International Journal of Aquatic Research and Education

Volume 11 | Number 3 Article 5

3-1-2019

Cardiorespiratory Responses to Shallow Water Exercise: A Sex Comparison

Mitchell Garant Fisher
Central Washington University, fishermi@cwu.edu

Laura Jean Miller
Central Washington Universtiy, laurajmiller18@gmail.com

Jerusalem Tesfaye
Central Washington University, Jerusalem.tesfaye@cwu.edu

Karen Roemer
Central Washington University, karen.roemer@cwu.edu

Debra Mary D'Acquisto
Central Washington University, debra.d'acquisto@cwu.edu

See next page for additional authors

Recommended Citation

Fisher, Mitchell Garant; Miller, Laura Jean; Tesfaye, Jerusalem; Roemer, Karen; D'Acquisto, Debra Mary; and D'Acquisto, Leo Joseph (2019) "Cardiorespiratory Responses to Shallow Water Exercise: A Sex Comparison," *International Journal of Aquatic Research and Education*: Vol. 11 : No. 3 , Article 5.
DOI: https://doi.org/10.25035/ijare.11.03.05
Available at: https://scholarworks.bgsu.edu/ijare/vol11/iss3/5

Cardiorespiratory Responses to Shallow Water Exercise: A Sex Comparison

Cover Page Footnote

Acknowledgments The authors would like to thank Bryan Contreras and Lance Miller for technical and computer programming support. We would also like to thank Wilton Kanavan and Michael Dohrman for assistance with data collection. We would also like to thank the aquatic director, Debbie Nethery for coordinating pool availability and lifeguard support. This study was supported by a Research Grant and a Creative Activities Fellowship from Central Washington University's School of Graduate Studies and Research in addition to a research grant from the Department of Health Sciences.

Authors

Mitchell Garant Fisher, Laura Jean Miller, Jerusalem Tesfaye, Karen Roemer, Debra Mary D'Acquisto, and Leo Joseph D'Acquisto

Abstract

This investigation examined physiological responses to shallow water exercise (SWE) and to a high-intensity interval SWE workout (HIISWE) in males (M, n=9) and females (F, n=9). Participants performed 5 X 5 min. SWE bouts (bts.) at ratings of perceived exertion (RPE) 9, 11, 13, 15 and 17 (Borg scale) and a maximal bout of SWE with metabolic, heart rate (HR), and blood lactate (BLa) responses monitored. The same measurements were performed during HIISWE (4 X 4-min bts., alternating 20-s "all-out" and 10-s rest). Peak oxygen uptake ($\dot{V}O_2$) and BLa were greater in M (3.6 ± 0.4 vs. 2.7 ± 0.3 $l \cdot min^{-1}$, 10.9 ± 1.3 vs. 8.1 ± 1.7 mM) ($p<0.05$), with no difference in peak HR (185±7 (M) vs. 181±7 (F) bpm). Irrespective of sex, $\dot{V}O_2$ and HR were not different among mins. 3, 4, and 5 of ea. SWE effort ($p>0.05$). Peak BLa for HIISWE was 11.1 ± 2.2 (M) and 9.2 ± 1.7 (F) mM ($p<0.05$) with RPE ~18-19 for both sexes. Relative cardiorespiratory responses were similar between males and females during HIISWE. Perceptual self-regulation of intensity is a viable approach to controlling physiological load during SWE. Regardless of sex, HIISWE elicited physiological and perceptual responses categorized as "vigorous" to "near maximal to maximal" intensity by the American College of Sports Medicine.

Keywords: shallow water exercise, oxygen uptake, heart rate, rating of perceived exertion, perceptual-regulated exercise

Introduction

Shallow-water exercise (SWE) is a style of aquatic activity with a participant immersed anywhere between waist and axillary level (Barbosa, Garrido, & Bragada, 2007; Cook, Scarneo, & McAvoy, 2013; Kruel, Posser, Alberton, Pinto, & Oliveira, 2009; Nagle, Sanders, Shafer, Gibbs, Nagle, Deldin, 2013). Propulsive force applied to the surrounding water and against pool floor allows for a variety of movements like walking, running, cross-country skiing and jumping. Intensity during these movements may be varied by manipulating translatory speed, surface area by changing the positioning of moving body limbs and/or wearing webbed gloves, and by varying force application (Torres-Ronda & Alcazar, 2014; Wertheimer & Jukic, 2013). Several tactics have been employed by aquatic instructors and investigators to systematically control intensity including the use of a metronome to vary stride rate (Benelli, Ditriolo, & de Vito, 2004; Delavatti, Alberton, Kanitz, Marson, & Kruel, 2015; Dowzer, Reilly, Cable, & Nevill, 1999; Hoeger, Hopkins, & Barber, 1995; Kruel, Beilke, Kanitz, Alberton, Antunes, Pantoja, 2013), an underwater treadmill (Barela & Duarte, 2008; Fujishima & Shimizu, 2003; Pohl & McNaughton, 2003; Shono, Fujishima, Hotta, Ogaki, Ueda, Otoki, et al, 2000; Silvers, Rutledge, & Dolny, 2007), cadence (Aquatic Exercise Association [AEA], 2010), and self-regulated efforts based on rating of perceived exertion (RPE) and instructional cues (Kruel et al, 2009; Nagle et al, 2013;

Campbell, D’Acquisto, & Renne, 2003; D’Acquisto, D’Acquisto, & Cline, 2001). Manipulating any one or a combination of these strategies during a continuous or interval SWE workout will directly impact cardiorespiratory demand (Cook et al, 2013; D’Acquisto, Miller, D’Acquisto, Roemer, & Fisher, 2015; Miller, D’Acquisto, D’Acquisto, Roemer, & Fisher, 2015; Torres-Ronda & Alcazar, 2014; Wertheimer & Jukic, 2013).

High-intensity interval training (HIIT) workouts entail alternating intense, intermittent physical efforts with periods of rest (Seiler & Hetfield, 2005; Tabata, Irisawa, Kouzaki, Nishimura, Ogita, & Miyachi, 1997; Zuniga, Berg, Noble, Harder, Chaffin, & Hanumanthu, 2011). The high-intensity, low-volume nature of HIIT results in a time-efficient improvement of maximal anaerobic capacity, cardiorespiratory power ($\dot{V}O_2$ max), enhanced muscle oxidative capacity and cycling performance (Burgomaster, Hughes, Heigenhauser, Bradwell, & Gibala, 2005; Burgomaster, Heigenhauser, & Gibala, 2006; Burgomaster, Cermak, Phillips, Benton, & Gibala, 2007; Gibala, Little, Essen, Wilkin, Burgomaster, Safdar et al, 2006; Gibala, Little, MacDonald, & Hawley, 2012; Laurent, Vervaecke, Kutz, & Green, 2014; Little, Safdar, Wilkin, Tarnopolsky, & Gibala, 2010; Tabata et al, 1997; Torres-Ronda & Alcazar, 2014). Land-based HIIT workouts may vary in total duration (~20-30 min), work interval time (20, 30, and 90-s), recovery between work efforts (10-s, 75-s, and 4-min), number of exertions, intensity (~75 to 170% $\dot{V}O_2$ max), and design (4-6 x 30-s, 8-12 x 90-s exertions, or 4-min bts. of alternating 20-s “all-out” efforts) (Burgomaster et al, 2005; Olson, 2014; Tabata et al, 1997). There are few HIIT-related studies with healthy populations that have used shallow water as the exercise medium (Rebold, Kobak, & Otterstetter, 2013; Ryzkova, Labudova, Grznar, & Smida, 2017) and limited investigations that have explored physiological responses to acute, high-intensity interval SWE workouts suitable for HIIT (Cook et al, 2013; Kruel et al, 2009). Physiological responses to several high-intensity SWE workouts (10 x ~15-s “all-out” w/ 30-s rest (Cook et al, 2013); 8 x 2-min @ RPE 17, 2-min rest (Kruel et al, 2009)) have been studied. These latter studies reported on absolute physiological responses (e.g. blood lactate, $\dot{V}O_2$) but provided little insight into relative cardiorespiratory load. More recently, D’Acquisto et al. (2015) and Miller et al. (2015) have reported absolute and relative cardiorespiratory responses to a continuum of sustained low to moderate-intensity exercise efforts and “all-out” intervals performed in shallow water in a sample of young, physically active females. The broad range of exercise efforts tested by D’Acquisto et al. (2015) and Miller et al. (2015) are suitable for moderate-intensity continuous training (MIC) or HIIT programs.

There is still a general lack of knowledge regarding physiological responses during carefully regulated SWE efforts, in particular, sex-specific responses over intensities that would be appropriate for MIC and HIIT programs. The overarching aim of this study was to quantify the absolute and relative cardiorespiratory responses to SWE in males and females. We examined sex-specific physiological responses to self-regulated (RPE) SWE efforts (RPE 9 "very light" through 17 "very hard" (Borg, 1998), and to a maximal SWE bout (bt.) to exhaustion for determination of peak oxygen uptake and heart rate. We also quantified sex-specific physiological responses to a high-intensity interval SWE workout (HIISWE) consisting of short, "all-out" bursts of exercise.

