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Original Research Article

A Comparison of the Submaximal and Maximal Cardiorespiratory Responses to Aquatic vs. Land Cycling

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Abstract

Introduction: Aquatic cycling has gained in popularity in recent years. There are inconsistencies in the literature regarding the submaximal and maximal HR and VO_2 responses to water-based vs. land-based cycling. Differences in these values could have an impact on exercise prescription in the two environments. **Purpose:** To compare submaximal and maximal HR and VO_2 between land and water exercise, as well as their impact on calculated relative exercise intensity. **Methods:** Sixteen healthy, active college-aged students completed two maximal cycling tests, one in the water and one on land. HR, VO_2, and ratings of perceived exertion (RPE) were assessed during both tests. **Results:** Heart rate and VO_2 were blunted in a linear fashion all the way up to and including maximal exertion during aquatic cycling compared to land-based cycling. Maximal HR was 14 bpm lower in water compared to on land and VO_2 was 12% lower in water compared to on land. There was no difference in relative exercise intensity (%HRR and %VO_2R) at any RPE level. **Conclusion:** Even though absolute HR and VO_2 were lower at all levels of exercise, at a given RPE subjects were working at the same relative intensity on land and in the water and should reap similar benefits.

Key Words: Hydrocycle, Aqua Cycling, Relative Exercise Intensity

Introduction

Water exercise is a popular exercise modality because the aquatic environment reduces the pressure on the joints due to the buoyancy of the water and moving in the water provides resistance which can potentially increase energy expenditure, as well as increase muscle strength[1]. As such, water exercise has been used to exercise a wide variety of populations, including athletes, sedentary adults, the elderly, and obese individuals[2-6]. Aquatic "spinning" classes have also been developed and the first class was reportedly held in New York City in 2013[7].

Numerous studies have compared the cardiorespiratory responses between aquatic cycling and dry land cycling. The majority of research evaluated differences in heart rate (HR) between both cycling environments and it is generally concluded that HR is lower in water at the same level of oxygen consumption (VO_2) [1,8-10]. However, several studies found that HR was not significantly different between the two environments[6,11] and one study reported that maximal HR was actually higher in the water[12]. The lower HR in the water is often attributed to a higher stroke volume, which is a result of an increase in venous return due to the hydrostatic pressure of being immersed[8].

Oxygen consumption has also been compared between aquatic cycling and land-based cycling. Similar to the data on HR, there are inconsistencies in the literature. Oxygen consumption has been shown to be lower in water[2,13], higher in water[14-15], or remain unchanged[1,10,16].

Rating of perceived exertion (RPE) is another method used to monitor exercise intensity[17]. Rating of perceived exertion has not been studied extensively during aquatic exercise, but RPE has generally been shown to be higher during aquatic exercises compared to land exercise at the same HR and VO_2[5,18]. Barbosa et al.[5] recorded RPE during aquatic exercise while 16 subjects were either immersed to the chest, immersed to the hip, or performed the same exercises on land. Rating of perceived exertion was considerably higher in water compared to on land at the same workload. The study concluded that a higher perceived effort in water compared to land could be related to the higher drag forces acting on the limbs when moving through the water.

Aquatic cycling is a new group fitness class that is gaining in popularity. Aquatic cycling is essentially a “spinning” class held in the water using specialized cycle ergometers, with the participant typically immersed up to the xiphoid process while cycling. Because the data are inconsistent regarding the physiological and perceptual responses to aquatic versus land-based cycling, potential differences could impact exercise prescription between the two environments. Therefore, the purpose of this study was to compare the submaximal and maximal HR and VO_2 responses among individuals performing maximal graded cycling both on land and in the water.

Methods

Participants

Sixteen apparently healthy college students between 19-24 years of age volunteered to participate in the study. Each subject completed a PAR-Q to screen for cardiovascular and orthopedic contraindications to exercise and all subjects provided written informed consent before undergoing any testing or training procedures. The study was reviewed and approved by the University of Wisconsin – La Crosse Institutional Review Board for the Protection of Human Subjects.

