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Research article

Five Weeks of Aquatic-Calisthenic High Intensity Interval Training Improves Cardiorespiratory Fitness and Body Composition in Sedentary Young Adults

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Abstract

Aquatic exercise may be better tolerated by sedentary, overweight individuals than land-based exercise. The purpose of the present study was to determine the effects of five weeks of aquatic high-intensity interval training (AHIIT) using standard calisthenic pool exercises, on cardiorespiratory fitness and body composition in sedentary young adults. Eleven college-age participants (9 women, 2 men) completed 15 exercise sessions that included three sessions per week for five weeks. Each session consisted of a five-minute warm-up period, 25 minutes of exercise, and a five-minute cool down. A training progression based upon standard progression principals from a pilot study was implemented. The exercises consisted of 25 exercise intervals lasting 10-30 seconds in duration, utilizing combinations of 8-12 different exercises. Twenty-two standard aquatic upper body, lower body, and full body aerobic exercises, most of which utilized aquatic dumbbells or hand paddles, were performed in an AHIIT protocol during each exercise session. Reductions in body composition (32.6 to 30.6% fat), submaximal (169 to 165 b·min^{-1}) and peak heart rate (199 to 192 b·min^{-1}), submaximal VO_2 (21.7 to 19.3 ml·kg^{-1}·min^{-1} and peak VO_2 (30.5 to 31.95 ml·kg^{-1}·min^{-1}) occurred from pre- to post-program. This is the first study to determine the effectiveness of standard aquatic calisthenic exercises used in an AHIIT protocol. Improvements in cardiorespiratory fitness and exercise economy as well as body composition were observed in these sedentary individuals.

Key words Oxygen Consumption, Heart Rate, Body Fat, Water Exercise.

Introduction

A weekly minimum of 150 minutes of moderate intensity exercise (3.0-5.9 METs) or 75 minutes of vigorous intensity exercise ($\geq$ 6.0 METs), and two resistance training sessions are recommended for individuals to maintain or improve health status (ACSM, 2018). However, a recent report from the Centers for Disease Control (CDC) revealed that only about 23% of adults in the United States currently meet the minimum requirements for weekly exercise (Blackwell and Clark, 2018). In addition, the combination of inadequate physical activity and increased sedentary behaviors can lead to negative health effects for all ages, including increased risk for cardiovascular disease, stroke, metabolic disease, cancer, hypercholesterolemia, hypertension and obesity (ACSM, 2018; Bailey et al., 2017; Bakrania et al., 2016; Jenkins et al., 2017; Silfee et al., 2017; Vieira et al., 2016). Each of these diseases can impact or increase other health problems. Therefore, it is important to investigate the effectiveness of different forms of exercise in an effort to increase physical activity and decrease sedentary behaviors.

A major benefit of water exercise is the reduction of weight bearing stress on the body, which may even improve the ability to perform some joint actions (Ruoti et al., 1994), allowing diverse patient populations to have the ability to exercise. As little as five weeks of aquatic aerobic exercise has been shown to improve heart rate responses to exercise in older women (Costa et al., 2017). Water exercise can also be helpful to overweight/obese populations resulting in improvements in dyslipidemia, body composition and cardiovascular fitness (Costa et al., 2018a; 2018b; Lopera et al., 2016; Taunton et al., 1996; Vasic et al., 2019).

Interval training is another popular form of exercise which typically involves exercise performed at a higher intensity for a shorter duration of time, including rest or active recovery periods at lower intensities between the intervals. Some studies have shown that high intensity interval training (HIIT) improves cardiometabolic health to a similar degree as steady state or moderate continuous types of exercise (Fisher et al., 2015; Foster et al., 2015). Other HIIT studies have shown greater improvements in blood pressure response, blood lactate levels, heart rate, and RPE than forms of continuous training (Sosner et al., 2016; Thum et al., 2017). HIIT is also beneficial because it can be adapted for the needs of individual participants. Interval and rest durations can be adjusted to alter the intensity of the exercise. Astorino et al. (2016) examined different types of HIIT that used short sprint intervals, longer intervals, or combinations of those two interval types. They found that the combination of the two interval types led to the greatest increases in maximal oxygen consumption, stroke volume and cardiac output. Therefore, it may be beneficial to alter the interval lengths over the course of the program to increase program adherence.