We hypothesized that regardless of sex, an invariant cardiorespiratory (oxygen uptake ($\dot{V}O_2$) and heart rate (HR)) response would be achieved for each self-regulated SWE effort (Hyp. I). We also hypothesized that $\dot{V}O_2$ and HR would be linearly and strongly related to RPE (9-17) regardless of sex (Hyp.II). Addressing these hypotheses would provide insight into the utility of RPE to systematically vary exercise intensity in a water medium, a task that is challenging, especially when compared to land-based exercise where one can more easily control the speed and grade of a treadmill or power output on a cycle ergometer. Additionally, our hypothesis was that no sex-specific differences should occur in the overall, relative physiological demand associated with HIISWE (Hyp. III). Lastly, we postulated that the HIISWE would result in physiological and perceptual responses that would be classified as "vigorous" to "near maximal or maximal" for both sexes (Hyp. IV) according to ACSM guidelines for exercise intensity (2017). We anticipated that the information gained from this study regarding the physiological responses associated with such a broad range of SWE intensities would interest exercise scientists, fitness professionals, coaches, health professionals and those individuals that simply wish to add variety to their water exercise training regimen.

Method

Participants

Eighteen physically active male (n=9) and female (n=9) participants provided their written informed consent (females: 26 ± 6 years; 168.2 ± 2.9 cm*; 66.1 ± 6.2 kg*; 24.7 ± 5.5% adipose tissue (AT)*; males: 24 ± 1 years; 179.2 ± 4.8cm; 84.5 ± 9.4kg; 18.0 ± 5.8% AT) (*$p < 0.05$). Volunteers completed a health history and physical activity questionnaire (PAQ) which was reviewed by the research staff. Individuals were excluded if they reported any injuries during the previous 2 months, presently taking medications to control heart or pulmonary function, pregnant, or did not feel comfortable exercising in water. Female and male volunteers had a similar physical activity history (females: 4.0 ± 0.8 exercise sessions$\cdot$wk^{-1}, 52.5 ± 13.8 min$\cdot$session^{-1}; male: 4.8 ± 2.0 sessions$\cdot$wk^{-1} and 50.5 ± 10.9 min$\cdot$session^{-1} for at least the last 10 weeks ($p > 0.05$). Additionally, all participants reported incorporating a mix of light, moderate, and vigorous exercise in their physical activity history.

Overall Study Design

This study explored sex-specific cardiorespiratory responses to an extensive continuum of SWE bts. ranging from sustained submaximal and maximal exertions to a high-intensity workout comprised of brief "all-out" efforts. Participants were immersed to axillary level for all testing with water temperature between 28.3 and 28.9^{o}C. Select physiological data in the present study explicit to our female subjects has previously been reported (D'Acquisto et al, 2015; Miller et al, 2015). We replicated methods from these previous studies with male volunteers, which positioned us to explore sex-specific cardiorespiratory responses associated with SWE and to specifically address aforementioned hypotheses. The research protocol was approved by the Central Washington University's (CWU) Human Subjects Review Council.

Physiological testing was completed at CWU's aquatic facility except body composition testing, which was completed at CWU's Anthropometric Laboratory. Participants completed three visits over a one-month period. Briefly, these visits included visit 1) Familiarization: study design presentation, instruction in SWE and use of 6-20 Borg scale (~1.5 hrs.); visit 2) Experiment I: anthropometric and resting cardiometabolic testing, submaximal and maximal (peak oxygen uptake) SWE tests (~2-2.5 hrs.), and visit 3) Experiment II: resting cardiometabolic testing and HIISWE challenge (~1.5-2.0 hrs.). All testing was performed during the morning hours. Approximately 1 to 2 weeks following the familiarization visit, participants completed Experiment 1. Two days to 2 weeks later, participants completed Experiment 2.

Familiarization. Following review of the research protocol and signing an informed consent, participants were instructed on basic principles of performing SWE and the use of Borg's 6-20 rating of perceived exertion (RPE) scale. Investigators reviewed and provided subjects with literature on basic principles of water exercise. Participants practiced investigator-guided SWEs that would be employed during Experiments I and II. Participants practiced regulating SWE intensity based on a RPE-effort guided model (described below). Participants also practiced wearing a two-way breathing valve and were allowed as much time as they wanted to become comfortable with the breathing apparatus.

Experiment I: Perceptually Self-regulated SWE. Approximately 1-2 weeks after familiarization, participants arrived at the Anthropometric Laboratory 4 hrs. postprandial, having refrained from strenuous exercise for 24 hrs., from any caffeine products 12 hrs. before testing, and in a hydrated state. Plethysmography was employed to estimate body volume for determination of body density (mass/volume) (BOD POD, Life Measurement, Inc., Concord, CA, USA), while a stadiometer (Detecto Inc., Webb City, MO, USA) was used to measure height. Siri equation was employed to estimate percent adipose tissue. After body composition measurements, subjects were escorted to the aquatic center in a wheel chair.

Participants were fitted with a heart rate monitor (Polar Electro, CEO537, Lake Success, NY, USA) and sat for 10-minutes while the SWE protocol was carefully reviewed. Participants were then fitted with a two-way breathing valve and assumed an upright stance for 8-min for metabolic and heart rate (HR) measurements (Parvo Medic Analyzer, Sandy, UT, USA). Metabolic analyzers were calibrated using standard gases (16.01 $\%O_2$ and 4.01 $\%CO_2$) before each testing session according to manufacturer's guidelines. At the conclusion of standing, a finger stick was performed, and blood was drawn into a capillary tube (~30 µl) for whole blood lactate (BLa) analysis (defined as resting lactate) (Analox Analyzer, Analox Instruments Ltd., The Vale, London, UK). Lactate analyzer was calibrated with an 8.0 mM standard before each testing session according to manufacturer's guidelines. With the assistance of the research team, participants stepped down into the pool and assumed a final standing position immersed to axillary level where they stood quietly for 8-min while metabolic and HR parameters were monitored. Total time from first assuming a seated position on deck to the start of quiet standing in water was about 20-min. Metabolic and HR responses over the final 5-min of standing on deck and in water were each averaged and designated as representing pre-exercise "resting" state under these two respective conditions. Standing $\dot{V}O_2$ and HR in shallow water were used, in part, for computation of $\%\dot{V}O_2$ and %HR reserve for perceptually-regulated SWE efforts RPE 9-17 (see computations).

Following resting measurements in water, the breathing value was removed, and participants performed an instructor-guided SWE warm-up (6-min) incorporating exercises that would be performed during the upcoming self-selected efforts. Subsequently, the breathing valve was re-secured on the participant. The participant then completed five, 5-min SWE bts. at prescribed RPEs 9, 11, 13, 15, and 17, and one 5-min effort (bt. 6) to maximal exertion to a theoretical maximum of RPE 20 under the guidance of a trained aquatic exercise instructor. Employing this perceptually-regulated protocol has been shown to result in a systematic step-up response in physiological load with land-based (Eston, Lamb, Parfitt, & King, 2005; Faulkner, Parfitt, & Eston, 2007) and water exercise protocols (D'Acquisto et al, 2015). The maximal 5-min effort (bt. 6) required participants to up-regulate intensity with each succeeding minute from RPE 17-18 (min. 1) to a theoretical maximum of RPE 20 (final min. 5). Webbed gloves were worn for all SWE efforts (Hydro-fit Wave Web Pro, Eugene, OR, USA).

A 1-minute rest period was allowed between 5-min efforts. During the 5-min perceptually regulated bts., participants were reminded of the prescribed RPE at 1, 2, and 3 mins and were informed of the elapsed time at 2, 4, and 5 mins. Such feedback was deemed appropriate given that aquatic exercise instructors periodically alert their clients about the movement pattern, intensity, and remaining time in an aquatic exercise workout. SWE was performed with maximal forward/back and lateral displacement of ~1 m from the start point. Exercise consisted of the following: bt. 1, RPE 9: Jog with swinging arms, slightly cupped hands; bout 2, RPE 11: Tuck Jumps with Plunge – start with knees slightly flexed, jump, both knees to chest as arms with extended wrists simultaneously push water downward; bout 3, RPE 13: Cross-Country Ski (X-C Ski) – start in X-C Ski stance, alternate legs and arms in opposition, hands in neutral position, slicing through least amount of water; bout 4, RPE 15: Deep Jump Lunge – start in staggered stance, knees slightly flexed, alternate stance, simultaneously swinging arms forward and back in tandem while breaking the water surface, elbows flexed, hands fisted; bout 5 RPE 17: Alternating Long Leg Kicks – alternate forward straight leg kicks toward water surface with opposing hands pushing perpendicular to water surface, extended wrists, fingers spread and finger tips breaking surface of water.

Instructions provided to participants regarding SWE movements for each minute of the 5-min maximal bout included the following: minute 1, RPE 17-18: Jog – jog with slightly cupped hands; minute 2, RPE 17-18: Tuck Jumps with Scoop – start with knees slightly flexed, jump, both knees to chest as long arms draw water from the sides of the body moving water toward chest, hands are cupped; minute 3, RPE 18: X-C Ski – start in X-C ski stance, alternate legs and arms in opposition, hands push and pull water; minute 4, RPE 19: Deep Jump Lunge – start in staggered stance, knees slightly flexed, alternate stance, simultaneously swinging arms forward and back in tandem while breaking the water surface, elbows flexed, hands fisted on the back swing and spread or flat in the forward swing as in scooping the water; minute 5, RPE 20: Alternating Long Leg Kicks – alternate forward straight leg kicks toward water surface with opposing hand reaching toward foot, extended wrists, fingers spread and hand fully submerged.

Metabolic and HR responses were monitored throughout the exercise protocol. Finger sticks for blood lactate determination were performed immediately after RPE bts. 9, 11, 13, 15 and 17, and one minute following the maximal effort. Subjects exposed a finger through a vented glove sleeve for a finger prick blood sample for BLa analysis. $\dot{V}O_2$ and HR peak were defined as the highest values a subject achieved during two consecutive 30-s sampling periods. Metabolic and HR measurements were continued during a 10-min cooldown at a freely chosen effort under the guidance of an instructor. RPE was obtained following the cooldown in addition to a finger stick for lactate analysis.

