned surfing competition held in Makaha, HI, the Buffalo Big Board Classic.

Standup paddleboarding remained mostly a Hawaiian activity until a Vietnam veteran, Rick Thomas, brought a board back to California. The activity became an overnight sensation. Standup paddleboarding is defined as the use of a long narrow board that propels riders over water, often in a standing position by means of a single-bladed paddle. The beauty of SUP is that it allows people of different ages and skill level to enjoy the water. Even experienced surfers have found that SUP has a few advantages over surfing, such as increased distance you can safely travel to remote surf locations, increased exercise time in the ocean, and it allows a better view of local scenery and wildlife. In addition to ocean use, SUP has become a popular alternative to kayaks and canoes on lakes and rivers. Standup paddleboards are recognized by the United States Coast Guard as navigation vessels, requiring the use of safety flotation devices while in use.

Despite the growth in popularity of the sport, only one study has evaluated the energy expenditure of SUP. Palakovich, Cuddy, and Ruby (2013) estimated the energy cost of moderate-intensity SUP to be 10.4 kcal/min. However, energy cost was not directly measured, but was estimated from laboratory derived prediction equations. The study concluded that the energy demand of SUP is comparable to moderate-intensity rowing, canoeing, and kayaking. The purpose of this study was to directly measure the energy cost and heart rate (HR) responses to three bouts of SUP at set rating of perceived exertion (RPE) levels of 11, 13 and 15.

METHODS

Subjects

Subjects for this study were 16 apparently healthy male (n=8) and female (n=8) college-aged individuals who regularly participated in recreational activity. Each subject provided written informed consent prior to any participation in the study. This study was approved by the Institutional Review Board for the Protection of Human Subjects at the University of Wisconsin-La Crosse.

Procedures

Each subject participated in SUP practice sessions until his or her skill level was considered proficient by the principle investigator. The number of practice sessions varied from 1-5 for each participant. Testing took place on a small bay located off the main channel of the Mississippi River. Subjects paddled on a Surftech 10' 6" SUP (Surftech, Santa Cruz, CA) using a BIC sport Alu ML Stand Up Paddle (BIC Sport, Vannes, France). Subjects wore a U.S. coast guard approved life jacket for all practice and testing sessions.

On testing day, subjects were required to complete three trials at RPE values corresponding to 11 (fairly light), 13 (somewhat hard) and 15 (hard) on the 6-20 Borg Scale (Borg, 1982). For each trial, the subject paddled for 3 minutes in order to reach steady-state exercise. During the last 30-seconds of each trial, expired air was collected into a 200 mL EconoGrab Tedlar Sampling Bag (Zefon International, Ocala, FL). The bag was strapped onto the subjects back using adjustable velcro straps (Figure 1). A J-valve was used to connect the bag to a standard Hans-Rudolph mouthpiece. The subject was prompted to turn the J-valve, effectively opening the valve and allowing expired air to enter the bag. At the conclusion of the 30-second collection period, the subject was prompted to quickly turn the valve again to block air from entering or escaping. A separate numbered bag was used for each data collection trial.

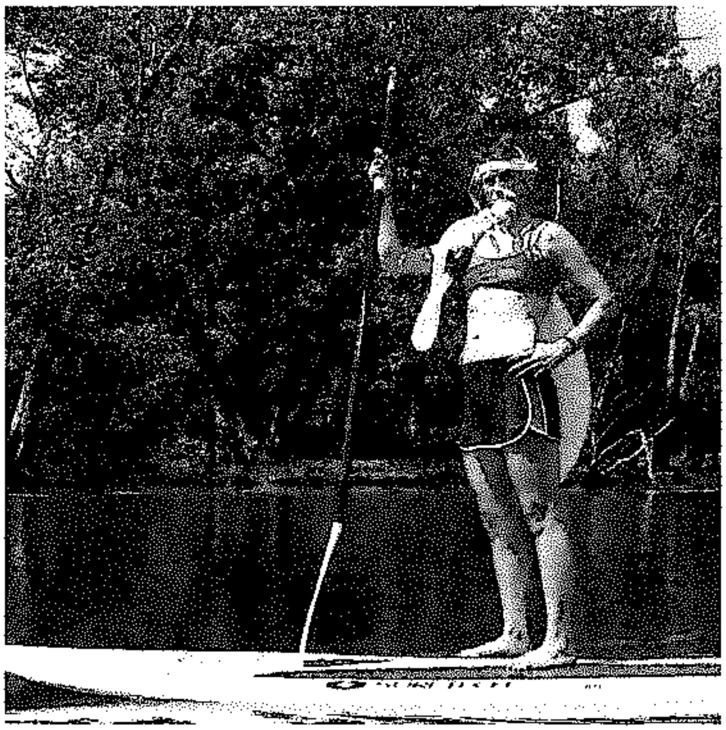
Figure 1. Subject wearing gas collection apparatus.