Maintaining an exercise regimen is an important factor for improving physical activity and therefore, it is crucial to consider factors which affect adherence to an exercise regimen. Exercise variety, perception of health benefits, competence of facility staff, self-efficacy, and enjoyment of exercise all have a positive influence on maintaining a regular exercise program (Sylvester et al., 2016; Trost et al., 2003; Whaley and Schrider, 2005). High intensity interval training has been shown to have positive effects on exercise adherence, including improved arousal and affect, leading to greater enjoyment over the course of the exercise program (Astorino et al., 2016; Fisher et al., 2015; Heisz et al., 2016; Kong et al., 2016; Martinez et al., 2015; Thum et al., 2017). Such factors may affect the person's perception

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of the exercise and therefore increase exercise adherence. Water-based exercise may also improve exercise adherence from its effect on quality of life, depression, anxiety, and mood scores (Schuch et al., 2014; Wei et al., 2006). Because of the positive effects that both aquatic and HIIT exercises have on health, fitness, and exercise adherence, it is important to consider how the combination of those types of exercise could affect participants.

Aquatic HIIT (AHIIT) studies, to date, have utilized modes of exercise such as machine-based aquatic running or cycling. Aquatic running programs have led to improvements in submaximal and maximal aerobic power, maximal ventilatory capacity, resting heart rate and blood pressure, joint pain, balance, function, and mobility (Bressel et al., 2014; Broman et al., 2006; Reichert et al., 2016). Aquatic cycling programs have resulted in reductions in blood pressure and when combined with a Mediterranean diet, led to improvements in body composition, fasting glucose, triglyceride levels, blood pressure, and fitness (Boidin et al., 2015; Sosner et al., 2016). However, the aquatic treadmills and aquatic cycles used in these studies are not always readily available for public use. Therefore, it is necessary to investigate the effectiveness of simple forms of aquatic exercise such as aquatic calisthenics which are easy for individuals to perform using readily available equipment such as swim paddles and aquatic dumbbells.

The main purpose of the present study was to determine whether a short AHIIT program using aquatic-calisthenic exercises could improve cardiorespiratory fitness and body composition in sedentary, overweight young adults. The program included a variety of aquatic-calisthenic exercises that have been utilized in water aerobics classes, but for the purpose of this study, were adapted to an interval training protocol. It was hypothesized that the five-week AHIIT program using calisthenic exercises would improve cardiorespiratory fitness and body composition.

Table 1. Baseline measurements for female and male participants (mean ± SD).

	Female (n=9)	Male (n=2)
Age (yrs)	20.0 (± 0.71)	23.5 (± 2.12)
Height (m)	1.57 (± 0.07)	1.74 (± 1.08)
Weight (kg)	67.25 (± 15.92)	98.64 (± 16.07)
% Body Fat	32.54 (± 6.06)	32.58 (± 4.04)

Methods

Participants

The study was approved by the institutional review board of a regional university. Eleven sedentary adults (9 females, 2 males) were recruited from university classes and completed the study (Table 1). Participants filled out a medical history questionnaire with questions regarding the number of hours they spent doing different activities including sleeping, working, eating, exercising, and driving. Each participant reported being seated or supine for 20 or more hours per day. The participants were determined to have met the following criteria: (1) no injuries over the previous six months that would prevent them from participating, (2) a majority of time spent sedentary each day, (3) a sedentary type of job (if currently employed), and (4) no regular physical activity for three months prior to the exercise program. Before beginning the program, the participants were informed that they must complete a preliminary testing session, a familiarization session, attend three exercise training sessions per week during each week for five weeks of the study and complete a post-testing session. All procedures performed in the current study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the University Institutional Review Board.