Experiment II HIISWE. Two to 14 days following experiment I, participants arrived at the Anthropometric Laboratory following the same pre-testing guidelines as Experiment I. Following body weight measurements, participants were fitted with a HR monitor, sat for 10-min and reminded of the SWE protocol. They were then fitted with a two-way breathing valve. Standing metabolic and HR responses (on deck and in water (axillary level), as outlined earlier) were measured to determine if participants were initiating the exercise in experiment II in a similar "resting" physiological state as in experiment I. Additionally, standing $\dot{V}O_2$ and HR in shallow water was collected, in part, for computation of $\%\dot{V}O_2$ and %HR reserve for HIISWE (see computations). After standing measurements, the two-way breathing valve was removed, and participants were allowed to drink water, secure webbed gloves, and followed an instructor-guided warmup in which they executed the same exercises comprising HIISWE.

Participants were then fitted with a two-way breathing valve which was interfaced to the Parvo-Medic metabolic cart located poolside. Participants then moved into their exercise area (immersed to axillary level) and were reminded about the specific exercise to be performed for the subsequent HIISWE which was guided by an aquatic exercise instructor. HIISWE consisted of four, 4-min bts. with each bt. containing 8 rounds of 20-s maximal ("all-out") exercise with a 10-s rest between rounds. Each bt. was separated by 1-min rest. Bts. 1, 2, 3 and 4 consisted of whole body movements described for minutes 2, 3, 4 and 5 of the maximal protocol described in Experiment I. The sequence of performed movements is representative of base movements in shallow water aquatic choreography (AEA, 2010).

At the end of each four-minute bt., participants moved to poolside and immediately reported their overall RPE for the bt. by pointing to a number on a board illustrating Borg's RPE 6-20 scale. Subjects would then expose a finger through a vented glove sleeve for a finger prick blood sample for BLa analysis. In addition, a blood sample was collected 60-s after the last 4-min. bt. and analyzed for BLa (defined as peak BLa). Participants then performed a 10-min. cool down. Upon completion, participants were asked to report their overall RPE for the cooldown and a sample of blood was collected for lactate analysis. Metabolic and HR responses were measured throughout the entire HIISWE workout and cool down.

Computations and Statistical Analysis

Percent $\dot{V}O_2$ and HR peak ($\%\dot{V}O_2$ and %HRpeak) for each SWE bt. (RPE 9, 11, 13, 15, 17) were calculated by dividing the exercise $\dot{V}O_2$ and HR response by $\dot{V}O_2$ and HR peak, respectively, and multiplying each quotient by 100. In addition, $\%\dot{V}O_2R$ ($\%\dot{V}O_2$ reserve) and %HRR (%HR reserve) for the SWE bts. were calculated from exercise $\dot{V}O_2$ and HR responses, $\dot{V}O_2$ peak and HR peak, and standing-resting (in water) $\dot{V}O_2$ and HR (S $\dot{V}O_2$rest and SHRrest). The following formulas were used to compute %$\dot{V}O_2$ and %HR reserves for SWE:

$$\%\dot{V}O_2R = [(SWE\ \dot{V}O_2 - S\dot{V}O_2rest) / (\dot{V}O_2peak - S\ \dot{V}O_2rest)] \times 100$$

$$\%HRR = [(SWE\ HR - SHR_{rest}) / (HRpeak - SHR_{rest})] \times 100$$

All data were tested for normality using the Shapiro-Wilk test and presented as means and standard deviations. A priori determination of sample size was determined using a desired statistical power of 0.8. In experiment I & II, a generalized linear mixed model was employed to investigate for a main effect of bt. within sex (5 x 5 min & 4 x 4 min, respectively), main effect of sex within bt., and interaction (bt. x sex). In experiment I, linear regression analysis was employed to examine the relationship between $\dot{V}O_2$ vs RPE, and HR vs RPE. Within the mixed model, independent t-tests were employed for sex comparisons for physiological variables. All data analyses were conducted using SPSS Version 22.0, and level of significance was set a-priori at an alpha level of 0.05. Findings are presented as mean ± SD. Significance levels for the pairwise comparisons within the mixed model were Bonferroni adjusted. Two one-sided test (TOST) was employed for comparisons between groups that had a research hypothesis expecting no differences (Walker & Nowacki, 2011).

Results

Resting Standing Pre-Exercise Comparisons

HR, ventilation ($\dot{V}_E$) and respiratory exchange ratio (RER) were similar between males and females during conditions of standing on deck and in water immersed to axillary level ($p > 0.05$) for experiments I and II (Table 1). $\dot{V}O_2$ and O_2 pulse ($\dot{V}O_2$/HR) were significantly greater in males compared to females on deck and in water ($p < 0.05$) while no sex-based difference in resting BLa was found in either experimental session (experiment I: 1.09 ± 0.40 (M) vs. 1.15 ± 0.30 (F) mM; Experiment II: 0.79 ± 0.20 (M) vs. 0.81 ± 0.30 (F) mM) ($p > 0.05$). Regardless of sex and irrespective of standing on deck or in water, $\dot{V}O_2$, HR, $\dot{V}E$, RER and O_2 pulse were the same between experiments I and II ($p > 0.05$), suggesting that participants began SWE during each test session in a similar physiological state.

Peak Metabolic and Heart Rate Response Comparisons

Absolute rate of $\dot{V}O_2$ (3.62 ± 0.39 vs. 2.72 ± 0.33 $l \cdot min^{-1}$), BLa (10.9 ± 1.3 vs. 8.1 ± 1.7 mM) and $\dot{V}_E$ (116.9 ± 14 vs. 84.3 ± 11 $l \cdot min^{-1}$) were all higher in males compared to females ($p < 0.05$). $\dot{V}O_2$ relative to body mass (42.8 ± 4.7 vs. 41.3 ± 4.6 $ml \cdot kg \cdot min^{-1}$), HR (185 ± 7 vs. 181 ± 7 $B \cdot min^{-1}$) and RER (1.08 ± 0.06 vs. 1.05 ± 0.05) were similar between males and females, respectively ($p > 0.05$). At the culmination of the maximal SWE test, males and females reported RPEs of 19.4 ± 0.5 and 19.7 ± 0.5, respectively ($p > 0.05$).

Table 1. Resting measures standing on deck and standing in water in Experiment I and II.

	Experiment 1				Experiment 2			
	Male		Female		Male		Female	
Parameter	Deck	Water	Deck	Water	Deck	Water	Deck	Water
Absolute VO_2 ($l \cdot min^{-1}$)	$0.31\pm0.05^{\dagger *}$	$0.35\pm0.06^{*}$	$0.25\pm0.04^{\dagger}$	0.28±0.07	$0.31\pm0.04^{*}$	$0.32\pm0.04^{*}$	$0.24\pm0.04^{\dagger}$	0.26±0.04
HR ($b \cdot min^{-1}$)	$82\pm9^{\dagger}$	65±8	$89\pm19^{\dagger}$	66±14	$86\pm8^{\dagger}$	64±7	$87\pm13^{\dagger}$	63±12
V_E ($l \cdot min^{-1}$)	8.3±2.1	8.5±2.8	7.5±1.4	7.5±1.9	8.0±1.5	7.6±1.1	7.0±1.4	7.1±1.9
RER	$0.85\pm0.04^{\dagger}$	$0.90\pm0.12^{*}$	0.85±0.08	0.86±0.09	$0.86\pm0.04^{\dagger}$	0.92±0.07	0.87±0.08	0.89±0.09
O_2 Pulse ($mlO_2 \cdot bt$)	$3.9\pm0.7^{\dagger *}$	$5.4\pm1.2^{*}$	$2.9\pm0.7^{\dagger}$	4.4±0.6	$3.6\pm0.4^{*\dagger}$	$5.1\pm0.6^{*}$	$2.8\pm0.5^{\dagger}$	4.2±0.5

Note. Data presented as mean ± SD, males n=9, females n=9. $\dot{V}O_2$ = rate of oxygen uptake; HR = heart rate; RER = respiratory exchange ratio; $\dot{V}_E$= Ventilation; O_2 pulse = surrogate of stroke volume. Condition = water or deck. * = difference between sexes in indicated condition; † = difference between conditions for indicated sex $p < 0.05$.

Perceptually Self-regulated SWE, RPE 9-17

Regardless of sex, HR and $\dot{V}O_2$ for minutes 3, 4 and 5 of each 5-min SWE bt. (RPE 9, 11, 13, 15, 17) were not different ($p > 0.05$). Consequently, HR and $\dot{V}O_2$ for min. 5 was used to represent the cardiometabolic demand for these perceptually self-regulated efforts. Figure 1A and 1B illustrate $\dot{V}O_2$ and HR versus RPE (9-17) in the context of respective reserves (difference between peak and resting (standing in water) values) for males and females. $\dot{V}O_2$ and HR were regressed against RPE in