Heart rate was recorded immediately at the end of each trial using a Timex Ironman watch with a Timex HR chest strap and. Speed was recorded by mirroring the paddleboarder's speed with the data collection boat. Speed was averaged over three speedometer readings during each trial. In order to minimize the effect of the current, each trial started from the same section of the bay and each paddleboarder was directed to paddle toward the same area of the bay.

Gas Analysis

Following completion of the three trials, the bags were taken into a temperature controlled climate and allowed to cool to room temperature. Expired gas was analyzed using a PARVO medics 2400 gas analyzer. Each bag was first connected to the PARVO analyzer for 10 seconds to measure expired gas concentrations of oxygen and carbon dioxide. The bag was then connected to a Parkinson Cowan gas spirometer to measure the volume of expired air in each bag. The air was carefully pushed out of the collection bag to insure that no air was left in the bag. Equations established by Egan (1999) were utilized to determine total VO_2 for each trial.

Statistical Analysis

Standard descriptive statistics were used to characterize the subject population and to summarize physiologic responses to SUP. Differences across RPE levels and between female and male paddleboarders were analyzed using two-way ANOVA with repeated measures. The alpha level was set at $p<0.05$ to achieve statistical significance. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS, version 22; SPSS Inc., Chicago, IL).

RESULTS

Descriptive characteristics of the subjects are summarized in Table 1. A significant difference in height and weight was found between male and female subjects.

Table 1. Descriptive characteristics of the subjects (N=16).

	Female (n=8)	Male (n=8)
Age (yrs)	23.4±1.06	22.8±1.58
Height (in)	66.4±1.92	70.0±1.31*
Weight (kg)	67.8±7.83	80.6±11.7*

Values represent mean ± standard deviation.
*Significantly greater than females ($p < 0.05$).

Responses of paddleboarders at RPE 11, 13 and 15 are summarized in Table 2. There was a significant increase in all variables across RPE levels. There was no significant difference between female and male paddleboarders for HR at any RPE. However, absolute oxygen consumption (VO_2) and energy cost (kcals) were statistically greater for males compared to female paddleboarders at all RPE levels. Additionally, relative VO_2 at an RPE of 15 was statistically greater for males than females.

Table 2. Responses of female and male paddle boarders at RPE 11, 13 and 15 (N=16).

	Heart Rate	VO_2(L/min)	VO_2(ml/kg/min)	Kcal/min
RPE 11				
Female (n=8)	136±20.9	1.53±.402	22.2±4.71	7.60±2.01
Male (n=8)	131±26.3	2.07±.463*	26.1±6.65	10.4±2.32*
Total (N=16)	133±23.6	1.80±.433	24.2±5.68	9.00±2.17
RPE 13				
Female (n=8)	161±15.5	1.88±.444	27.5±5.89	9.40±2.22
Male (n=8)	156±27.2	2.45±.450*	30.7±6.26	12.3±2.25*
Total (N=16)	159±21.4	2.17±.447	29.1±6.08	10.9±2.24
RPE 15				
Female (n=8)	175±13.1	2.18±.558	31.9±7.19	10.9±2.79
Male (n=8)	174±19.6	3.38±.500*	42.7±8.86*	16.9±2.50*
Total (N=16)	175±16.4	2.78±1.06	37.3±8.03	13.9±2.65

Values represent mean ± standard deviation.
*Significantly greater than females ($p<0.05$).

