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The Effects of Land vs. Aquatic HIIT Treadmill Running on Aerobic and Anaerobic Performance – A Pilot Study

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Abstract

The purpose of this study was to investigate how high intensity interval training (HIIT) performed on a land treadmill (LT) versus HIIT on an underwater aquatic treadmill (AT) would affect aerobic and anaerobic performance. The HIIT program consisted of running 8 intervals beginning with a 20 second workout and increasing exercise 5 seconds each interval until 55 seconds was reached. Ten seconds rest between each interval was protocol for a total interval running time of 5 minutes. The frequency of this training program was 3 times/week for 6 weeks. Nineteen college aged subjects were recruited, 13 subjects completed the program including pre and post-testing which consisted of maximal oxygen consumption tests (VO_{2max}) and Wingate anaerobic tests (mean power and peak power). The subjects were randomly placed into an aquatic treadmill group (ATG, n=6) or land treadmill group (LTG, n=7). The VO_{2max} tests were conducted on an AT for the ATG subjects and a LT for LTG subjects. The exercise intensity for the training program intervals was calculated off the greatest treadmill velocity and grade/jet resistance that the subject achieved during the VO_{2max} test. The test results showed that the LTG and ATG both increased their VO_{2max}, mean power, and peak power. The LTG showed a higher increase in VO_{2max}, where as the ATG showed greater increases in mean and peak power. In conclusion, an increasing interval HIIT program performed 3 times/wk for 6 weeks may produce similar improvements in aerobic (VO_{2max}) and anaerobic (mean power and peak power) performance on an aquatic treadmill as a land treadmill.

Key Words: land running, aquatic running, Wingate, VO_{2max}, HIIT, increasing interval, aerobic performance, anaerobic performance

The Effects of Land vs. Aquatic HIIT Treadmill Running on Aerobic and Anaerobic Performance – A Pilot Study

There are many different training methods used to achieve increases in aerobic and anaerobic performance. Currently, The American College of Sports Medicine (ACSM) recommendations, for a healthy population, include aerobic training 3 to 5 days per week, for 20 to 60 minutes at a moderate to high intensity for a total of 150 min/wk at moderate intensity or 75 min/wk at vigorous intensity, and performed continuously using large muscle groups in order to develop and improve aerobic fitness (Ehrman, 2010). However, less than half of adults meet these exercise recommendations (Garber et al., 2011). One of the most common barriers preventing individuals from engaging in physical activity is "lack of time," indicating that shorter duration, but effective exercise may increase adherence (Reichert, Barros, Domingues, & Hallal, 2007). Jakicic, Winf, Butler, and Robertson (1995) found that individuals performing multiple, short bouts of exercise achieved greater adherence and similar aerobic results in comparison to individuals performing continuous exercise (Jakicic et al., 1995; Shiraev & Barclay, 2012). Furthermore, ACSM states that short, ten minute bouts of exercise are beneficial when completed 2 to 3 times a day to develop and maintain fitness (Pollock et al., 1998). Evidence indicates that prescribing short bouts of exercise can increase adherence for individuals, while eliciting physiologic benefits equal to or greater than continuous exercise training (Nagle, Sanders, & Franklin, 2015).

In order to ascertain aerobic benefits from short bouts of exercise similar to longer continuous bouts, the intensity of the exercise must increase (Nagle et al., 2015; Burgomaster et al., 2008). One such form of short bout aerobic exercise is high-intensity interval training (HIIT). This can be defined as short intervals of high intensity exercise performed at 85% to 95% maximal heart rate or >90% maximal oxygen consumption (VO_{2max}) with periods of rest or low intensity active recovery (Kessler, Sisson, & Short, 2012). The physiological and aerobic benefits of HIIT has shown to be similar or greater than traditional continuous aerobic training programs in both normal and clinical populations (Kessler et al., 2012; Gillen & Gibala, 2014; Schjerve et al., 2008; Tjonna et al., 2008). The general population seems to be aware of HIIT fitness benefits as it was identified as the number two fitness trend for 2015 and the number one trend in 2014 by Thompson (2015). Reasons for the popularity of HIIT over moderate-intensity continuous exercise are the short workout durations, increased enjoyment, less boredom (varied protocols) and improved fitness levels (Bartlett et al., 2011). In addition, HIIT is appropriate when properly prescribed for a variety of populations (healthy, at-risk, and clinical populations), but could be contraindicated or too complex for some individuals warranting proper medical assessment and instruction from trained professionals (Shiraev & Barclay, 2012)