In the preliminary session, participants signed an informed consent form that outlined expectations for each session and eligibility requirements for participation, and then completed a medical history questionnaire. Once eligibility was determined, the following data were collected for each participant after 5-min rest in a seated position: heart rate via a heart rate monitor (Polar H10, Polar Electro, Kempele, Finland), blood pressure via auscultation using a hand-held sphygmomanometer and stethoscope, 3-site skinfold assessment of body composition with skinfold calipers (Lange Instruments, Santa Cruz, CA), and peak oxygen consumption (VO_2peak) during a graded exercise treadmill test (GXT). The 3 sites anatomic points for skinfold assessment for female participants were the triceps, suprailiac, and thigh, whereas the chest, abdominal, and thigh measurements were used for male participants (ACSM, 2018). The participants were familiarized with the treadmill and breathing mask of the metabolic system before completing the graded exercise test. A modified Kraemer protocol (Kraemer et al., 2011) was used for the graded exercise test, which began with a 3-minute warm up at 1.2 mph followed by the first stage at 2.5 mph and a 4% grade elevation. Each stage lasted for 3 minutes with a 4% grade of elevation and the speed was increased by 1 mph until the participant indicated that they could not continue. Expired gases were collected and analyzed using a metabolic cart (Parvomedics, Sandy, UT). VO_2 and HR were determined using the metabolic system and HR monitor during the last 30s of stage 1 and stage 2 of the test. The last 30s of stage 1 and 2 was used to allow subjects to reach steady state. The sampling rate for expired gases was every 15 seconds. VO_2peak and HRmax were determined in the last 30s of the last stage of the test and were the highest values recorded during the graded exercise test. The participants continued with a cool down period at approximately one mph for three minutes. The participants were informed of dates and times for the familiarization sessions and exercise sessions.

The familiarization sessions occurred in an indoor pool on the same university campus. Each participant was requested to attend one of these sessions; a few sessions were offered at different times to accommodate the participants' schedules. A 15-point (6-20) Rating of Perceived Exertion (RPE) scale (Borg, 1970) was explained to the participants, and they were encouraged to exercise at an RPE of 17-18 for the aquatic high intensity intervals and at a rating of 11-12 for the active recovery intervals. The familiarization session consisted of practicing the aquatic-calisthenics exercises to be used during the exercise sessions (Table 2). This session began with a warm-up period, followed by practice of each aquatic exercise, and ended with a cool-down period.

Each of the 15 exercise training sessions occurred in an indoor pool on a university campus. The criteria adopted to validate the progressive training for aquatic-calisthenic HIIT was developed from a pilot study with monitoring participant RPE and HR during exercise. HR was monitored periodically in the water using the same HR monitor used during the graded exercise tests. The training sessions began with a 5-minute warm-up period that included pool walking, jogging, and pool wall stretches. A variety of the different upper body (UB), lower body (LB), and full body (UB/LB) calisthenic exercises were performed in each training session during the five weeks (Table 2). Each week there were regimented increases in exercise duration and reductions in recovery time. The training interval and recovery durations for each week were as follows: (Week 1) 10-second exercise intervals and 50-second active recovery intervals using eight exercises; (Week 2) 15-second exercise intervals and 45-second active recovery intervals using eight exercises; (Week 3) 20-second exercise intervals and 40-second active recovery intervals using 12 exercises; (Week 4) 25-second exercise intervals and 35-second active recovery intervals using 12 exercises; (Week 5) 30-second exercise intervals and 30-second active recovery intervals using 12 exercises. All participants were required to complete the training program in the allotted 5 weeks. Failure to complete 3 sessions per week resulted in dismissal from the study.

During these training sessions, participants reported their RPE following the 6th, 12th, 18th, and 25th intervals. Participants were also monitored for heart rate using a Polar H10 monitor during one session per week to check for appropriate changes in heart rate. Heart rates from these sessions were obtained from the same intervals as the RPE data, as well as the peak heart rate for the session. Each session ended with a 5-minute cool down consisting of stretching and locomotor activities. Upper body and full body exercises (Table 2) were completed with or without pool exercise equipment such as water dumbbells or swim paddles.