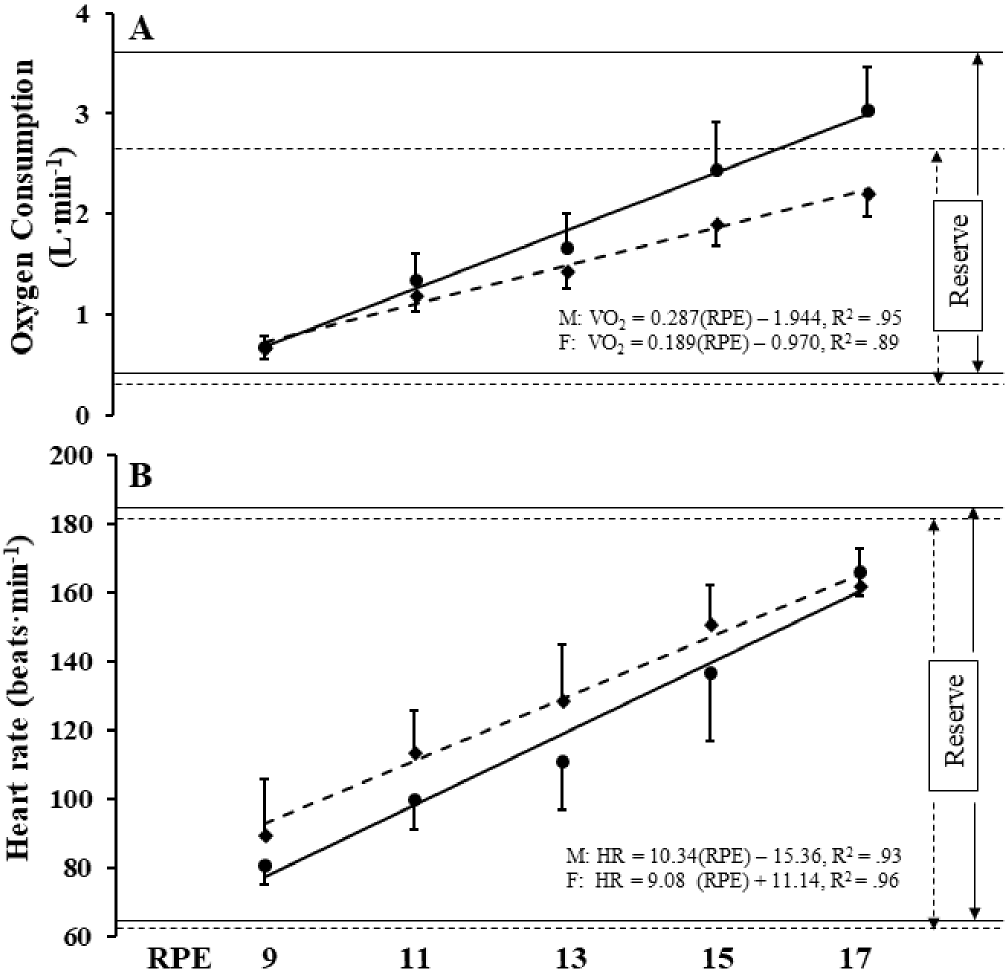

Figure 1. Oxygen uptake (A) and heart rate (B) at rest in water (lower horizontal bars in A & B), fifth minute of each bout mean ± SD (RPE 9, 11, 13, 15, 17) and peak absolute measures (upper horizontal bars); males n=9, females n=9. Physiological reserve shown as the difference between rest and peak measures. *Note:* female data represented with diamonds and dashed lines and male data represented with closed circles and solid lines.

a linear regression analysis. Regression equations are presented within Fig1A and 1B. BLa (mM) for bts. 1, 2, 3, 4, and 5 were the following: males, 1.67 ± 0.53, 1.98 ± 0.46, 1.77 ± 0.73, 3.04 ± 1.33 and 6.44 ± 1.25; and, females, 2.32 ± 1.19, 2.15 ± 1.03, 2.34 ± 1.03, 2.62 ± 1.10 and 3.90 ± 1.64. BLa for bts. 1, 2, 3 and 4 were similar between males and females ($p > 0.05$); however, males had a greater BLa for bt. 5 ($p < 0.05$). For males and females, BLa for bt. 5 was greater than all other bts. ($p < 0.05$), and, for females, BLa for bt. 4 was greater than bts. 1, 2 and 3 ($p < 0.05$).

For the 10-min. cooldown, HR and RPE were similar for males and females, respectively (115 ± 10 vs. 115 ± 9 $b \cdot min^{-1}$; 7.9 ± 0.8 vs. 7.7 ± 0.7) ($p > 0.05$). $\dot{V}O_2$ (1.03 ± 0.2 vs. 0.83 ± 0.1 $l \cdot min^{-1}$), RER (1.15 ± 0.10 vs. 1.04 ± 0.10), O_2 pulse (9.0 ± 1.7 vs. 7.2 ± 1.1 $mlO_2 \cdot bt^{-1}$), $\dot{V}_E$ (38.0 ± 9.5 vs. 28.7 ± 4.7 $l \cdot min^{-1}$) and BLa (9.8 ± 1.9 vs. 6.4 ± 1.6 mM) were all greater in males ($p < 0.05$).

HIISWE

Overall physiological responses to the 20-min HIISWE are shown in Table 2. Males had a greater absolute $\dot{V}O_2$, RER and $\dot{V}_E$ ($p < 0.05$). Measures of relative cardiorespiratory strain (%$\dot{V}O_2$ peak, %HR peak, %R, %HRR) were similar between sexes ($p > 0.05$). Additionally, $\dot{V}O_2$ relative to body mass, HR, and RPE were similar ($p > 0.05$).

Physiological responses for the individual four-minute HIISWE bts. for males and females are shown in Table 3. Absolute $\dot{V}O_2$ ($l \cdot min^{-1}$) was greater in males when compared to females regardless of bt. ($p < 0.05$). Regardless of sex, absolute $\dot{V}O_2$ for bt. 4 was greater than all other bts. ($p < 0.05$). Additionally, absolute $\dot{V}O_2$ increased from bt. 1 to 3 in males ($p < 0.05$). RER was greater in males during bts. 1, 2, and 3 ($p < 0.05$). In females, RER for bt. 3 was lower compared to all other bts. ($p < 0.05$). RER for bt. 4 in males was lower compared to bts. 2 and 3 ($p < 0.05$). There were no sex differences in RPE for each bt. (Table 3) ($p > 0.05$). In females, RPE in bt. 4 was greater than all other bts. ($p < 0.05$). In males, RPE in bt. 4 was greater than bts. 1 and 2 ($p = 0.00$), but bts. 3 and 4 were not different ($p > 0.05$). $\dot{V}_E$ was greater in males regardless of bts. ($p < 0.05$). $\dot{V}_E$ in bt. 4 was greater than all other bts., regardless of sex ($p < 0.05$). Additionally, in males, $\dot{V}_E$ for bt. 1 was lower than bts. 2 and 3 ($p < 0.05$).

Table 2. Physiological responses to a 20-min high intensity interval shallow water workout

Parameters	**Female**	**Male**
VO_2 ($l \cdot min^{-1}$) *	1.98 ± 0.19	2.63 ± 0.42
VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	29.9 ± 2.4	31.1 ± 4.6
HR ($b \cdot min^{-1}$)	156 ± 8	155 ± 11
RER *	1.05 ± 0.04	1.12 ± 0.05
V_E ($l \cdot min^{-1}$) *	60.5 ± 5.8	84.1 ± 13.5
%VO_2peak	73.0 ± 4.7	72.4 ± 6.5
%HRpeak	86.3 ± 2.2	83.9 ± 4.9
%VO_2 Reserve	70.0 ± 5.0	69.7 ± 7.1
%HR Reserve	78.9 ± 3.2	75.5 ± 7.1
RPE	18.5 ± 1.1	18.6 ± 0.9

Note. Data presented as mean ± SD, males n=9, females n=9. $\dot{V}O_2$ = rate of oxygen uptake; HR = heart rate; RER = respiratory exchange ratio; $\dot{V}_E$ = minute ventilation; %$\dot{V}O_2$peak = percent peak oxygen uptake; %HRpeak = percent peak heart rate; %$\dot{V}O_2$ reserve = percent oxygen consumption reserve; %HR reserve = percent HR reserve; RPE = rating of perceived exertion (Borg). * = $p<0.05$.

%$\dot{V}O_2$peak did not differ between males and females among the exercise bts. ($p > 0.05$). %$\dot{V}O_2$ peak for bt. 4 was greater than the other 3 exercise bts. regardless of sex ($p < 0.0.5$), and bt. 1 in males was also different than bt. 3 ($p < 0.05$). %HRpeak was only different between sexes in bt. 1 ($p < 0.05$). All-pairwise comparisons among bts. were different in males for %HRpeak ($p < 0.05$). In females, %HRpeak for bt. 4 was different than all other bts. ($p < 0.05$), and bt. 1 was also different than bt. 3 ($p < 0.05$). In females, %$\dot{V}O_2$R for bt. 4 was greater compared to all other exercise bts. ($p < 0.05$). %HRR was only different between sexes in the first bt. with females having the greater value ($p < 0.05$). Females %HRR in bt. 4 was different than all other bts. ($p < 0.05$) and bt. 1 was different than bt. 3 ($p < 0.05$). %HRR for males was different for all pairwise comparisons between bts. ($p < 0.05$). Figure 2 presents %$\dot{V}O_2$R for bt. 4 in males was greater compared to all other bts. ($p < 0.05$), and bt. 1 was also different than bt. 3 ($p < 0.05$).

Table 3. Physiological responses to individual high intensity interval shallow water exercise bouts.