There was no significant difference in paddling speed between male and females at any RPE. Average speed at RPE 11, 13, and 15 were 2.6±.45, 3.3±.50, and 4.0±.51 respectively. A graph of percentage of HR maximum at each RPE level is presented in Figure 2 and average caloric expenditure for females and males at each RPE level is presented in Figure 3. The relationship between speed and energy expenditure is presented in Figure 4.

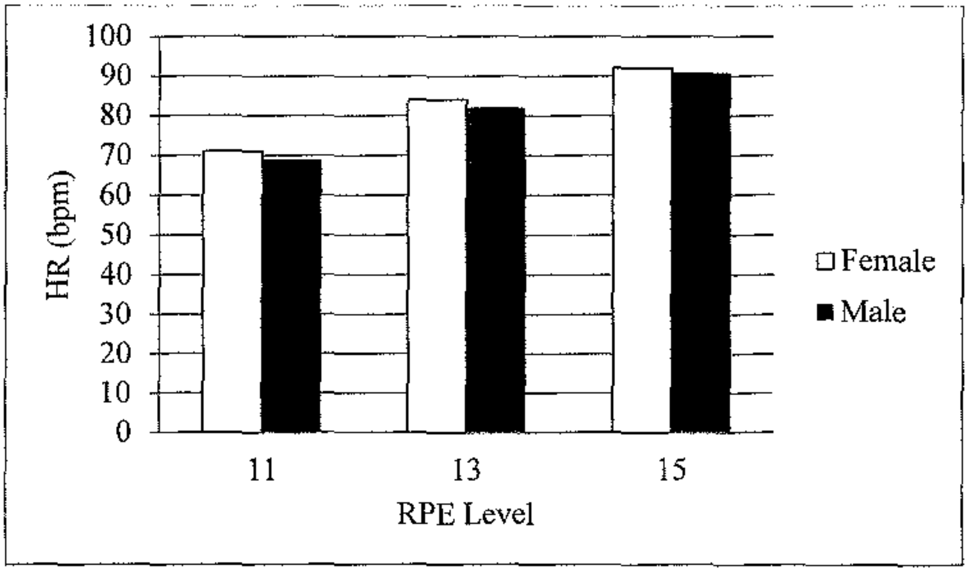

Figure 2. Percentage of HR maximum at RPE levels 11, 13, and 15.

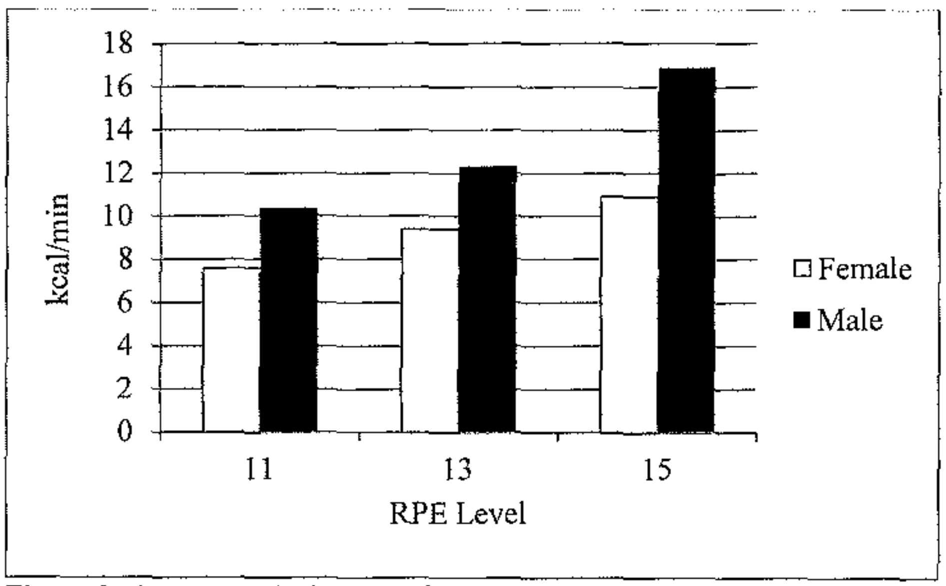

Figure 3. Average caloric expenditure at RPE levels 11, 13, and 15.