Data analyses

Data from participants who completed all required sessions, including the pre-program session, familiarization session, 15 exercise sessions (three per week), and post-program session, were analyzed using the SPSS 20.0 system (IBM Corporation, Armonk, New York). Descriptive statistics were used to determine the averages for the participants' pre- and post-program data. Paired sample *t*-tests were computed for the pre- and post-program data for blood pressure, resting heart rate, body weight, body composition, submaximal VO_2, VO_2peak, submaximal heart rate, and maximum heart rate. A repeated measures ANOVA was completed to assess possible changes in the maximum heart rate values for each weekly checkpoint during the exercise sessions. The alpha level was set at $p \leq 0.05$ for significance. We tested the normality of all of data using a Shapiro-Wilk test. Results were not significant ($p > 0.05$) indicating normal data distribution for all of the data except the Stage 2 post VO_2 values. Thus, we ran a Wilcoxon Rank Sum Test for those data to account for the abnormal distribution.

Table 2. Lists of exercises used during the exercise sessions.

Upper Body Exercises	Lower Body Exercises	Full Body Exercises
Sweeping Arms	High Knee Jog	Cross Country Ski
Arm Curls	Back Kicks	Cross Country Ski with Knee Tucks
Rolling Arms	Straight Back Extensions	Jumping Jacks
Tricep Push Backs	Flutter Kicks	Jumping Jacks with Knee Tucks
Punches	Bicycles	Squat Jumps
Tricep Dips	Scissors	Hackey Sack
Push Ups	Hopscotch	Russian Twist
Breast Stroke Arms		

Results

There were pre- to post-training changes in body composition, maximum heart rate, submaximal VO_2, and VO_2peak ($p < 0.05$; Table 3). The values for systolic blood pressure, diastolic blood pressure, resting heart rate, and body weight were not significantly different (Table 3). Significant *p* values (≤ 0.05) are marked with an asterisk in Table 3. The values for resting systolic blood pressure approached significance. The data for body weight and resting diastolic blood pressure revealed essentially no change. There was a decrease in percent body fat ($t(10) = 3.709$, $p = 0.004$) from the pre- to post-program sessions (Table 3). The decrease in percentage of body fat was approximately 2% from pre- to post-program. Thus, it should be noted that while the body fat significantly declined, body weight did not change significantly (Table 3).

There was a significant reduction in submaximal VO_2 at two points during the graded exercise test, stage 1 ($t(10) = 3.006$, $p = 0.013$) and stage 2 ($t(10) = 2.516$, $p = 0.031$), from the pre-program session to the post-program session (Table 4). Stage 1 submaximal VO_2 declined 10.24% from pre- to post-program. Similarly, stage 2 submaximal VO_2 declined 11.45% from pre- to post-program (Table 4). Since stage 2 VO_2 post-program data were found not to be normally distributed by the Shapiro-Wilk test, we conducted a Wilcoxon Signed Rank Test to account for normality of distribution and confirmed that results were significantly different. Additionally, there was an increase in VO_2peak ($t(10) = 2.430$, $p = 0.035$) between the pre- and post-program sessions (Table 4). Overall, the VO_2peak increased 4.65% from pre- to post-program.

A reduction in peak heart rate occurred during weekly checkpoints across the five-week study ($F_{[1,20]} = 70.352$, $p < 0.001$). Peak heart rates were determined by analyzing heart rate over the course of the weekly heart rate checkpoint sessions. Weekly checkpoint sessions occurred at the same session each week (session 1, 2, or 3) for each participant. The peak heart rates of the weekly checkpoint session tended to gradually increase over the first few weeks, but ultimately began to decline in the fourth week (Figure 1). The peak heart rate values from the pre- and post-program graded exercise tests revealed a significant 3.4% reduction. Submaximal heart rates declined at stage 1 (1.63%) and 2 (2.8%) of the GXT from pre- to post-program (Table 4).

Table 3. Pre- and post-program resting values (mean ± SD).