Procedures

Each subject completed two maximal exercise tests as part of this study. One test was completed on land while the other maximal test was performed in the water. Tests were performed in random order with a minimum of 48 hours between tests. Subjects reported to the laboratory having not eaten or consumed caffeine for at least 3 hours and having not exercised on the same day prior to testing. For the land-based test, subjects exercised on a Lode electrically-braked cycle ergometer (Groningen, Netherlands). Before testing began, subjects sat quietly on the bike for 10 minutes to obtain a resting HR. The test started at 20 Watts for men and increased by 20-25 Watts each minute until the subject reached volitional exhaustion. For the female subjects, the test started at 15 watts and increased by 15-20 Watts each minute. For the water-based test, subjects exercised on a Hydrorider Professional Bike (Biscayne Park, FL). Each subject participated in one practice session to become accustomed to cycling in the water. The height of the bike frame was adjusted so that all subjects were immersed to the xiphoid process. Prior to the test, a resting HR was obtained by having each subject sit quietly on the bike in the water for 10 minutes. The test began at 50 rpms and increased by 3 rpm each minute until the subject reached volitional exhaustion. It has been shown that even small increases in rpm generate rapid increases in the physiological responses[13]. Pilot testing found that this protocol resulted in a similar time frame as the land-based test. The Hydrorider has three resistance settings and the hardest setting was used for testing all subjects. On the flywheel there are three separate holes; the flywheel was set to the third hole which made the scoop of the flywheel longer. Thus, for every pedal revolution the flywheel scooped up more water than the two lower resistance levels, making it more difficult to turn the pedals.

For both tests, VO_2 was measured continuously using a Parvo Medics metabolic cart (Sandy, UT) and HR was measured each minute using a Polar HR monitor (Bethpage, NY). Prior to each maximal exercise test, the metabolic cart was calibrated as per manufacturer guidelines with gases of known concentrations (15.98% O_2, 4.12 % CO_2) and with room air (20.94% O_2 and 0.03% CO_2). Calibration of the pneumotachometer was done via a 3 Liter calibration syringe. Rating of perceived exertion was recorded every minute during each maximal test using the 6-20 Borg scale[17].

Statistical analyses

Descriptive statistics were used to summarize all data. A two-way ANOVA with repeated measures was used to compare the HR and VO_2 responses during land-based and water-based exercise at RPEs of 11, 13, 15, and at maximal exercise. Differences between specific means were made using Tukey's post-hoc tests. Alpha was set at .05 to achieve statistical significance. All analyses were performed using the Statistical Package for Social Sciences (SPSS) version 25.0 (Chicago, IL).

Results

Descriptive characteristics of the 16 subjects who participated in the study are presented in Table 1.

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

	Males (n=8)	Females (n=8)
Age (yrs)	22.0 ± 1.70	21.0 ± 1.50
Height (cm)	176.8 ± 1.88	168.9 ± 6.17
Weight (kg)	78.6 ± 8.24	65.4 ± 9.53

There was no significant difference in the average length of time for the land and water-based tests (13:48 ± 1.47 min vs. 14:00 ± 1.79 min). For the land-based test the average maximal power output was 249.7 ± 39.05 watts. For the water-based test the average maximal rpms was 89.0 ± 5.37. For ease of comparison between the land and water-based conditions, HR and VO_2 data were extrapolated to RPE levels of 11, 13, and 15 using individual linear regression equations derived from the respective maximal tests. Summary data for HR and VO_2 at the three RPE levels and at maximal exercise during both cycling protocols are presented in Table 2 and Figures 1 and 2, respectively. Heart rate and VO_2 on land were significantly greater than in the water at all three RPE levels and at maximal exercise (Table 2). Heart rate (Figure 1) and VO_2 (Figure 2) for both tests went up in a linear fashion with an increase in exercise intensity and higher levels of perceived effort.

Table 2. Heart rate and oxygen consumption (VO_2) responses at RPE levels of 11, 13, 15, and maximal exercise.