	Bout 1		Bout 2		Bout 3		Bout 4	
Parameter	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
VO_2 (l·min^{-1})	1.94 ± 0.30	2.57 ± 0.50^{*A}	2.02 ± 0.20	2.67 ± 0.50*	2.07 ± 0.20	2.79 ± 0.50*	2.32 ± 0.20†	3.02 ± 0.50$^{\dagger *}$
VO_2 (ml·kg^{-1}·min^{-1})	29.4 ± 4.2	30.3 ±5.4^{A}	30.5 ± 2.4	31.7 ± 5.7	31.3 ± 1.9	32.9 ± 5.2	35.0 ± 3.3†	35.7 ± 5.6†
HR (b·min^{-1})	152 ± 8^{A}	147 ± 16^{F}	157 ± 9	155 ± 14^{F}	162 ± 9	161 ± 13^{F}	171 ± 6†	170 ± 10$^{\dagger F}$
RER	1.07 ± 0.1^{A}	1.18 ± 0.1‡	1.06 ± 0.04^{D}	1.14 ± 0.06$^{\ddagger DC}$	0.98 ± 0.04^{E}	1.03 ± 0.03$^{\ddagger E}$	1.05 ± 0.04	1.08 ± 0.06
VE (l·min^{-1})	57.8 ± 6.4	78.2 ± 15.7^{A*}	63.1 ± 7.1	86.2 ± 15.9*	62.1 ± 6.9	85.4 ± 16.7*	73.9 ± 7.6†	102.3 ± 16.9$^{\dagger *}$
%VO_2peak	71.5 ± 5.5	70.4 ± 7.8^{A}	74.5 ±5.6	73.8 ± 9.2	76.7 ± 7.2	76.7 ± 9.1	85.5 ± 6.2†	83.3 ± 8.5†
%HRpeak	84.4 ± 4.1$^{\ddagger A}$	79.4 ± 7.2^{F}	86.9 ± 2.7	84.1 ± 6.5^{F}	89.5 ± 3.0	87.3 ± 5.4^{F}	94.7 ± 1.6†	92.1 ± 3.5$^{\dagger F}$
%HRR	76.1 ± 5.5$^{\ddagger A}$	68.6 ± 10.7^{F}	79.8 ± 4.0	75.8 ± 9.3^{F}	83.9 ± 4.7	80.7 ± 7.8^{F}	91.7 ± 3.0†	88.0 ± 5.3$^{\dagger F}$
RPE	18.1 ± 1.5	17.4 ± 1.5^{AB}	18.6 ±1.3	18.1 ± 1.4^{DC}	18.0 ± 1.2	19.0 ± 1.0	19.4 ± 0.9†	19.7 ± 0.5

Note. Data presented as mean ± SD. VO_2 = rate of oxygen uptake; HR = heart rate; RER = respiratory exchange ratio; %VO_2peak = percent of peak oxygen uptake; %HRpeak = percent of peak heart rate; %HRR = percent of heart rate reserve; RPE = ratings of perceived exertion (Borg). * indicates M>F all Bouts; †, Bout 4> all Bouts for indicated sex; ‡, F≠M in respective bout; A, Bout 1 ≠ Bout 3; B, Bout 1 ≠ Bout 4; C Bout 2 ≠ Bout 4; D, Bout 2 ≠ Bout 3; E, Bout 3 ≠ Bout 4; F, all pairwise comparisons among bouts for males ($P<0.05$).

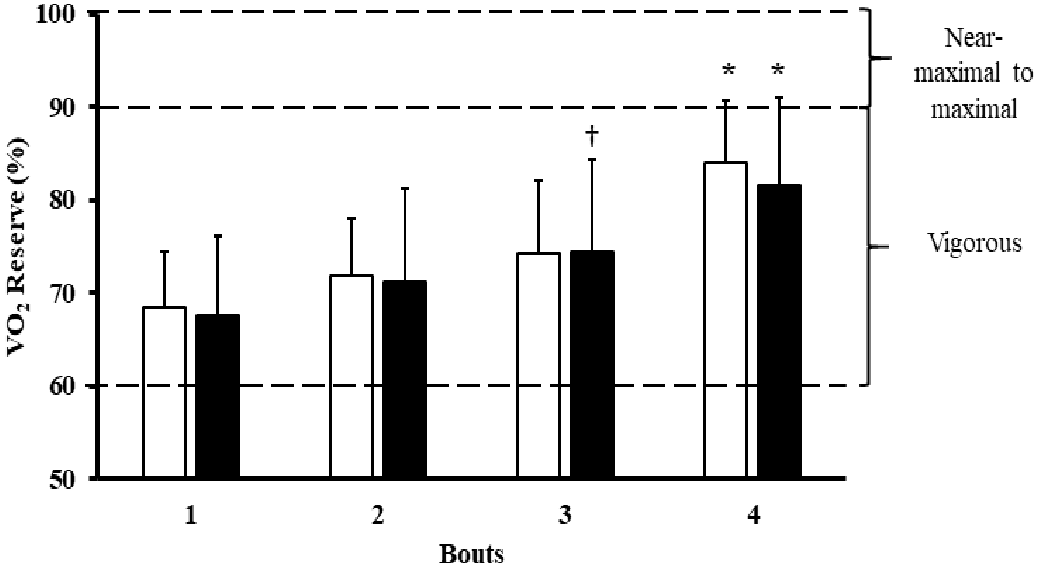

Figure 2. Percentage of V̇O2 Reserve during each 4-min bout of HIISWE) in reference to vigorous and near-maximal to maximal exercise intensity ranges according to ACSM guidelines (ACSM, 2017). *Note:* Female = unshaded bar; Male = shaded bar. * greater than first 3 bouts, † bout 3 greater than bout 1 ($p < 0.05$).

Figure 3 illustrates BLa response for individual bts. for males and females. Blood lactate was similar between males and females for bt. 1, but males accumulated more lactate in the successive three bts. ($p < 0.05$). For both sexes, blood lactate in bt. 4 was greater than all other bts. ($p < 0.05$). In addition, males showed a difference in BLa between bt. 1 and bts. 2 and 3 ($p < 0.05$). Peak blood lactate (mM) was 9.2 ± 1.7 and 11.1 ± 2.2 mM in females and males, respectively ($p < 0.05$).

During the 10-min cooldown, male and female $\dot{V}O_2$ was 0.91 ± 0.17 and 0.83 ± 0.11 $l \cdot min^{-1}$, while HR was 115 ± 8 and 114 ± 8 bpm, respectively ($p > 0.05$). Absolute O_2 pulse was also similar between males and females, respectively (7.9 ± 1.6 vs. 7.3 ± 1.0 $mlO_2 \cdot bt^{-1}$) ($p > 0.05$). RER during the cooldown was greater in males (1.10 ± 0.10) than females (1.01 ± 0.10) ($p < 0.05$). BLa at the conclusion of the cooldown was greater in males (9.2 ± 1.5 vs. 6.4 ± 1.4 mM), while both males and females reported a similar RPE (9.3 ± 1.4 and 8.7 ± 1.4, respectively) ($p > 0.05$).

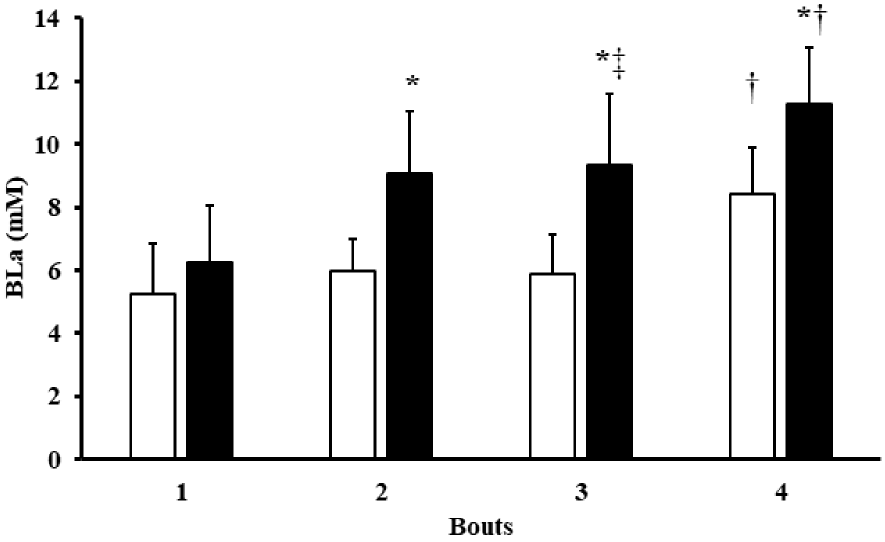

Figure 3. Blood lactate concentration immediately following each 4-min bout of HIISWE. *Note:* * Significant between females (unshaded bars) and males (shaded bars) for each bout; † indicated bout is greater than all other bouts for each sex; ‡ bout 3 greater than bout 1 ($p < 0.05$).

Discussion

This study elucidated the cardiorespiratory demands of performing SWE ranging in intensity from submaximal sustained efforts to relatively brief “all-out” work intervals. Unique elements of this investigation included the use of a perceptually self-guided approach to regulating exercise intensity. Studies have confirmed the usefulness of RPE to self-regulate intensity during land-based exercise (Eston, Lambrick, Sheppard, & Parfitt, 2008; Faulkner et al, 2007; Faulkner & Eston, 2008). Only one recent study confirmed the use of this method for systematically self-modulating effort in a shallow water medium in females (D’Acquisto et al, 2015). Applying the protocol employed by D’Acquisto et al. (2015) and using select data from their study positioned our team to analyze the usefulness of a perceptually self-guided intensity model in a male population, an understudied group in aquatic exercise research. In addition, it allowed us to explore sex-specific cardiorespiratory demands of SWE.