Variable	Pre	Post	*p*-value
Systolic Blood Pressure (mmHg)	116.73 (± 11.53)	111.45 (± 5.59)	0.053
Diastolic BP (mmHg)	73.09 (± 8.92)	73.45 (± 9.84)	0.920
Rest HR (bpm)	83.09 (± 10.21)	79.27 (± 8.22)	0.273
Weight (kg)	72.95 (± 19.74)	73.00 (± 20.37)	0.956
% body fat	32.55 (± 5.57)	30.55 (± 6.31)	0.004*

* Denotes a significance of p<0.05.

Table 4. Pre- and post-program graded exercise test (GXT) values (mean ± SE) for submaximal and peak heart rate (HR) and oxygen consumption (VO_2) .

Variable	Pre	Post	*p*-value
GXT Stage 1 HR (bpm)	139 (± 2)	137 (± 2)	<0.001*
GXT Stage 2 HR (bpm)	169 (± 2)	164 (± 2)	<0.001*
HR Peak (bpm)	199 (± 1)	192 (± 2)	<0.001*
GXT Stage 1 VO_2 (mL·kg^{-1}·min^{-1})	15.72 (± 0.66)	14.11 (± .69)	0.013*
GXT Stage 2 VO_2 (mL·kg^{-1}·min^{-1})	21.74 (± 0.93)	19.25 (± 1.06)	0.031*
GXT VO_2 Peak (mL·kg^{-1}·min^{-1})	30.53 (± 1.32)	31.95 (± 1.53)	0.035*

* Denotes a significance of p<0.05.

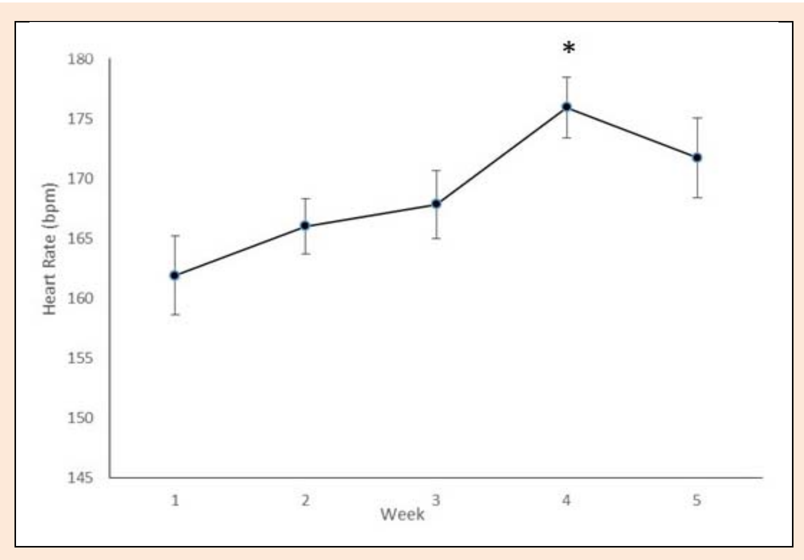

Figure 1. Average peak heart rate values during weekly checkpoint sessions. Values represent mean ± SE. * significant (p < 0.05) different from values in week 1-3 and week 4.

Discussion

The hypothesis of the study was shown to be tenable. A five-week aquatic-calisthenic HIIT training regimen induced physiological adaptations that significantly improved body composition, submaximal VO_2, VO_2peak, peak heart rate, and peak training heart rate for program participants. The present study is the first study to determine the effectiveness of an aquatic HIIT program using aquatic-calisthenic exercises without using aquatic treadmills or aquatic cycles.