A popular form of HIIT developed in the late 1990's is termed "Tabata training" which involves performing 8 rounds of 20 seconds intense exercise followed by 10 seconds of rest (Tabata et al., 1996; Rebold, Kobak, & Otterstetter, 2013). Tabata et al. (1996) examined the physiological outcomes of aerobic vs. anaerobic training using a moderate intensity endurance training group (60 minutes, 5 $d \cdot wk^{-1}$, 70% VO_{2max}) and a high intensity group (eight 20 second intervals with 10 seconds rest, 5 $d \cdot wk^{-1}$, 170% of VO_{2max}) both performed on a cycle ergometer. Results indicated significant increases in aerobic and anaerobic performance following training for the high intensity group. Due to the favorable results of "Tabata training," it appears the Tabata style training could be adapted into the common exercise modality of running. However, the intensity of 170% VO_{2max} in the Tabata et al. (1996) study was an intensity beyond the maximal-intensity threshold; thus, increasing the risk of injury (Shiraev & Barclay, 2012).

Consequently, the exercise intensity of "Tabata training" was altered in the present study to increase safety.

In recent years, aquatic treadmill running (ATR) has become a popular modality for not only runners recuperating from injury, but also as a useful mode of cross training (Michaud, Brennan, Wilder & Sherman, 1995). It is attractive as it limits the amount of force and joint compression applied to the lower extremities due to the hydrodynamic properties of water (Batterham, Heywood, & Keating, 2011). Therefore, aquatic walking/running exercise might be a useful alternative to land based exercise for injured athletes, at-risk populations, and the general population seeking a different or new modality of aerobic exercise. A study by Loupias and Golding (2004) indicated that if ATR is performed at a high enough intensity, aerobic fitness levels can be maintained and even be improved. Similarly, a study conducted by Eyestone, Fellingham & George (1993) implemented a 6 week program using three different groups (water running, cycling, and treadmill running) who all performed the equivalence of frequency, duration, and intensity. Results indicated that all subjects either maintained or improved their VO_{2max}, demonstrating that ATR was capable of maintaining or even improving VO_{2max} (Eyestone et al., 1993). In reference to the positive results of aquatic aerobic exercise on VO_{2max}, a recent review by Nagle et al. (2015) determined that no studies have explored the cardio-metabolic responses of an HIIT aquatic-based program to a HIIT land-based program, warranting further investigation.

According to Rebold et al. (2013) an 8 week aquatic Tabata interval training program can elicit improvements in anaerobic performance in terms of mean power. However, Rebold et al. (2013) did not implement their exercise protocol on a land treadmill for comparison so it is unknown if the increase in anaerobic performance is a result of the water's hydrodynamic properties or the exercise protocol they implemented. Their study suggested that various aquatic HIIT protocols could be implemented, other than “Tabata style,” to improve fitness performance variables as long as the stimulus was strong enough (Rebold et al., 2013).

As a result of no current research study comparing a HIIT running protocol on land vs. aquatic for fitness performance variables, the purpose of this study was to investigate the effects that a 6 week HIIT program would have on an LTG versus an ATG for aerobic and anaerobic performance in recreationally active college-aged students. It was hypothesized that a 6 week ATG versus LTG HIIT program would lead to no significant difference within or between groups for aerobic or anaerobic performance.