Both males and females reported a similar exercise history and nearly the same relative $\dot{V}O_2$ peak ($ml\cdot min^{-1}\cdot kg^{-1}$), thus indicating a comparable cardiorespiratory fitness level. Additionally, we measured cardiorespiratory reserve (peak – resting $\dot{V}O_2$ & HR) specific to the shallow water medium. Our findings clearly agreed with reports of reduced HR associated with standing water immersion (Graef & Kruel, 2006; Keskinen, Ferran, Keskinen, & Merikarj, 2003; Matsui & Onodera, 2013; Onodera, 2013; Pendergast, Moon, Krasney, Held, & Zampero, 2015; Wilcock, Cronin, & Hing, 2006). Collectively (Exp. I & II, Table 1.) we found a 24% and 27% decrease in standing resting HR after being immersed to axillary level compared to standing on the pool deck for both males and females, respectively. Additionally, O_2 pulse ($\dot{V}O_2$/HR), a surrogate of stroke volume, was significantly greater (40% (M), 51% (F)) when immersed compared to standing on deck. These findings likely illustrate the impact of increased hydrostatic pressure on the immersed body resulting in an increased venous return and cardiac pre-load, thus causing an enhanced stroke volume accompanied by reduced HR (Pendergast et al, 2015). The lower standing "resting" HR during water immersion in addition to lower $\dot{V}O_2$ and HR peak values compared to land (Alberton et al, 2014; Dowzer et al, 1999; Town & Bradley, 1999) lent justification for having measured both resting and peak $\dot{V}O_2$ and HR in shallow water prior to exercise. This allowed for a more accurate determination of reserve and relative cardiorespiratory demand (%$\dot{V}O_2$R, %HRR) associated with SWE. This approach is especially relevant given that measures of cardiorespiratory demand during SWE relative to $\dot{V}O_2$ and HR reserve are scarce in the aquatic exercise research literature.

A primary finding of this research was that a perceptually self- regulated effort using Borg's 6 to 20 scale is a viable approach to regulating exercise intensity in a shallow water medium regardless of sex. Both males and females achieved an invariant $\dot{V}O_2$ and HR response by minute 3 for each prescribed 5-min. effort (RPE 9 ("very light"), 11 ("light"), 13 ("somewhat hard"), 15 ("hard") and 17 ("very hard")), thereby supporting hypothesis I. Since there were no differences in physiological response among mins 3, 4, and 5, we used $\dot{V}O_2$ and HR of minute five as a representative cardiorespiratory response. Regression of this $\dot{V}O_2$ and HR response on RPE (Figure 1A, 1B) revealed very strong correlations (all participant r values > 0.94) thus supporting hypothesis II. Our findings clearly agreed with previous land-based exercise studies using treadmills and cycle ergometers that have shown that a RPE-guided effort model results in a strong positive correlation (r > 0.88) between $\dot{V}O_2$ regressed on RPE 9 through 17 (Eston et al, 2008; Faulkner et al, 2007; Faulkner et al, 2008). Figures 1A and 1B also illustrated the broad range of absolute cardiorespiratory loads captured with the perceptually self-regulated exercise protocol. Furthermore, relative cardiorespiratory responses associated with RPE 9-17 were extensive with %$\dot{V}O_2$R ranging from 16-82% and ~10-79%

for males and females, respectively. %HRR for RPE 9-17 ranged from 14-85% and 21-84%, for males and females, respectively. Adding to the metabolic profile, BLa was <3.0 mM for RPE efforts 9-17 for females, while males were < 4.0 mM for the first four exertions (RPE 9, 11, 13, and 15). Despite males having a BLa of 6.4 mM (~59% of peak BLa) for RPE 17, $\dot{V}O_2$ and HR were invariant when comparing minutes 3, 4, and 5 for this effort. Attainment of a steady physiological response over this extensive range of precisely self-regulated physiological efforts and a strong tracking of $\dot{V}O_2$, HR on RPE highlights the utility of RPE as a tool for systematically regulating intensity during SWE.

Our findings were particularly relevant because regulating exercise intensity in a shallow water medium can be somewhat challenging for researchers wishing to understand the physiological demands associated with a systematic up-regulation of water exercise effort. To regulate intensity in water, previously researchers had used cadence (Alberton et al, 2016; Benelli et al, 2004; Delavatti et al, 2015; Dowzer et al, 1999; Hoeger et al, 1995; Kruel et al, 2013), underwater treadmills (Barela & Duarte, 2008; Fujishima & Shimizu, 2003; Pohl & McNaughton, 2003; Shono et al, 2000), or instructional cues (Barbosa et al, 2007; Kruel et al, 2009; Nagle et al, 2013). Because underwater treadmills are expensive and may only accommodate one or several individuals at any one time depending on belt size. Although treadmill ergometers serve a purpose in a research or rehabilitation setting, they are not practical for use in group fitness settings such as an aquatic exercise class. Cadences that can be conveyed through music are very popular in group aquatic exercise settings; however, a set cadence may result in a metabolic load that is highly varied among individuals. According to Dunbar et al. (1992), a RPE-guided approach to regulating intensity requires little familiarization and should result in similar relative cardiorespiratory loads across participants. Aquatic fitness instructors may find our results associated with RPE self-regulated intensity especially appealing given the challenges of individualizing efforts when working with a group of clients exercising in shallow water.

Inspection of the $\dot{V}O_2$ vs RPE regression equation slopes provides additional information regarding the usefulness of RPE in self-regulation of effort. We found an increase of ~0.2 $l \cdot min^{-1}$ (3.0 $ml \cdot kg^{-1} \cdot min^{-1}$) and ~0.3 $l \cdot min^{-1}$ (3.5 $ml \cdot kg^{-1} \cdot min^{-1}$) per one unit increase in RPE for females and males, respectively. In our SWE protocol, RPE was increased in increments of two units (i.e., 9-11-13-15-17) thereby corresponding to an average $\dot{V}O_2$ increase of ~ 6.0 and 7.0 $ml \cdot kg^{-1} \cdot min^{-1}$ for the females and males, respectively. This step-up in physiological load captured the upper range of ACSM's recommendation of a one to two metabolic equivalent increase during a submaximal incremental exercise protocol (ACSM, 2017). This finding is important because it lends further credibility to the use of a perceptually self-guided approach to up-regulating intensity in a measured and acceptable fashion during an incremental SWE test for research purposes or during an aquatic exercise workout.

Measured $\dot{V}O_2$ peak did not differ from the predicted value for either sex. Estimated $\dot{V}O_2$ peak was determined from extrapolating $\dot{V}O_2$ on RPE 9-17 out to a theoretical maximum of RPE 20, an approach employed by previous investigators using land-based exercise protocols (Eston et al, 2005; Eston, Faulkner, Mason, & Parfitt, 2006; Faulkner et al, 2007; Faulkner et al, 2008). The final 5-min SWE "max" effort was also RPE self-regulated. The first and second mins were performed at RPE 17-18, while the third and fourth minutes were up-regulated to 18 and 19, respectively, with the final minute performed at RPE-20. As expected, males had a greater absolute $\dot{V}O_2$ peak (3.6 vs 2.7 $l \cdot min^{-1}$) while relative $\dot{V}O_2$ peak was similar (42.8 (males) vs 41.3 (females) ($ml \cdot kg^{-1} \cdot min^{-1}$). We believe that the highest attainable SWE $\dot{V}O_2$ was reached during the perceptually regulated maximal SWE test. Both sexes achieved ~95-97% of land predicted HR max (~190 bpm; 207-(0.67 x Age), Gellish et al. (2007)), RERs of 1.08 (males) and 1.05 (females), and a blood lactate of ~11 (males) and 8 mM (females). Furthermore, participants appeared exhausted at the conclusion of the maximal effort with many commenting on the intense nature of the test. The great physiological strain imposed by the final 5 min maximal exertion is further highlighted if one considers that following the 10 min. cooldown (reported RPE ~8), males and females still had a blood lactate concentration of 9.8 and 6.4 mM, respectively.

The cardiorespiratory and perceptual responses elicited by the 20-min HIISWE for both males and females are aligned with an intensity classification of "vigorous" to "near maximal to maximal" according to ACSM guidelines for improvement of cardiovascular fitness (ACSM, 2017). To the authors' knowledge, no published studies exist comparing sex-specific physiological and psychobiological responses to an acute high intensity interval workout performed in shallow water. HIISWE elicited an overall relative cardiorespiratory response equating to ~70% $\dot{V}O_2R$ and 75-79% HRR ($p > 0.05$) regardless of sex. Peak BLa for males and females was ~11 and 9 mM, respectively, with an overall RPE of 18-19 ("very hard" to "extremely hard"). Another indication of the intense nature of the workout was a BLa concentration still at ~9 and 10 times above resting values following the 10-min cooldown, respectively for males and females. The accumulation of BLa suggested a substantial metabolic load and anaerobic energy contribution during the 20-min HIISWE (di Prampero & Ferretti, 1999).

The physiological load imposed by the HIISWE agreed with previous findings during 20 to 30 minutes of land-based high intensity workouts (Emberts et al, 2013; Gist et al, 2014). Laurent et al. (2014) and Skelly et al. (2014) have found that land-based high intensity interval workouts with a 2:1 work to rest ratio elicited a varying relative physiological load of 80-96% HR max and 74-88% $\dot{V}O_2$ max. Also, the peak BLa values found in our study (11 (M) 9 mM (F)) fell in the 7 – 13 mM range reported for land-based (Emberts et al, 2013; Gist et al, 2014; Laurent et al, 2014; Nicolo et al, 2014; Rozenak, Fubato, Kubo, Hoshikawa, & Matsuo, 2007; Skelly et al, 2014) and water-based interval workouts (Cook et al, 2013). Given the popularity of water exercise, aquatic fitness professionals may promote to their clients that a HIISWE workout, such as the one employed in this study, can elicit an overall comparable cardio-metabolic response similar to land-based high intensity interval workouts.