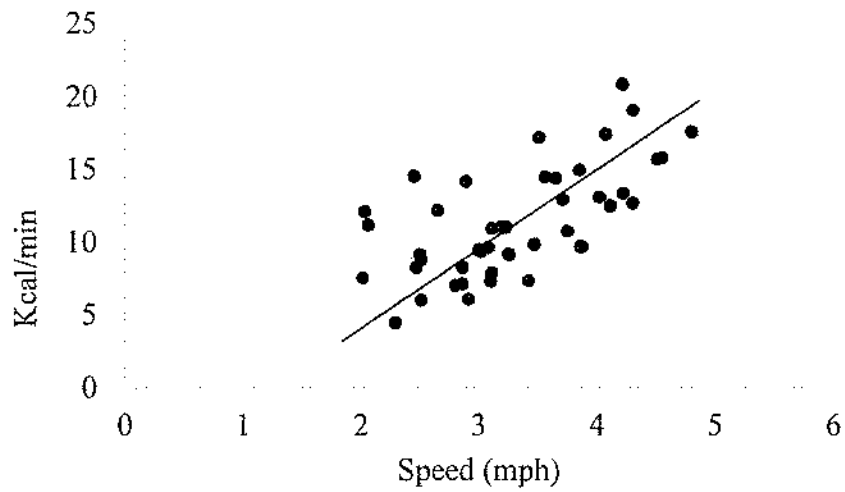

Figure 4. Relationship between speed and energy expenditure.

DISCUSSION

The purpose of this study was to determine the energy cost and HR responses to three bouts of SUP at set RPE values of 11 (light), 13 (somewhat hard), and 15 (hard) on the 6-20 Borg scale. Additionally, the study examined relative exercise intensity in order to determine if SUP meets physical activity guidelines defined by the American College of Sports Medicine (ACSM). ACSM recommends 30 minutes of moderate-intensity exercise 5 days a week or 20 minutes of vigorous-intensity exercise 3 days a week to achieve health benefits. The ACSM defines moderate-intensity as a HR between 64% and 76% and vigorous-intensity as a HR between 77% and 96% of maximal HR. In the current study maximal HR was predicted using the equation of Gellish et al. (2007). At an RPE of 11, female and male paddleboarders worked at 71% and 69% of predicted maximal HR, respectively. At an RPE of 13, heart rates increased to 84% and 82% of predicted maximal HR, respectively. At an RPE of 15, these values increased to 92% and 91% of predicted maximal HR, respectively. The results indicate that SUP at an RPE of 11, 13 and 15 are within ACSM's recommendations for moderate to vigorous-intensity exercise based on HR responses.

At all RPE levels, males expended more energy than females. The differences in energy expenditure can be attributed to the fact that the males weighed significantly more than females. Energy expenditure of the paddleboarders at RPE levels 11, 13 and 15 were 9.0, 10.9, and 13.9 kcal/min, respectively. When extrapolated to 30-minutes of exercise, males performing SUP at RPE levels of 11, 13, and 15 would burn an average of 312, 369, 507 kcals, respectively. Females performing SUP at RPE levels of 11, 13, and 15 would burn an average of 228, 282, and 327 kcals, respectively. The values were similar to those found by Palakovich et al. (2013) who found the estimated energy expenditure of SUP to be 10.4 kcal/min when performed at a moderate-intensity pace. In the present study we had subjects paddleboard at three increasing RPE levels accordingly. Speed increased with increasing RPE, as did caloric expenditure.

Metabolic equivalents (METs) are commonly used by ACSM to describe exercise intensity. At rest a person's energy expenditure is equal to 1 MET. Moderate-intensity is considered 3-6 METs while vigorous-intensity is greater than 6 METs (ACSM, 2013). Paddleboarding at RPE levels 11 and 13 resulted in average energy expenditure values of 6.3 and 8.8 METs, which is considered vigorous-intensity activity. During RPE of 15, MET levels reached 9.1 and 12.2 for female and male paddleboarders, respectively. These levels are equivalent to running at an 8 to 10 minute mile pace, which is considered a very vigorous-intensity activity level.