Blood pressure and peak heart rate

There was no change is resting systolic and diastolic blood pressure from pre- to post-training. However, there was a trend (p = 0.053) for reduction in systolic blood pressure with pre-training values of 116.43 mmHg and post-training values of 111.45 mmHg. The peak aquatic exercise heart rate increased over the first few weeks and declined by the fourth week of the study. Since the exercise interval duration increased and rest interval duration decreased each week, the initial increases in peak heart rate were likely due to the increasing aquatic exercise stress during the exercise sessions. The exercise program lasted only five weeks, and there was only one week with a demonstrated reduction in peak training heart rate. However, this likely indicates an adaptation to peak heart rate as shown in the pre-program and post-program data changes. Short-term (11 sessions) of land-based HIIT at 90-95% HR maximum has been shown to reduce maximal heart rate in well trained males and females (Menz et al., 2015) which is likely offset by larger increases in maximal stroke volume (Vella and Robergs, 2005). Previous aquatic HIIT training studies did not determine changes in peak heart rate over weeks of training with increasing intensity each week (Boidin et al., 2015; Bressel et al., 2014; Broman et al., 2006; Sosner et al., 2016). A previous study by Costa et al. (2017) revealed that five weeks of aquatic aerobic training led to improved heart rate responses in older women. The present study demonstrates the effectiveness of AHIIT to improve cardiorespiratory fitness over a five-week training period in a younger, inactive, overweight population.

Oxygen consumption

The VO_2 values following stage 1 and 2 of the GXT revealed a reduction from pre- to post-program sessions, indicating an improvement in exercise economy causing the exercise to be easier to maintain at the same intensity from pre- to post-program (Hunter et al., 2005). Heart rate also decreased at a submaximal work rate following training as there was a reduction in energy cost for the same activity (Wilmore et al., 1996). Efficiency adaptations to water exercise HIIT may occur more readily than land exercise due to a variety of conditions. For instance, improvements in balance and strength from aquatic exercise can be factors in improving efficiency because they help improve postural control which can affect mobility (Padua et al., 2018). Water-based exercise has been shown to improve balance and strength so this also could have played a role in the improvement of efficiency (Bento and Rodacki, 2014; Bergamin et al., 2013; Padua et al., 2018; Schuch et al., 2014; Walia, 2012; Wang et al., 2006). Improvements in efficiency are beneficial for individuals seeking to improve fitness, because when work becomes easier, individuals may be less likely to avoid physical activity and may increase their participation in regular exercise. This is also crucial for older adults who would benefit from improvements in balance.

VO_2peak also improved from pre- to post-program session. All the values from the pre-program session met at least two of the criteria to be considered maximal VO_2 values (ACSM, 2018). However, four participants had post-program values that only met one criterion, but these values were close to meeting the criterion of a 1.10 RER value (ACSM, 2018). While these values may not have reached the true VO_2max, the RER values did exceed 1.00. An increase in VO_2peak values indicates significant improvements in exercise economy and cardiorespiratory fitness. There is an inverse relationship between aerobic capacity and exercise economy, i.e. higher VO_2peak values would indicate a decrease in economy of effort during exercise (Borges et al., 2018). Changes in VO_2 are typically due to cardiac output and/or arteriovenous oxygen difference (a-vO_2diff), with a-vO_2diff being the main factor for older adults (Murias et al., 2010). A meta-analysis of 13 previous investigations revealed that untrained to moderately healthy young adults completing 5 – 13 weeks of endurance training were found to increase maximal oxygen consumption because of increases in maximal cardiac output but not a-vO_2diff (Montero et al., 2015). However, the effects of AHIIT on a-vO_2diff have not been investigated, thus it is possible that there may have also been changes in a-vO_2diff in participants in the present study that were caused by angiogenesis and/or aerobic metabolic adaptations of skeletal muscle (Haykowsky et al., 2012). Cardiac output is thought to be the main factor for this change for most adults and is due to greater increases in stroke volume that overcompensates for reductions in heart rate (Vincent, 2008). With training, the left ventricle of the heart can stretch to allow for more forceful contractions. This increases stroke volume resulting in improvements in cardiac output as shown by previous research (Plotnick et al., 1986; Vincent, 2008). Training also decreases heart rate because the improvements in cardiac output are met with improvements in stroke volume instead of heart rate, which is related to increases in efficiency (Plotnick et al., 1986). Other water-based training studies have also shown increases in VO_2peak and VO_2max (Schuch et al., 2014; Taunton et al., 1996). The improvements in VO_2peak after five weeks of aquatic-calisthenic HIIT in the present study underscore the effectiveness of this form of training. Therefore, the current study provides strong support for recommending the use of HIIT using aquatic-calisthenic exercises for improving cardiorespiratory fitness.