Method

Subjects

Thirteen subjects (21.85 ± 2.70 (yrs); 177.02 ± 8.19 (cm); 75.00 ±16.88 (kg)) college aged students participated in the 10 week study. Prior to participation each subject completed an informed consent which was approved by the University of Akron’s Institutional Review Board. Subjects were eligible to participate if they had no contraindications to exercise, were injury free, and had participated in regular exercise including both cardiovascular and resistance training within the past 3 months at least 3 days per week. Exclusion criteria consisted of orthopedic injuries of the shoulder, hip, knee, foot, ankle, or neck or any sprains or strains in the 3 months preceding the study which may impact exercise performance. If subjects missed more than 3 exercise training sessions, they were excluded from the study. A total of nineteen subjects were recruited for the study, but only thirteen subjects completed the training along with the pre and post-training tests. Subjects participating in the study were randomly assigned to either a LTG or ATG.

Procedure

Weeks 1 and 8 consisted of pre and post-testing to assess aerobic and anaerobic performance via a VO_{2max} test and 30 second Wingate anaerobic test (WAT), respectively. Each test was conducted at least 24 hours apart for each subject to ensure a maximal effort could be given.

Wingate Anaerobic Test (WAT)

Anaerobic performance was measured using the WAT which is a 30-second maximal effort cycle ergometer test designed to assess anaerobic work capacity of an individual. A Excalibur® sport ergometer (Lode BV, Groingen, The Netherlands) was used to examine peak and mean power outputs (Watts). Seat height on the ergometer was fitted to each subject's comfort, recorded and used for pre and post-testing. For this test, subjects warmed up on the ergometer at a self-selected workload for 5 minutes. After the warm-up, each subject increased their cadence to their maximum revolutions per minute (RPM) at which point a resistance equivalent to 7.5% of the subjects body weight was applied to the flywheel of the cycle ergometer. Each subject then pedaled as fast as possible for 30 seconds. A cool down equivalent to the warm up followed the maximum effort.

Maximal Oxygen Consumption Test (VO_{2max})

Aerobic performance was measured using a VO_{2max} test which examines the maximum amount of oxygen that an individual can consume, transport and utilize to produce ATP or energy. Maximal oxygen consumption was measured using a Parvo Medics TrueOne 2400 metabolic measurement system (Parvo Medics Inc, Sandy, UT, USA) which was calibrated following manufacture guidelines prior to each test. For the LTG, the VO_{2max} was performed on a Quinton Q-Stress TM55 Treadmill (Quinton Caridoloav Inc, Bothell, WA). The ATG VO_{2max} was performed on a HydroWorx® 1200 aquatic treadmill (HydroWorx, Middletown, PA).

The testing protocol for both the LTG and ATG consisted of a 5 minute warm up at a self-selected velocity. To begin the test, the treadmill velocity started to 6.5 miles·h^{-1} then increased .5 miles·h^{-1} every minute for the first 5 minutes until 8.5 mile·h^{-1} was reached. Then the incline for the LTG or jet resistance for the ATG increased until each subject reached volitional exhaustion regardless of group randomization. **Table 1** outlines the VO_{2max} protocol for both the LTG and ATG.

Stage/Minute	**LTG**		**ATG**	
	Velocity (miles·h^{-1})	Incline (% grade)	Velocity (miles·h^{-1})	Jet Resistance (% max)
1	6.5	0	6.5	40
2	7	0	7	40
3	7.5	0	7.5	40
4	8	0	8	40
5	8.5	0	8.5	40
6	8.5	2	8.5	50
7	8.5	4	8.5	60
8	8.5	6	8.5	70
9	8.5	8	8.5	80
10	8.5	10	8.5	90
11	8.5	12	8.5	100
12	8.5	14	8.5	100
13	8.5	16	8.5	100

Table 1: VO_{2max} protocol used for LTG and ATG tests.

Training Intensity for LTG and ATG

After each subject completed a treadmill/protocol familiarization session, VO_{2max} test, and WAT during week 1, each subjected in the LTG and ATG performed three training sessions each week for weeks 2 through 7 of the study. All of the training sessions followed the protocol outlined in **Table 2**. The training intensity for each subject (LTG and ATG) was determined via the final velocity and incline/jet resistance achieved during the VO_{2max} test. For example, if an

LTG subject reached their VO_{2max} during the 6^{th} minute, their training program velocity and grade would be 8.5 miles·h^{-1} with a 2% grade.