Prior to beginning the HIISWE protocol, participants were reminded that they were to exercise "all-out" during each 20-s work interval. Thus, they were aware of the nature of the task as well as the end point. Participants appeared highly motivated and were familiar with the nature of the water exercises because of further instruction and practice and their recent participation in experiment I. Despite participants being aware of the heavy nature of the workout and what looked to be their full engagement from the very beginning, cardiorespiratory reserve was not fully taxed. Relative metabolic responses for both males and females modestly increased from bouts 1 to 3 (~70 to 73% $\dot{V}O_2$ peak) with the most pronounced increase noted between bouts 3 and 4 (~73 to 80-82% $\dot{V}O_2$peak, Table 3). RER values were consistently at ~1.0 and greater throughout the entire workout. Remaining physiological parameters such as HR, $\dot{V}_E$, and %HRR (Table 3) in addition to BLa (Figure 3) increased significantly during bout 4 compared to the first three, 4-min work sessions. These results clearly indicated a cardiometabolic "end-spurt" which implied that both sexes may have unconsciously employed a pacing strategy to prevent themselves from overexerting and thus avoided premature fatigue. Lambert, St. Clair Gibson, & Noakes (2005), Noakes (2012) and Ulmer (1996) have reported that the brain formulates an unconscious game-plan to modulate the mechanical power output during a heavy exercise task (especially a prolonged task) when an individual is aware of the end point. The basic idea is to prevent premature fatigue in order to complete the workout. The HIISWE was indeed a demanding task consisting of 32 x 20 second "all-out" efforts, thus, an unconscious pacing strategy possibly employed by our participants to make it through the workout seems a plausible explanation.

In summary, this study highlighted cardiorespiratory responses for an extensive continuum of shallow water exercise efforts for males and females. This investigation also provided valuable information for both researchers and aquatic fitness instructors who are interested in systematic regulation of exercise intensity in a shallow water medium by employing a perceptually self-guided model. Our results corroborated previous findings using land-based exercise protocols that have shown the usefulness of RPE to self-regulated exercise intensity (Eston et al, 2005; Eston et al, 2006; Eston et al, 2008; Faulkner et al, 2007; Faulkner & Eston, 2008). Additionally, we found that a highly intense SWE interval workout elicited a similar relative cardiorespiratory response between males and females. Although relative cardiorespiratory reserve (%$\dot{V}O_2$R and &HRR) were not fully taxed, perhaps due to the nature of the interval workout design, other measures of physio-psychological load such as BLa, RER, and RPE clearly suggested that the workout was heavy in nature for both sexes; the SWE interval workout resulted in relative cardiorespiratory and perceptual responses categorized as "vigorous" to "near maximal to maximal" intensity (ACSM, 2017). This finding suggested that the interval workout employed in this study is suitable for incorporation into HIIT programs.

References

Alberton, C.L., Pinto, S.S., Antunes, A.H., Cadore, E.L., Finatto, P., Tartaruga M.P., & Kruel, L.F.M. (2014). Maximal and ventilator thresholds cardiorespiratory responses to three water aerobic exercises compared with treadmill on land. *Journal of Strength and Conditioning Research, 28*(6):1679-1687, PubMed doi: 10.1519/JSC.0000000000000304

Alberton, C.L., Pinto, S.S., Gorski, T., Antunes, A.H., Finatto, P., Cadore, E.L., … & Kruel, L.F.M. (2016). Rating of perceived exertion in maximal incremental tests during head-out water-based aerobic exercises. *Journal of Sports Sciences, 34*(18), 1691-1698. PubMed doi: 10.1080/02640414.2015.1134804

American College of Sports Medicine (2017). *ACSM's guidelines for exercise testing and prescription* (10th ed.). Baltimore, MD: Lippincott Williams & Wilkins. PubMed doi: 10.1249/JSR.0b013e31829a68cf

Aquatic Exercise Association. (2010). *Aquatic fitness professional manual* (6th ed.) Champaign, IL: Human Kinetics.

Barbosa, T.M., Garrido, M.F., & Bragada, J. (2007). Physiological adaptations to head-out aquatic exercises with different levels of body immersion. *Journal of Strength Conditioning Research, 21*(4): 1255-59. PubMed doi: 10.1519/R-20896.1

Barela, A.M., & Duarte, M. (2008). Biomechanical characteristics of elderly individuals walking on land and in water. *Journal of Electryomyography and Kinesiology, 18*(3): 446-454. PubMed doi: 10.1016/j.jelekin.2006.10.008

Benelli, P., Ditriolo, M., & de Vito, G. (2004). Physiological responses to fitness activities: A comparison between land-based and water aerobics exercise. *Journal of Strength and Conditioning Research, 18*, 719-722. PubMed doi: 10.1519/14703.1

Borg, G. (1998). *Borg's perceived exertion and pain scales.* Champaign IL: Human Kinetics.

Burgomaster, K.A., Hughes, S.C., Heigenhauser, G.J.F., Bradwell, S.N., & Gibala, M.J. (2005). Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. *Journal of Applied Physiology, 98*(6), 1985–1990. PubMed doi:10.1152/japplphysiol.01095.2004

Burgomaster, K.A., Heigenhauser, G.J.F., & Gibala, M.J. (2006). Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. *Journal of Applied Physiology*, *100*(6), 2041-47. PubMed doi:10.1152/japplphysiol.01220.2005

Burgomaster, K.A., Cermak, N.M., Phillips, S.M., Benton, C.R., & Gibala, M.J. (2007). Divergent response of metabolic transport proteins in human skeletal muscle after sprint interval training and detraining. *American Journal of Physiology-Regulatory Integrative and Comparative Physiology*, *292*(5), 1970-76. PubMed doi:10.1152/ajpregu.00503.2006

Campbell, J.A., D'Acquisto, L.J., D'Acquisto, D.M., & Renne, D. (2003). Metabolic and cardiovascular responses to shallow water exercise in young and older women. *Medicine and Science in Sports and Exercise, 35*, 675-681. PubMed doi:10.1249/01.MSS.0000058359.87713.99

Cook, B.S., Scarneo, S.E., & McAvoy, R.M. (2013). Physiological effects of an acute bout of shallow water sprinting. *International Journal of Aquatic Research and Education, 7*, 105-115.DOI: 10.25035/ijare.07.02.03

D'Acquisto, L.J., D'Acquisto, D.M., & Cline, M.G. (2001). Metabolic and cardiovascular responses in older women during shallow-water exercise. *Journal of Strength and Conditioning Research, 15*(1), 12-19.

D'Acquisto, L.J., Miller, L.J., D'Acquisto, D.M., Roemer, K., & Fisher, M.G. (2015). Physiological and psychosocial aspects of shallow water exercise. *International Journal of Aquatic Research and Education, 9,* 273-291. DOI: 10.25035/ijare.09.03.05

Delavatti, R., Alberton, C.L., Kanitz, A.C., Marson, E.C., & Kruel, L.F.M. (2015). Vertical ground reaction force during land and water-based exercise performed by patients with type 2 diabetes. *Medicina Sportiva, 11*(1), 2501-2508.

di Prampero, P.E., & Ferretti, G. (1999). The energetic of anaerobic muscle metabolism: A reappraisal of older and recent concepts. *Respiration Physiology, 118*(2–3), 103–115. PubMed doi:10.1016/S0034-5687(99)00083-3

Dowzer, C.N., Reilly, T., Cable, N.T., & Nevill, A. (1999). Maximal physiological responses to deep and shallow water running. *Ergonomics, 42*(2), 275-281. PubMed doi:10.1080/001401399185649

Dunbar, C.C., Robertson, R.J., Baun, R., Blandon, M.F., Metz, K., Burdett, R., & Goss F.L. (1992). The validity of regulating exercise intensity by ratings of perceived exertion. *Medicine and Science in Sports and Exercise, 24*, 94-99. PubMed doi:10.1249/00005768-1992010000-00016

Emberts, T., Porcari, J., Doberstein, S., & Foster C. (2013). Exercise intensity and energy expenditure of a Tabata workout. *Journal of Sports Science & Medicine, 12*, 612-613.

Eston, R.G., Lamb, K.L., Parfitt, G., & King, N. (2005). The validity of predicting maximal oxygen uptake from a perceptually-regulated graded exercise test. *European Journal of Applied Physiology*, *94*, 221–227. PubMed doi:10.1007/s00421-005-1327-2

Eston, R.G., Faulkner, J.A., Mason, E.A., & Parfitt, G. (2006). The validity of predicting maximal oxygen uptake from perceptually-regulated graded exercise tests of different durations. *European Journal of Applied Physiology*, *97*, 535–541. PubMed doi:10.1007/ s00421-006-0213-x

Eston, R., Lambrick, D., Sheppard, K., & Parfitt, G. (2008). Prediction of maximal oxygen uptake in sedentary males from a perceptually-regulated submaximal graded exercise test. *Journal of Sports Science, 26*(2), 131-39. PubMed doi:10.1080/02640410701371364

Faulkner, J., Parfitt, G., & Eston, R.G. (2007). Prediction of maximal oxygen uptake from the ratings to perceived exertion and heart rate during a perceptually-regulated submaximal exercise test in active and sedentary participants. *European Journal of Applied Physiology, 101*(3), 397-407. PubMed doi:10.1007/s00421-007-0508-6

Faulkner, J., & Eston, R.G. (2008). Perceived exertion in the 21st century: Developments, reflections and questions for the future. *Journal of Exercise Science and Fitness, 6*(1), 1-13.

Fujishima, K., & Shimizu, T. (2003). Body temperature, oxygen uptake and heart rate during walking in water and on land at an exercise intensity based on RPE in elderly men. *Journal of Physiology Anthropology and Applied Human Science, 22*(2), 83-88.