Body composition

Body composition improved from pre- to post-program. Previous research has shown improvements in body composition (from reduced body fat and improved muscle mass) with water-based exercise (Bergamin et al., 2013; Gappmaier, et al., 2006; Waller et al., 2017). Aerobic training in water can improve body composition similar to that of land-based exercise as long as the same exercise intensity, duration, and frequency are used (Gappmaier et al., 2006). Changes in body composition in water-based exercise may be due to differences in caloric cost of exercise in water. VO_2 values during training in water are higher than VO_2 values during training on land at the same intensity (Darby and Yaekle, 2000; Dolbow et al., 2008; Farahani et al., 2010; Hall et al., 2004; Kruel et al., 2013; Schaal et al., 2012), leading to greater caloric cost. Therefore, if water exercise elicits higher VO_2 values, there should be a higher caloric cost resulting in loss of body fat over time. Additionally, when exercise programs are used during a period of weight loss the activity helps to maintain or increase energy expenditure including free living energy expenditure and resting energy expenditure by maintaining or improving muscle mass or fat-free mass (Hunter et al., 2015). This allows the individual to continue to use more calories at rest and during daily activities which would promote more body weight and fat mass loss over time. While body fat percentages did decrease during the present study, body weight did not decrease. However, increases in fat-free mass (lean body mass) that is denser than fat mass can counteract the weight changes from reductions in fat mass which can cause the body weight to remain the same (Hull et al. 2007).

Aquatic high intensity interval training

To our knowledge, this is the first study to reveal that a regimen of aquatic-calisthenic, resistance-based high intensity interval exercises improves cardiorespiratory fitness and body composition. More research using these types of water exercises should be performed in order to build a larger body of knowledge about this form of training. Although there is recent evidence that participation in HIIT is associated with greater risk for injury (Rynecki et al., 2019), performing HIIT in an aquatic environment reduces stress on joints and risk of falls, making AHIIT a safer form of exercise for overweight individuals than HIIT on land. Previous studies have examined AHIIT using machine-based running and cycling (Boidin et al., 2015; Bressel et al., 2014; Broman et al., 2006; Sosner et al., 2016). The aforementioned research showed that AHIIT using underwater treadmills and cycles improves balance, function, mobility, submaximal and maximal aerobic power, maximal ventilatory capacity, blood pressure, body composition, fasting glucose, triglyceride levels, and fitness levels. The current study revealed improvements in body composition, VO_{2peak}, and maximal heart rate, similar to the results from these previous AHIIT studies. However, AHIIT in the current study utilized different forms of aquatic calisthenic exercise with minimum equipment and yet provided improvements in cardiorespiratory fitness and health.

Limitations

No control group was used in the present study. However, the baseline values of participants in the present study were carefully and systematically assessed. Moreover, during the study, the participants were monitored, and they verified no participation in any other physical activity that could have affected the results of the study.

Conclusion

The present study revealed that an AHIIT program using standard aquatic, aerobic/resistance type calisthenic exercises was effective in improving cardiorespiratory fitness and body composition in an overweight, sedentary population. The findings of the study suggest that this form of exercise could be helpful to improve the health of overweight participants with access to a pool, but without using specialized aquatic treadmills or cycles. Moreover, the water environment allows for participation in an HIIT regimen that is safe for overweight individuals.

Acknowledgements

The experiments comply with the current laws of the country in which they were performed. The authors have no conflicts of interests.

References

American College of Sports Medicine [ACSM] (2018) *ACSM's guidelines for exercise testing and prescription* (10th ed.). Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health.

Astorino, T. A., Schubert, M. M., Palumbo, E., Stirling, D., McMillan, D. W., Gallant, R. and Dewoskin, R. (2016) Perceptual changes in response to two regimens of interval training in sedentary women. *Journal of Strength and Conditioning Research* **30(4),** 1067-1076.