	Land	Water
HR at RPE 11 (bpm)	132 ± 21.2*	116 ± 12.3
HR at RPE 13 (bpm)	149 ± 17.7*	129 ± 13.2
HR at RPE 15 (bpm)	163 ± 15.7*	146 ± 15.1
HRmax (bpm)	180 ± 9.3*	166 ± 14.0
VO_2 at RPE 11 (ml/kg/min)	22.9 ± 4.74*	20.3 ± 2.93
VO_2 at RPE 13 (ml/kg/min)	27.7 ± 5.53*	24.6 ± 4.13
VO_2 at RPE 15 (ml/kg/min)	34.3 ± 5.10*	30.6 ± 5.13
VO_2max (ml/kg/min)	44.0 ± 5.94*	39.3 ± 6.87

*Significantly greater than water ($p < 0.05$). All values represent mean ± standard deviation.

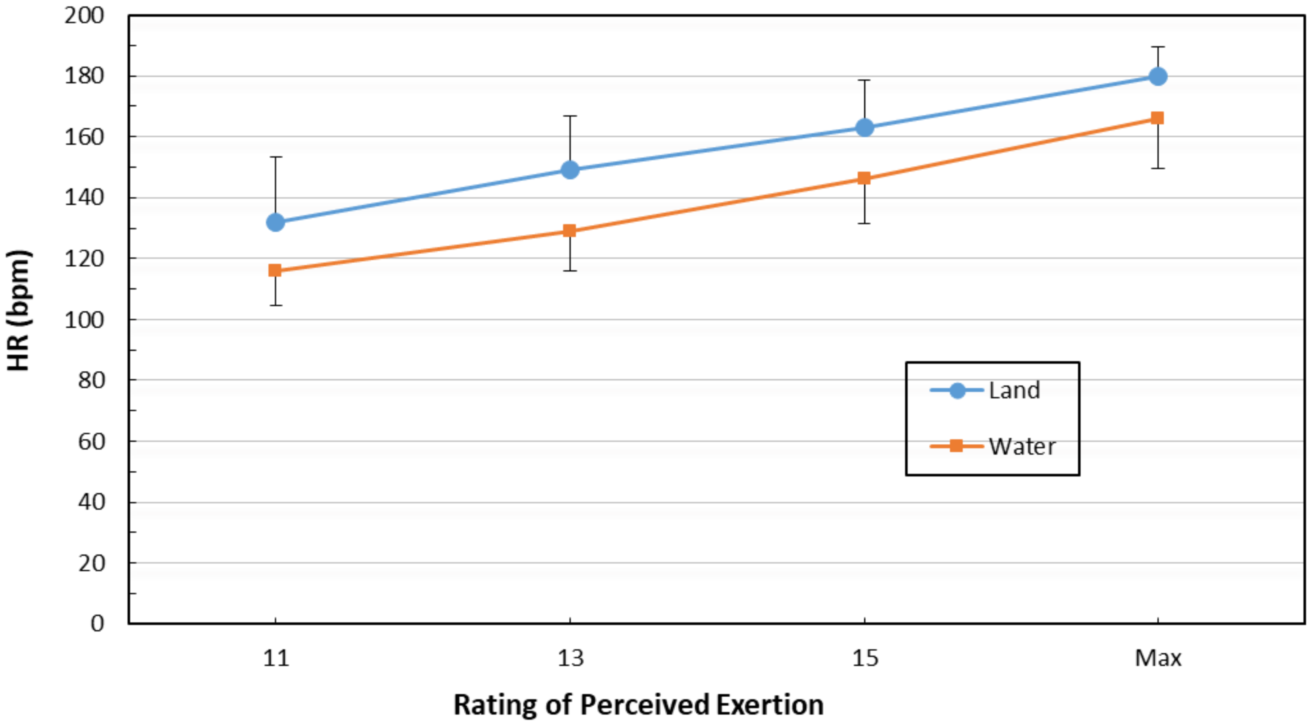

Figure 1. Heart rate responses on land and in water during the maximal exercise tests.