Interval Number	Time on Treadmill (seconds)	Intensity
Warm-up	180-300	Chosen by subject
1	20	Intensity based off last stage achieved during VO_{2max} test. Intensity remained the same throughout the 8 rounds. Ten second rest between intervals.
2	25	
3	30	
4	35	
5	40	
6	45	
7	50	
8	55	
Cool-down	180-300	Chosen by Subject

Table 2: Layout of increasing interval HIIT program used by ATG and LTG for duration of study.

LTG and ATG: Training Program Specifics

The LTG used a Quinton Q-Stress TM55 Treadmill (Quinton Caridoloav Inc, Bothell, WA) during the training program. Male and female subjects were instructed to wear athletic clothing and running shoes. The temperature in the room was maintained between 68°F and 72°F. For the 10 second rest bouts, the subjects straddled the treadmill belt.

The ATG used a HydroWorx 1200 (HydroWorx, Middletown, PA) aquatic treadmill, which was equipped with a variable speed motor and pump driven water jets to provide frontal resistance, with the pool temperature maintained between 27-29 °C for the training program. Male subjects wore athletic/swim shorts. Females wore athletic/swim shorts and a sports bra/ t-shirt. The subjects performed the training sessions barefoot. All subjects wore a 9 lb (4.1 kg) weight vest (MiR Vest, Inc., San Jose, CA) to limit buoyancy during running. The AT water depth was maintained between the chest and shoulder regions depending on the subject's height. The AT water jet was directed at the umbilicus/chest region for each subject. During the 10 second rest bouts, the subjects stepped to the side of the treadmill to limit jet resistance.

Statistical Analyses

The HIIT program was the independent variable. Dependent variables were VO_{2max}, mean power, and peak power. Data was analyzed using a two sample statistical t-test with statistical significance being accepted at $p < 0.05$. Between and within group differences for pre and post VO_{2max}, mean power and peak power tests were examined along with the percent change. Statistical analyses were performed using SPSS (IBM version 21, SPSS Inc., Chicago, IL, USA).

Results

Performance Variable		Land Treadmill Group (LTG) (Mean ± Standard Deviation)	Aquatic Treadmill Group (ATG) (Mean ± Standard Deviation)
VO_{2Max} (ml· kg^{-1}·min^{-1})	Pre	48.23 ± 6.74	45.82 ± 8.25
	Post	51.70 ± 5.62	47.34 ± 5.57
	p-value	0.316	0.743
	% Difference	7.88	4.48
Mean Power (Watts)	Pre	624.71 ± 248.46	750.17 ± 278.50
	Post	628.71 ± 255.80	765.17 ± 293.41
	p-value	0.977	0.929
	% Difference	0.29	1.74
Peak Power (Watts)	Pre	952.86 ± 381.29	1005.33 ± 237.12
	Post	1067.14 ± 362.31	1157.33 ± 347.03
	p-value	0.576	0.399
	% Difference	16.17	13.77

Table 3: Pre and post-training values, p-value, % difference (pre–post) for aerobic and anaerobic performance within the LTG and ATG.

A two sample statistical t-test revealed no significant difference from pre to post VO_{2max} testing in the LTG (p=.316) or ATG (p=.743), but an average % increase of 7.88% (LTG) and 4.48% (ATG) did occur for VO_{2max} values. A t-test revealed no significant difference from pre to post WAT for mean/peak power for the LTG (p=.977/.576) or the ATG (p=.929/.399). The % increase for mean power for the LTG and ATG was < 2%, but the peak power increased 16.17% (LTG) and 13.77% (ATG). See **table 3** for complete results. No significant results occurred when using a two sample statistical t-test comparing the LTG to the ATG for VO_{2max} (p=.54), mean power (p=.65), or peak power (p=.58). However, average VO_{2max} was 1.95 $ml \cdot kg^{-1} \cdot min^{-1}$ greater for the LTG group; whereas, average mean and peak power were greater for the ATG by 11.00 watts and 37.71watts, respectively.