It is unrealistic to expect untrained paddleboarders to maintain such high MET levels (9-12) for an extended SUP session. The resultant MET levels may be explained by the variation in subject perception of the RPE scale. Even though each subject received an explanation of the RPE chart prior to data collection, some subjects may have rated SUP exertion higher than others. For example, weight lifters consistently rate RPE lower than endurance athletes due to the differences in training (Gearhart et.al, 2002). This suggests that paddleboarders looking to achieve ACSM guidelines of 30 minutes of moderate-intensity activity by SUP should stay around a RPE of 11 or 13.

Palakovich et al. (2013) concluded that the energy demand of SUP is comparable to moderate-intensity rowing, canoeing, and kayaking and validates SUP as an effective form of aerobic exercise. For the current SUP study, MET levels were found to be 6.3, 8.8, and 9.7 at RPE levels 11, 13, and 15, respectively. According to the 2011 physical activity compendium, moderate-intensity canoeing requires 6 METs, moderate-intensity kayaking requires 5 METs, SUP requires 6 METs, and recreational surfing requires 4 METs. Therefore, SUP can be considered a moderate-intensity activity that can be used as a benefit to cardiovascular health.

The study had several limitations. The bags used in the current study only allowed for 30-seconds of expired air to be collected. Furthermore, at RPE 15, two male subjects only had room in the bag to collect a 20-second sample due to the high volume of expired air which we related to increased body size. In the future larger bags should be considered due to the space restraint during the expired gas collection. Initially a GPS watch was used to collect speed, but it failed to accurately measure speed over such short distances. Therefore, the speed was collected using a speedometer on the testing boat. In future testing, a more accurate way to record speed should be used.

CONCLUSION

The results of this study suggest that SUP meets ACSM guidelines for improving cardiorespiratory endurance and positively affecting body composition. Exercising at RPE levels of 11-13 would appear to be most appropriate for recreational SUP. The relative exercise intensity at RPE level 15 fell into the very vigorous range. Participating in SUP can be a fun and unique alternative to traditional cardiovascular endurance sports such as jogging, biking, and swimming while still achieving an intense workout.

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APPENDIX A

INFORMED CONSENT

INFORMED CONSENT

HEART RATE RESPONSE AND ENERGY COST OF STANDUP PADDLEBOARDING

I, ________________________, volunteer to participate in a research study being conducted by the University of Wisconsin-La Crosse. Jessica Andres, a graduate student in the Clinical Exercise Physiology Program, is conducting this study under the supervision of Dr. John P. Porcari, a Professor in the Department of Exercise and Sport Science.

PURPOSE
The purpose of this study is to determine heart rate, oxygen consumption, perceived exertion, and caloric expenditure during stand-up paddle boarding. My participation in this study will require me to:

- Complete the necessary amount of practice sessions to become a proficient stand-up paddle boarder.
- Participate in one session (3 trials) of data collection while paddle boarding on the river. The paddle boarding will be conducted on a Surftech stand-up paddleboard equipped with a paddle.
- Wear a heart rate monitor strap, scuba-like mouthpiece and a backpack-like fitting to collect my expired air. The air will be collected into a Tedlar gas sample bag then analyzed on shore.
- Wear either a provided life vest or flotation belt fastened securely to my body.

POTENTIAL RISKS
I may experience muscle fatigue, muscle soreness, and possible musculoskeletal injuries from participating in leisure paddle boarding. Additionally, shortness of breath, irregularities in heart rhythm, heart attack, stroke, and even death are possibilities of vigorous exercise. However, the risk of serious or life-threatening complications is very low (<1/10,000 tests) in apparently healthy adults. Being on the river also exposes me to the risk of drowning, which will be minimal due to a provided life vest/ flotation belt.

All testing will be stopped immediately if there are any complications.

Individuals trained in CPR will be available during all testing sessions.

BENEFITS
As a participant in this study, I will learn my individual aerobic fitness level as well as my heart rate response, oxygen consumption, and caloric expenditure when using stand-up paddle boarding as exercise.

RIGHTS AND CONFIDENTIALITY

My participation in this study is entirely voluntary. I may choose to discontinue my involvement in the study at any time, for any reason, without penalty.

The results of this study have the potential of being published or presented at scientific meetings, but my personal information will be kept confidential and only group data will be presented.