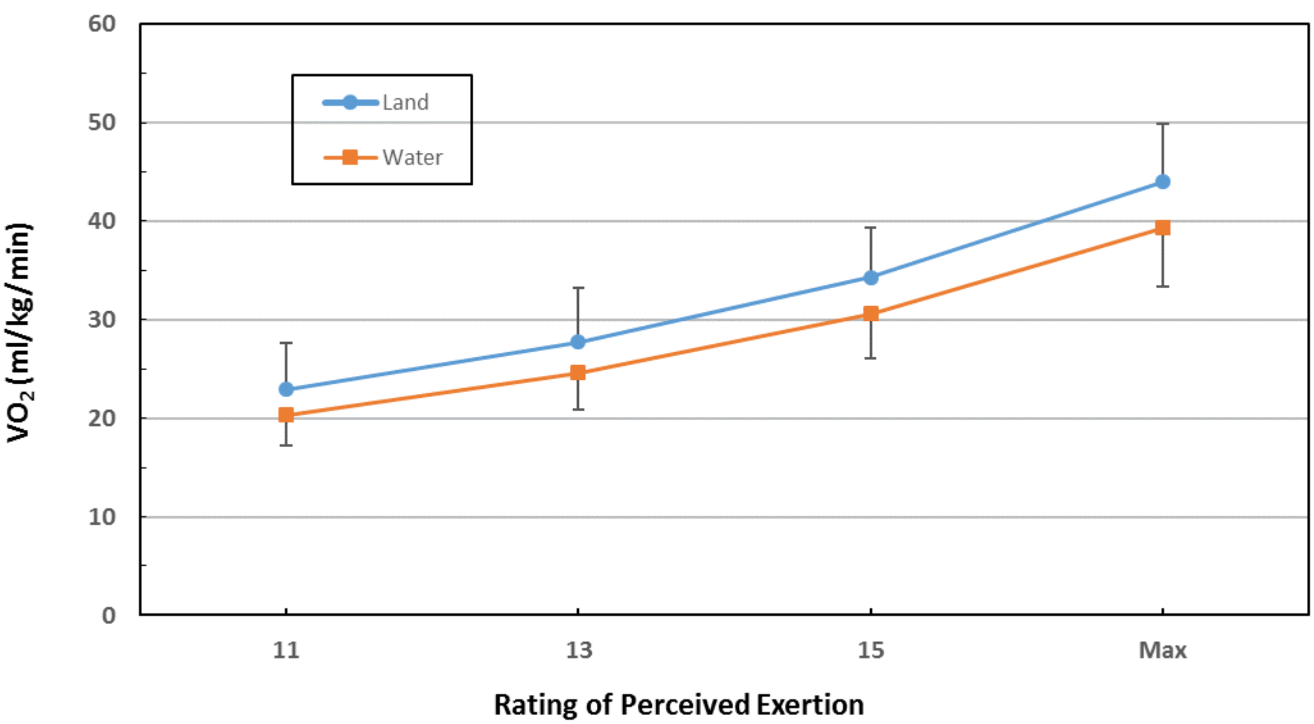

Figure 2. Comparison of VO_2 during the land and water-based maximal exercise tests.

Relative exercise intensity (%HRR and %VO_2R) at each RPE level was calculated and is presented in Table 3 and Figures 3 and 4, respectively. The boxed area in each figure represents ACSM recommendations for improving cardiorespiratory endurance using both methods (40 – 89% of HRR or VO_2R). To calculate %HRR, the resting HR determined on land or in the water were used in the respective calculations. To calculate VO_2R, a constant of 3.5 ml/kg/min was used for all subjects. There were no significance differences in the %HRR or %VO_2R at RPE 11, 13, or 15 between land and water-based exercise.

Table 3. Relative HR (%HRR) and VO_2 (%VO_2R) responses at RPE levels of 11, 13, and 15.

	Land	Water
%HRR at RPE 11	55.4 ± 15.73	50.9 ± 9.99
%HRR at RPE 13	70.6 ± 11.61	63.6 ± 9.65
%HRR at RPE 15	83.4 ± 8.41	79.6 ± 10.74
%VO_2R at RPE 11	48.3 ± 11.02	47.6 ± 7.87
%VO_2Reserve 13	60.0 ± 11.42	59.2 ± 7.21
%VO_2Reserve 15	76.2 ± 7.49	76.3 ± 11.58

*Significantly greater than water ($p < 0.05$). HRR = Heart Rate Reserve; VO_2R = VO_2 Reserve. All values represent mean ± standard deviation.