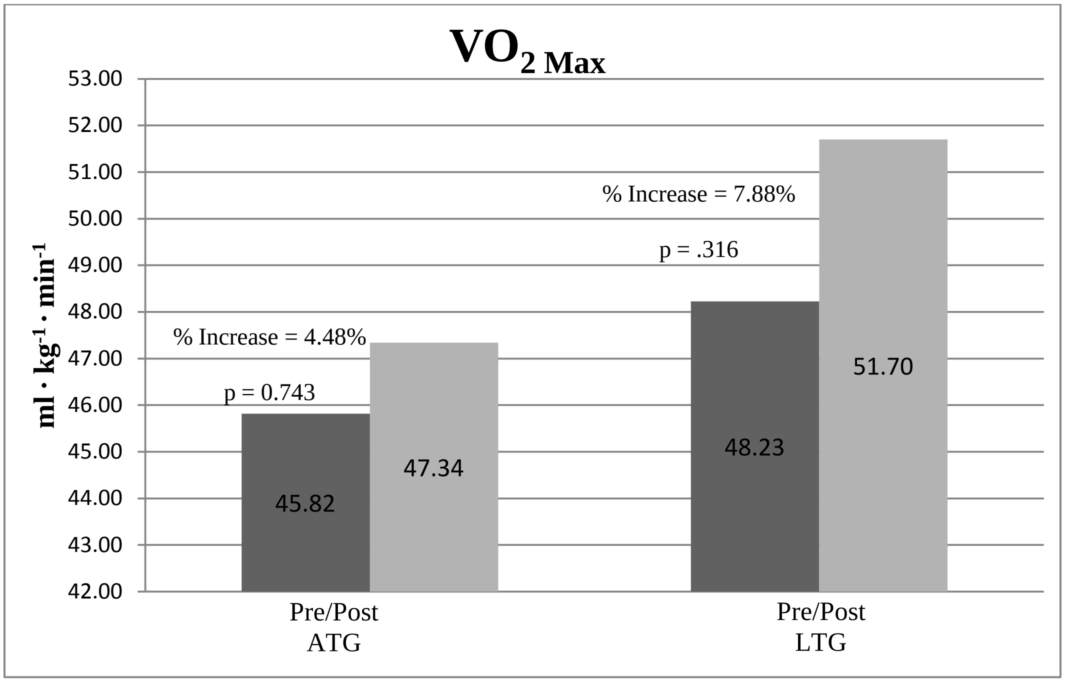

Figure 1: Average VO_{2max} values pre and post program training for ATG and LTG with % increase and p-value listed.