I have read the information provided on this consent form. I have been informed of the purpose of this study, the procedures, the expectations of myself and the testers, and of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that concerned me and received clear answers so as to fully understand all aspects of this study.

If I have any other questions that arise, I may feel free to contact Dr. John P. Porcari, the principal investigator, at (608) 785-8684 (office) or (608) 386-5416 (cell). Questions in regards to the protection of human subjects may be addressed to the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects at (608) 785-8124.

Subject: ______________________ Date: ____________

Investigator: ____________________ Date: ____________

APPENDIX B

REVIEW OF RELATED LITERATURE

The goal of this paper is to review the literature regarding heart rate (HR) response and energy cost of standup paddleboarding (SUP). Few SUP studies exist and focus primarily on physical characteristics of paddleboarders and paddleboard design. Due to the lack of SUP studies our knowledge of the physiological demands must be supplemented with activities requiring similar body mechanics.

Introduction

The origins of SUP come from Hawaiian surf instructors who found that standing up on surfboards allowed for a better view of their students' surf technique. The instructors quickly found that using a paddle gave them more control to navigate the waves and change directions. The sport slowly gained momentum over the next 60 years. In 2003, SUP racing became an event at the Buffalo Big Board Classic (a world-renowned surfing competition) in Makaha, HI. Despite SUP's popularity in Hawaii, the activity did not become a mainland sport until veteran, Rick Thomas, brought a board to California. The activity became an overnight sensation.

Standup paddleboarding is defined as the use of a long narrow board that propels riders over water, usually in the standing position by means of a single-bladed paddle. The activity allows for people of all ages and skill levels to enjoy the water. Even elite surfers found that SUP has a few advantages over surfing, such as the increased distance you can travel allowing surfers to travel longer distances to remote surf destinations. In addition to ocean use, SUP has become a popular alternative to canoeing and kayaking.

To better understand the physical demands of SUP, specifically HR and energy cost responses, the physical demands of other activities that share similar body mechanics and intensity were evaluated. Studies reviewed include: kayaking, rowing, and surfing.

Energy Expenditure of SUP

Palakovich, Cuddy, and Ruby (2013) published an abstract that summarized their study regarding the energy expenditure of three different paddleboard designs; touring, ocean, and inflatable. The study instructed 25 subjects with an average age of 23 years to complete a trial on each paddleboard design. The subjects were required to complete a submaximal exercise test to develop prediction equations in order to estimate VO_2 across paddleboard designs. The study found that the average energy expenditure of SUP was 10.4 kcal/min, but that no significant difference exists for the energy expenditure between the paddleboard designs. However, speed was significantly slower during the completion of a time trial for the inflatable design than the ocean and touring paddleboards. The mean time trials for the inflatable, ocean, and touring were 6.97±1.43 minutes, 5.92±1.22 minutes, and 5.96±1.26 minutes, respectively. The researchers concluded that the energy demand of SUP is comparable to moderate rowing, canoeing, and kayaking and validates SUP as an effective form of aerobic exercise.

Physiologic Characteristics of Paddleboarders

Schram, Hing, and Climstein (2016) evaluated the physiologic characteristics of 15 elite and 15 recreational paddleboarders, with 15 sedentary participants serving as control subjects. Subject demographics included age, height, weight, body mass index (BMI), and percent body fat. Compared to elite and recreational paddleboarders, sedentary subjects had significantly higher BMI and percent body fat values. Lipid profiles included total cholesterol, high-density lipoproteins (HDL), triglycerides, and low-density lipoproteins (LDL). Compared to elite and recreational subjects, sedentary subjects had significantly lower HDL and significantly higher triglycerides and LDL values. Additionally, the recreational paddleboards had significantly higher triglycerides compared to elite paddleboards. The physiological characteristics measured included maximum relative oxygen consumption (VO_2), peak HR, peak lactate, aerobic power, peak stroke rate, distance covered, peak speed, and anaerobic power. Compared to sedentary subjects, the elite paddleboarders had a significantly higher VO_2max (43.7 vs. 20.4 ml/kg/min). Additionally, elite paddleboarders were capable of generating greater aerobic power (30.5 W vs. 10.6 W), greater anaerobic power (35.7 W vs. 13.4 W), greater peak stroke rate (69.6 vs. 42.3 strokes/min), and higher peak speed (2.2 vs. 1.5 m/s). The study concluded that SUP requires a high level of aerobic and anaerobic fitness, dynamic postural control, and high trunk muscle endurance for all paddleboarders and that superior levels of fitness, balance, and strength are associated with elite paddleboarders (Schram, 2015).