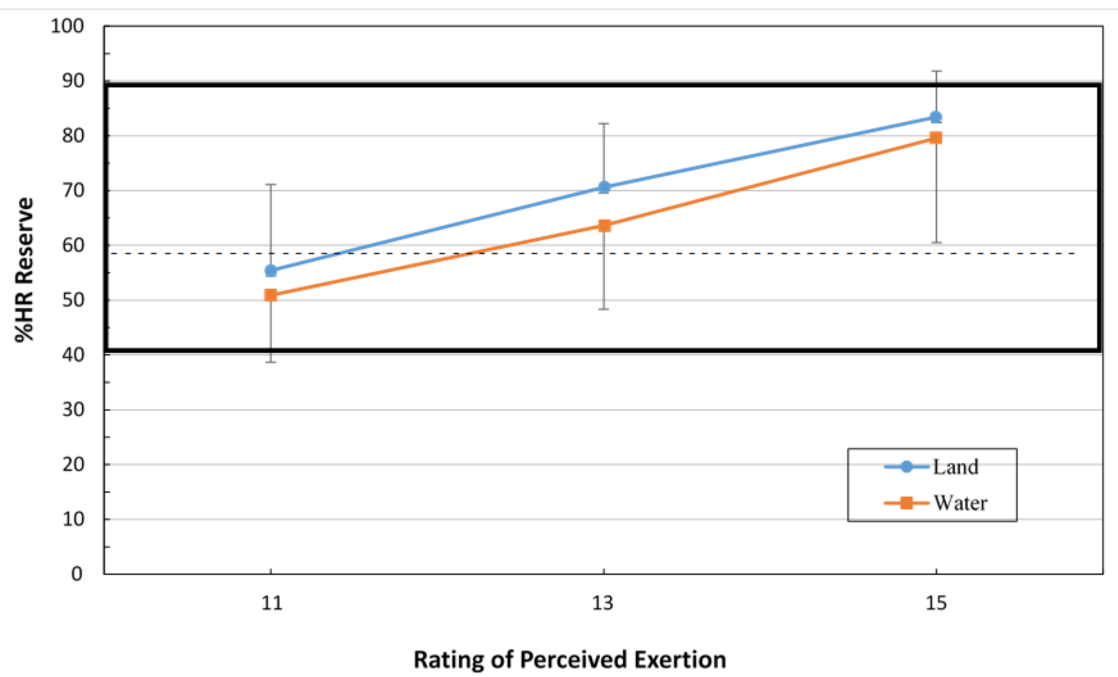

Figure 3. Comparison of %HRR between land and water-based exercise at RPE levels of 11, 13, and 15. ACSM guidelines recommend exercising between 40-89% of HRR which is represented by the boxed area on the graph. The separation between moderate and vigorous intensity ranges within the guidelines is represented by the dotted line.