Gellish, R.L., Goslin, B.R., Olson, R.E., McDonald, A., Russi, G.D., & Moudgil, V.K. (2007). Longitudinal modeling of the relationship between age and maximal heart rate. *Medicine and Science in Sports and Exercise, 39,* 822–829. PubMed doi:10.1097/ mss.0b013e31803349c6

Gibala, M.J., Little, J.P., Essen, M., Wilkin, G.P., Burgomaster, K.A., Safdar, A., … & Tarnopolsky, M.A. (2006). Short-term sprint interval versus traditional endurance training: Similar initial adaptations in human skeletal muscle and exercise performance. *Journal of Physiology*. *575*(3), 901-11. PubMed doi:10.1113/jphysiol.2006.112094

Gibala, J.M., Little, J.P., MacDonald, M.J., & Hawley, J.A. (2012). Physiological adaptations to low-volume, high-intensity interval training in health and disease. *Journal of Physiology, 590*(5), 1077-1084.

Gist, N.H., Freese, E.C., & Cureton, K.J. (2014). Comparison of responses to two high-intensity intermittent exercise protocols. *Journal of Strength and Conditioning Research*, *28*(11), 3033-3040. PubMed doi:10.1519/JSC.0000000000000522

Graef, F.I., & Kruel, L.F.M. (2006). Heart rate and perceived exertion at aquatic environment: Differences in relation to land environment and applications for exercise prescription: a review. *Revista Brasileira de Medicina Esporte, 12*(4), 198-204.

Hoeger, W., Hopkins, D., & Barber, D. (1995). Physiologic responses to maximal treadmill running and water aerobic exercise. *National Aquatic Journal, 11*(1),4-7.

Keskinen, K.L., Ferran, F.A., Keskinen, O.P., & Merikari, J. (2003). Human cardiorespiratory responses to resting water immersion to the neck with changing body positions. *Biomechanics and Medicine in Swimming IX, Publ. L'Universite de St. Etienne, France 21-23*.337-342.

Kruel, L.F., Posser, M.S., Alberton, C.L., Pinto, S.S., & Oliveira, A.S. (2009). Comparison of energy expenditure between continuous and interval water aerobic routines. *International Journal of Aquatic Research and Education, 3*, 186-196. DOI: 10.25035/ijare.03.02.09

Kruel L.F.M., Beilke, D.D., Kanitz, A.C., Alberton, C.L., Antunes, A.H., Pantoja, P.D., … & Pinto S.S. (2013). Cardiorespiratory responses to stationary running in water and on land. *Journal of Sport Science and Medicine*, *12*, 584-600.

Lambert, E.V., St. Clair Gibson, A., & Noakes, T.D. (2005). Complex systems model of fatigue: Integrative homoeostatic control of peripheral physiological systems during exercise in humans. *British Journal of Sports Medicine*, *39*(1), 52–62. PubMed doi:10.1136/bjsm.2003.011247

Laurent, C.M., Vervaecke, L.S., Kutz, M.R., & Green, J.M. (2014). Sex-specific responses to self-paced, high-intensity interval training with variable recovery period. *Journal of Strength and Conditioning Research*, *28*, 920-7. PubMed doi:10.1519/JSC.0b13e3182a1f574

Little, J.P., Safdar, A., Wilkin, G.P., Tarnopolsky, M.A., & Gibala, M.J. (2010). A practical model of low-volume high intensity interval training induces mitochondrial biogenesis in human skeletal muscle: potential mechanisms. *Journal of Physiology, 588*(6), 1011-1012.

Matsui. T., & Onodera, S. (2013). Cardiovascular responses in rest, exercise, and recovery phases in water immersion. *Journal of Physical Fitness Sports Medicine*, *2*(4), 475-480.

Miller, L.J., D'Acquisto, L.J., D'Acquisto, D.M., Roemer, K., & Fisher, M.G. (2015). Cardiorespiratory Responses to a 20-Minute Shallow Water Tabata-Style Workout. *International Journal of Aquatic Research and Education*, *9*, 292-307. DOI: 10.25035/ijare.09.03.06

Nagle, E.F., Sanders, M.E., Shafer, A., Gibbs, B.B., Nagle, J.A., Deldin, A.R., … & Robertson, R.J. (2013). Energy expenditure, cardiorespiratory, and perceptual responses to shallow-water aquatic exercise in young adult women. *The Physician Sportsmedicine*, *41*(3), 67-76. PubMed doi:10.3810/psm.2013.09.2018

Nicolo, A., Bazzucchi, I., Lenti, M., Haxhi, J., Scotto di Palumbo, A., & Sacchetti, M. (2014). Neuromuscular and metabolic responses to high-intensity intermittent cycling protocols with different work-to-rest ratios. *International Journal of Sports Physiology and Performance*, *9*(1), 151-160. PubMed doi:10.1123/ijspp.2012-0289

Noakes, T.D. (2012). Fatigue is a brain-derived emotion that regulates the exercise behavior to ensure the protection of whole body homeostasis. *Frontiers in Biology*, www.frontiersin.org doi:10.3389/fphys.2012.00082

Olson, M. (2014). Tabata it's a HIIT! *ACSM's Health & Fitness Journal, 18,* 17-24.

Onodera, S., Yoshioka, A., Nishimura, K., Kawano, H., Ono, K., Matsui, T., Ogita, F., & Hara, H. (2013). Water exercise and health promotion. *The Journal of Physical Fitness and Sports Medicine*, *2*(4), 393-399. PubMed doi:10.7600/jpfsm.2.393

Pendergast D.R., Moon, R.E., Krasney, J.J., Held, H.E., & Zampero, P. (2015). Human physiology in an aquatic environment. *Comprehensive Physiology*, *V5*, 1705-1750. PubMed doi:10.1002/cphy.c140018

Pohl, M.B., & McNaughton, L.R. (2003). The physiological responses to running and walking in water at different depths. *Research in Sports Medicine, 11*, 63-78.

Rebold, M.J., Kobak, M.S., & Otterstetter, R. (2013). The influence of a Tabata interval training program using an aquatic underwater treadmill on various performance variables. *The Journal of Strength and Conditioning Research*, *27*(12), 3419-3425. PubMed doi:10.1519/JSC.0b013e3182908a09

Rozenak, R., Funato, K., Kubo, J., Hoshikawa, M., & Matsuo, A. (2007). Physical Physiological responses to interval training sessions at velocities associated with $\dot{V}O_2$max, *Journal of Strength and Conditioning Research*, *21*, 188-192. PubMed doi:10.1519/R-19325.1

Ryzkova, E., Labudova, J., Grznar, L., & Smida, M. (2017). Effects of aquafitness with high intensity interval training on physical fitness. *Journal of Physical Education and Sport*, *18*(1), 373-381.

Sanders, M.E., Takeshima, N., Rogers, M.E., Colado, J.C., & Borreani, S. (2013). Impact of the S.W.E.A.T. water-exercise method on activities of daily living for older women. *Journal of Sports Science & Medicine, 12*(4), 707-715.

Seiler, S., & Hetlelid, K.J. (2005). The impact of rest duration on work intensity and RPE during interval training. *Psychobiological Behavioral Strategies*, *37*(9), 1601-07.

Skelly, L.E., Andrews, P.C., Gillen, J.B., Martin, B.J., Percival, M.E., & Gibala, M.J. (2014). High-intensity interval exercise induces 24-hour energy expenditure similar to traditional endurance exercise despite reduced time commitment. *Applied Physiology, Nutrition, and Metabolism*, *39*(7), 845-848. PubMed doi:10.1139/apnm-2013-0562

Shono, T., Fujishima, K., Hotta, N., Ogaki, T., Ueda, T., Otoki, K., . . . Shimizu, T. (2000). Physiological responses and RPE during underwater treadmill walking in women of advanced age. *Journal of Physiological Anthropology and Applied Human Science*, *19*(4), 195-200. PubMed doi:10.2114/jpa.19.195

Silvers, W.M., Rutledge, E.R., & Dolny, D.G. (2007). Peak cardiorespiratory responses during aquatic and land treadmill exercise. *Medicine and Science in Sports and Exercise*, *39*(6), 969-975. PubMed doi:10.1097/mss.0b013e31803bb4ea

Tabata, I., Irisawa, K., Kouzaki, M., Nishimura, K., Ogita, F., & Miyachi, M. (1997). Metabolic profile of high intensity intermittent exercises. *Medicine and Science in Sports and Exercise, 29*(3), 390-95. PubMed doi:10.1097/00005768-199703000-00015

Town, G.P., & Bradley, S.S. (1991). Maximal metabolic responses of deep and shallow water running in trained runners. *Medicine and Science in Sports and Exercise*, *23*, 238-241.

Torres-Ronda, L., & I del Alcazar, X.S. (2014). The properties of water and their applications for training. *Journal of Human Kinetics*, *44*, 237-248. PubMed doi:10.2478/hukin-2014-0129

Ulmer, H.V. (1996). Concept of an extracellular regulation of muscular metabolic rate during heavy exercise in humans by psychophysiological feedback. *Experientia*, *52*(5), 416–420. PubMed doi:10.1007/BF01919309

Walker, E., & Nowacki, A.S. (2011). Understanding equivalence and noninferiority testing. *Journal of General Internal Medicine*, *26*(2), 192-96. PubMed doi:10.1007/s11606-010-1513-8

Wertheimer, V., & Jukic, I. (2013). Aquatic training – an alternative or a compliment to land-based training. *Croatian Sports Medicine Journal*, *28*, 57-66.

Wilcock, I.M., Cronin, J.B., & Hing, W.A. (2006). Physiological response to water immersion. *Sports Medicine*, *36*(9), 747-765.

Zuniga, J.M., Berg, K., Noble, J., Harder, J., Chaffin, M.E, & Hanumanthu, V.S. (2011). Physiological responses during interval training with different intensities and duration of exercise. *Journal of Strength and Conditioning Research*, *25*(5), 1279-1284. PubMed doi:10.1519/JSC.0b013e3181d681b6