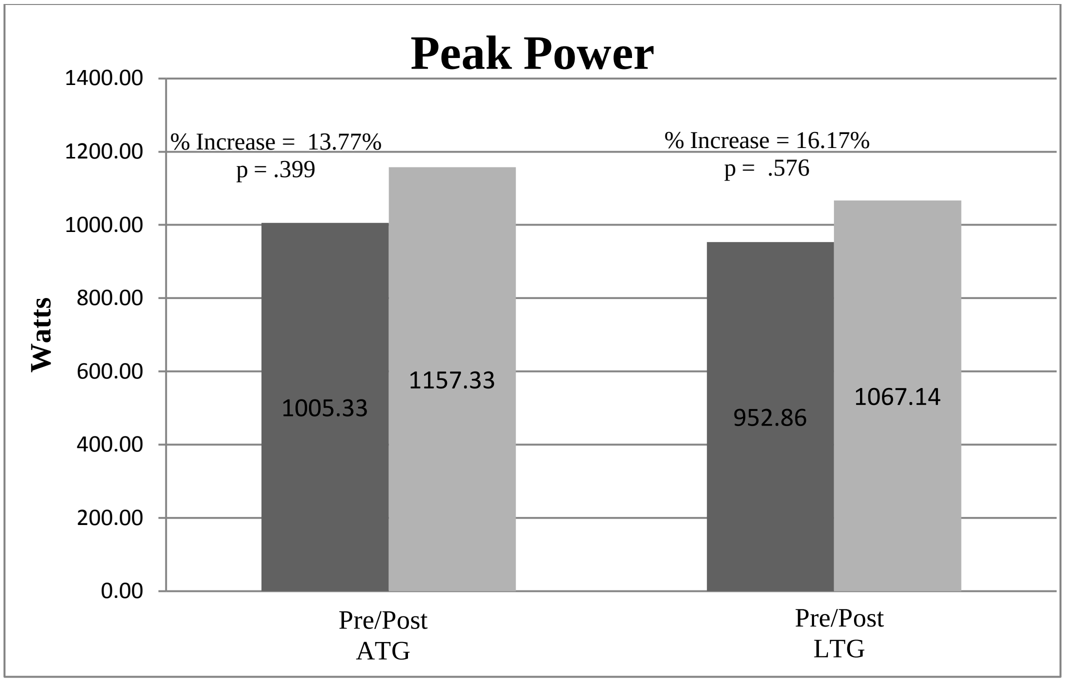

Figure 2: Average peak power values pre and post program training for ATG and LTG with % increase and p-value listed.

Comparison of LTG to ATG				
Mean Difference for:	**LTG**	**ATG**	Difference	P-value
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	3.47	1.52	1.95 higher for **LTG**	.54
Mean Power (Watts)	4.00	15.00	11.00 higher for **ATG**	.65
Peak Power (Watts)	114.29	152.00	37.71 higher for **ATG**	.58

Table 4: Comparison of VO_{2max}, mean power, and peak power results between LTG and ATG.

Discussion

The purpose of the present study was to investigate the effects that a 6 week HIIT program would have on a land treadmill group (LTG) versus an aquatic treadmill group (ATG) for aerobic and anaerobic performance in recreationally active college-aged students. It was hypothesized that no statistically significant increases on aerobic or anaerobic performance for the LTG or ATG would occur. While no significant increases occurred between or within the LTG or ATG for $VO_{2\ max}$, mean power, or peak power, both groups experienced an increase in all three performance measures. These results indicate that a 3 day/wk, 6 week HIIT program with minimal rest can improve aerobic and anaerobic performance on an LT and AT in a college aged population. Additionally, the increases attained are similar between the LTG and ATG indicating further promise that an AT HITT program may be equal to an LT HIIT program while also reducing ground impact forces when compared to a LT HITT protocol.

For VO_{2max}, the ATG and LTG achieved an increase of 1.52 ml· kg^{-1}·min^{-1} and 3.42 ml· kg^{-1}·min^{-1}, respectively. Silvers, Rutledge, and Dolny (2007) concluded that an AT with water jets will elicit peak cardiorespiratory responses that are similar to an inclined land treadmill. Therefore, the VO_{2max} differences (pre and post-testing) should be similar between the ATG and LTG; however, in the present study, the LTG group achieved a VO_{2max} of 1.95 ml· kg^{-1}·min^{-1} higher than the ATG group. The smaller increase in post-training VO_{2max} values for the ATG could be attributed to the limitation of the AT not providing a high enough stimulus for some of our subjects. Several ATG subjects maxed out the AT's velocity and jet settings during their pre and post-training VO_{2max} test. The possible ramifications for these ATG subjects were twofold: 1) the program training intensity and 2) the pre and post-training VO_{2max}, were both potentially reduced. The intensity for the training program was established via the final stage velocity and jet resistance achieved during the pre-training VO_{2max} test. In a review by Nagle et al. (2015), the short, near maximal intensity of HIIT programs are believed to be responsible for greater improvements in VO_{2max} compared with aerobic continuous training. In relation to the present study, the subjects that maxed the AT settings may have been able to attain a greater intensity (velocity and/or jet strength) before during their VO_{2max} test if the AT afforded them this opportunity. Consequently, a greater training intensity could have resulted in greater aerobic improvements, thus; greater post-training VO_{2max} values.