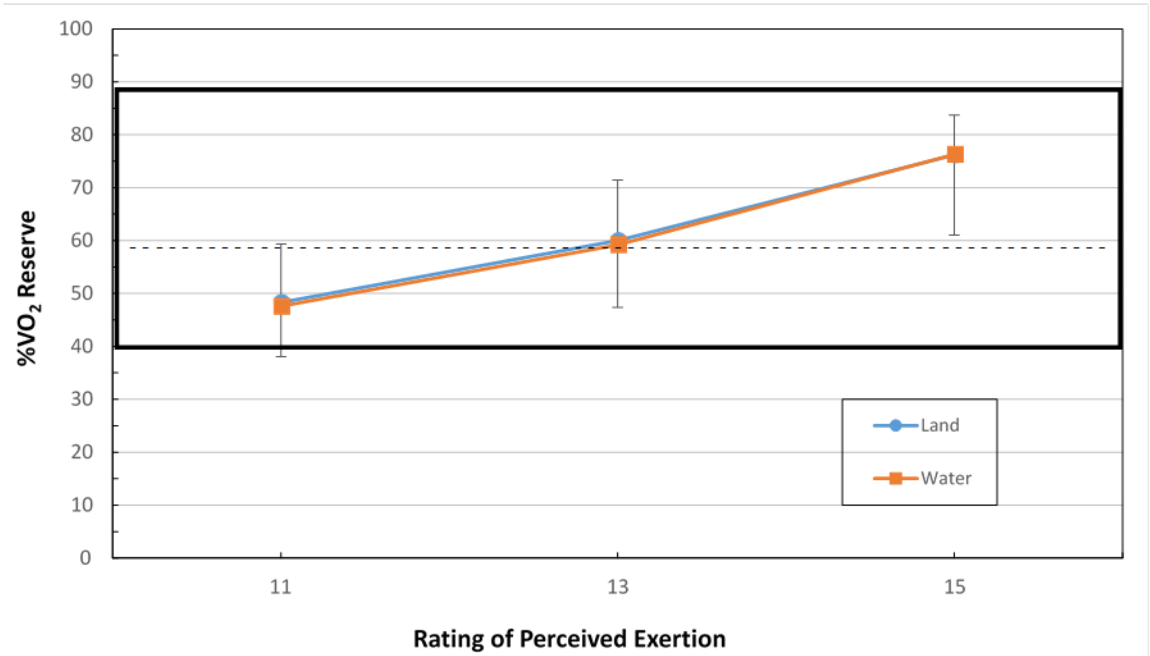

Figure 4. Comparison of %VO_2R between land and water-based exercise at RPE levels of 11, 13, and 15. ACSM guidelines recommend exercising between 40-89% of VO_2R, which is represented by the boxed area on the graph. The separation between moderate and vigorous intensity ranges within the guidelines is represented by the dotted line.

Discussion

The purpose of this study was to compare the submaximal and maximal cardiovascular responses to cycling exercise on land and in the water and to determine the potential impact on exercise prescription. It was found that HR and VO_2 were significantly lower at each RPE level and at maximal exercise in the water compared to on land. Maximal HR was 14 bpm lower and VO_2max was 12% lower in the water compared to on land. These findings are similar to those of several other studies who also compared maximal cycling on land and in water. Garzon et al.[3] found a 9 bpm lower maximal HR and 28% lower VO_2max in water compared to land and Garzon et al.[13] found a 10 bpm lower maximal HR and a 40% lower VO_2max during water-based vs. land-based cycling.

The lower maximal HR and VO_2max in water could be due to the several factors. It is possible that participant's legs became fatigued before their cardiovascular system reached maximal levels. The reason a person's legs become fatigued quickly is partially due to the fact that the drag forces acting on the legs increases substantially as pedaling speed increases. Previous research has shown that workload increases in the water as a function of the velocity of movement[2,18]. Additionally, anecdotally several subjects commented that they just could not turn the pedals any faster, despite having practiced the protocol previously. Heart rate was most likely lower at a relative VO_2 because the increase in hydrostatic pressure from being immersed increases central blood volume which increases venous return[9,19]. As a result, stroke volume increases via the Frank Starling mechanism and HR does not have to be as high to maintain a given cardiac output[20].

Even though absolute HR and VO_2 values were lower in water compared to land, they were blunted in a linear fashion all the way up to maximal exertion. Thus, there was no difference in the relative exercise intensity (%HRR or %VO_2R) at any RPE level. When exercising at a certain RPE (e.g., 13) on land and in water, the participant was working at the same relative intensity in both environments. This is in agreement with the findings of Garzon et al.[13] who also investigated %HRR and %VO_2R as it relates to prescribing the correct exercise intensity for individuals exercising on an immersible ergometer. They concluded that even though absolute HR and VO_2 during exercise in the water were lower compared to on land, the relative intensity was similar.

A possible limitation to this study was that none of the subjects had performed water-based exercise cycling previously. It is possible that more experienced subjects would have similar HRmax and VO_2max values in the water as on land.

Conclusions

The current study found that HR and VO_2 during submaximal and maximal cycling were significantly lower in the water compared to on land. However, when compared in relation to %HRR and %VO_2R, land and water-based cycling elicited the same relative exercise intensity at a given RPE and should result in similar cardiorespiratory benefit.

Disclosures

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