Similarity to Kayaking

Hoffman, Garner, Krings, Ottney, and Beckner (2006) completed a study on the energy expenditure of recreational kayaking, utilizing 10 recreationally active subjects. Baseline testing found a mean VO_2max of 54.2 ml/kg/min and a mean maximum HR of 191 bpm. The subjects were then required to kayak for 1.5 miles at a rating of perceived exertion (RPE) of 3-4, corresponding to moderate to hard-intensity level. The study found the average energy expenditure to be 9.9 kilocalories per minute with an average HR of 119 bpm, corresponding to 62% of maximal HR. The study concludes that kayaking at an RPE level of 3-4 fulfills the ACSM energy expenditure recommendation for moderate-intensity exercise. Because SUP and kayaking share similar movement patterns and core engagement the energy cost may be similar between the activities.

Similarity to Rowing

Hagerman and Lee (1971) measured oxygen consumption and HR in seven competitive oarsmen. Each subject was required to row for 6 minutes for both a tank and river tests. The tank test measured oxygen consumption and heart rate while in a simulated rowing environment. The river test measured only heart rate. The tank test found absolute VO_2 to be 4686±130.2 ml/min. The study found that maximum HR was 12±1.3 beats per minute greater for the tank test compared to the river test. The authors concluded that the rowers experienced more strenuous work using the tank than anticipated, indicating that comparative conditions were not achieved. The river intensity can be variable due to wind and current, thus, laboratory set ups may not be comparable. Because rowing and SUP share similar body mechanics and utilize natural waterways, SUP measurements may be better collected on a river rather than in a laboratory setting.

Similarity to Surfing

During SUP, the board is in a constant unstable condition which requires the paddleboarders to focus on balance while propelling themselves across the water using a paddle. To keep from falling in the water, balance and core strength are crucial. Balance is correlated with core strength because many of the muscles involved with stabilization reside in the core. While no research in core strength has been studied with respect to SUP, it has been studied in relation to surfing. Surfing requires the athlete to transfer force from their core musculature to maneuver a surfboard successfully with powerful, rotational movements on an unpredictable wave's surface (Axel, 2013). This description is similar to SUP because paddleboarders are encouraged to transfer force from their core, into their shoulders, and down the paddle for each stroke in order to be efficient.

Because both SUP and surfing focus on balance control, surfing may be comparable in relation to core strengthening ability.

Standup paddleboarding is a relatively easy activity to grasp. However, to become an elite paddleboarder it is important to consider core-strengthening exercises. Axel (2013) completed an 8-week study where elite junior male surfers implemented a core-strengthening program into their routine. The study found significant improvements in time to peak maximal acceleration, rotational power, core strength, core endurance, and rotational flexibility. These improvements translated to greater athletic performance. Thus, it can be concluded that SUP may benefit from core-strengthening exercises.

Farley, Harris, and Kilding (2012) studied 12 nationally ranked male surfers during multiple heats at several competitions. The study monitored HR and recorded video of each surfer. The study found that the surfers spent 60% of their total time between 56-74% of age-predicted HR maximum and only 3% of their total time above 83% of age-predicted maximum HR. The peak HR was 190±12 bpm while mean HR during the competitions was 140±11.6 bpm, corresponding to 64% of maximal HR. Farley (2012) stated that the HR values suggest that periods of moderate-intensity activity are interspersed with bouts of high-intensity exercise. Because surfing and SUP share similar body mechanics and variable workloads, paddleboards may experience similar HR responses.

Conclusion

The goal of this paper was to review the literature related to the HR and energy cost responses of SUP. However, there has been little published research on this topic. To better understand the physical demands placed on the body during SUP, activities with similar body mechanics were examined. In conclusion, kayaking, rowing, and surfing seem to be relevant to the current studies body mechanics. Although these topics may not directly correlate with the current study, they give an overview of the HR and energy expenditure responses that could be expected during SUP.

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