The increasing interval HIIT program used in the present study resulted in small anaerobic increases in terms of mean and peak power. Interestingly, the post-training mean and peak power results achieved by the ATG exceeded those of the LTG group by 11 watts and 37.71 watts, respectively. While these differences were not statistically significant between the two groups, the higher values achieved by the ATG suggest that AT HIIT running could be equal to if not better than LT HIIT running for increasing anaerobic performance. It is believed the density of the water provides a resistant force that is equal to the force exerted by the exercising individual, which can vary depending on the velocity and movement of the subject (Miller et al., 2007; Rebold et al., 2013). For the ATG, the greater improvements in anaerobic performance could be a result of the water density causing resistance to movement; therefore, causing a greater stimulus on the muscles and increased involvement of the anaerobic system (Rebold et al., 2013; Glass, Wilson, Blessing, & Miller, 1995). In another study, Greene et al. (2009) found that underwater treadmill training may increase lean body mass of the lower extremities in obese adults. This may have occurred in the ATG causing an increase in mean and peak power, but this cannot be verified as lower extremity lean body mass was not measured in the present study. On the other hand, the greater anaerobic gains may not be due to gains in lean body mass, but rather neuromuscular adaptations as the body adjusted to the resistance; therefore, resulting in strength gains without an increase in muscular hypertrophy (Tillin & Folland, 2014).

Kobak, Rebold, DeSalvo, and Otterstetter (2015) found that plyometric training in water yields increases for leg strength, vertical jump height and balance similar to land plyometric training. The training stimulus of our study was aerobic HIIT running performed on land and in water, not plyometric training, but our results are similar in that aquatic running, when a HIIT format is implemented, may improve the anaerobic systems equal to, if not more than land training. Again, the added benefit of aquatic training is the reduced weight bearing environment of water.

Several limitations are apparent in this study which may have interfered with the lack of significant results. Specifically to the ATG, the greatest issue arose with the limitations on velocity and jet resistance of the AT as previously discussed. However, another issue with the AT was placement of the jets on the subjects. The jets were intended to be directed at the subject's chest; however, this was difficult to achieve as our subjects varied in heights, though we did adjust for each subject individually. As a result, inconsistency in jet placement on any ATG subject during any given training session could have caused the training bout to be easier and less intense.

The test group (both LTG and ATG) consisted of recreationally active college aged students. This is a narrowly focused and one of the healthiest populations to study. Including a greater variety of individuals ranging from unfit to fit would have produced results more representative of the general college aged population. Even though the results for VO_{2max}, mean power, and peak power were not statistically significant from pre to post-testing, very few subjects experienced a decrease in post-testing measures. This indicates that HIIT with increasing intervals can produce positive results for $VO_{2max,}$ peak power, and mean power for an active college aged population on land and in water while keeping training volume and reducing the risk of injury. Since the results were positive for this population, the same results, if not even greater, could be experienced by an unfit or older population. Therefore, implementation of this exercise protocol on different populations warrants further investigation.

Practical Applications

One of the desires of exercising in today's culture is efficiency and effectiveness to counter the "lack of time" barrier (Reichert, Barros, Domingues, & Hallal, 2007). This is a reason HIIT is so popular, because it provides effective results in less time (Hughes, 2015). The protocol utilized in the present study reduced the extremely high intense nature of Tabata training to a safe level that is personalized to an individual's current fitness level. The intensity of the training was relative to each person's fitness via the pre-testing VO_{2max} and provided an appropriate stimulus that our subjects could maintain with effort throughout each interval. At first glance the exercise protocol used in this study is not practical for the general population due to the fact that the intensity was determined via the VO_{2max} test, which most people do not have access to. However, a person does not need to perform a VO_{2max} test, but simply conduct the VO_{2max} test protocol outlined in **table 1**. The velocity and grade/jet resistance an individual reaches exhaustion at is the intensity to implement into the exercise protocol of this study.

Another benefit of the exercise protocol is the progression from short intervals to long intervals allowing the cardiovascular system to adapt to the exercise intensity. It would be interesting to test the same training protocol but switch the interval lengths starting with the longest interval and working down to the shortest interval. The overall volume of exercise would be the same but the performance of the volume would be different. Further research is needed to investigate whether reversing the exercise protocol would elicit different results.

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