Bailey, D. P., Charman, S. J., Ploetz, T., Savory, L. A. and Kerr, C. J. (2017) Associations between prolonged sedentary time and breaks in sedentary time with cardiometabolic risk in 10-14-year-old children: The happy study. *Journal of Sports Sciences* **35,** 2164-2171.

Bakrania K., Edwardson C.L., Bodicoat D.H., Esliger D.W., Gill J.M., Kazi A., Velayudhan L., Sinclair A.J., Sattar N., Biddle S.J., Khunti K., Davies M. and Yates T. (2016) Associations of mutually exclusive categories of physical activity and sedentary time with markers of cardiometabolic health in English adults: A cross-sectional analysis of the Health Survey for England. *BMC Public Health* **16(25),** 1-10.

Bento, P.C.B. and Rodacki, A.L.F. (2014) Muscle function in aged women in response to a water based exercise program and progressive resistance program. *Geriatrics and Gerontology International* **15(11),** 1193-1200.

Bergamin. M., Ermolao, A., Tolomio, S., Berton, L., Sergi, G. and Zaccaria, M. (2013) Water- versus land-based exercise in elderly subjects: Effects on physical performance and body composition. *Clinical Interventions in Aging* **8,** 1109-1117.

Blackwell, DL. and Clarke, Tainya C. (2018) State Variation in Meeting the 2008 Federal Guidelines for Both Aerobic and Muscle-strengthening Activities Through Leisure-time Physical Activity Among Adults Aged 18–64: United States, 2010–2015. *National Health Statistics Reports* Number **112**, 2018.

Boidin, M., Lapierre, G., Tanir, L. P., Nigam, A., Juneau, M., Guilbeault, V., Latour E. and Gayda, M. (2015) Effect of aquatic interval training with Mediterranean diet counseling in obese patients: Results of a preliminary study. *Annals of Physical and Rehabilitation Medicine* **58(5),** 269-275.

Borg, G. (1970) Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine* **2(2),** 92-98.

Borges, J., Carter, S. J., Singh, H. and Hunter, G. R. (2018) Inverse relationship between changes of maximal aerobic capacity and changes in walking economy after weight loss. *European Journal of Applied Physiology* **118(8),** 1573-1578.

Bressel, E., Wing, J. E., Miller, A. I. and Dolny, D. G. (2014) High-intensity interval training on an aquatic treadmill in adults with osteoarthritis: Effect on pain, balance, function, and mobility. *Journal of Strength and Conditioning Research* **28(8),** 2088-2096.

Broman, G., Quintana, M., Lindberg, T., Jansson, E. and Kaijser, L. (2006) High intensity deep water training can improve aerobic power in elderly women. *European Journal of Applied Physiology* **98(2),** 117-123.

Costa, R.R., Buttelli A.C.K., Barreto, M.E., Vieiro, P.A., Alberton, C.L., Bracht, C.G. and Kruel, L.F.M. (2018a) Water-based aerobic training successfully improves lipid profile of dyslipidemic women: A randomized controlled trial. *Research Quarterly for Exercise and Sport* **89(2)**, 173-182.

Costa RR, Kanitz AC, Reichert T, Prado AKG, Coconcelli L, Buttelli ACK, Pereira LF, Masiero MPB, Meinerz AP, Conceição MO, Sbeghen IL. and Kruel LFM. (2018b) Water-based aerobic training improves strength parameters and cardiorespiratory outcomes in elderly women. *Experimental Gerontology* **15(108),** 231-239.

Costa RR, Reichert T, Coconcelli L, Simmer NM, Bagatini NC, Buttelli ACK, Bracht CG, Stein R. and Kruel LFM (2017) Short-term water-based aerobic training promotes improvements in aerobic conditioning parameters of mature women. *Complementary Therpies in Clinical Practice* **28,** 131-135.

Darby, L. A. and Yaekle, B. C. (2000) Physiological responses during two types of exercise performed on land and in the water. *Journal of Sports Medicine & Physical Fitness* **40(4),** 303-311.

Dolbow, D. R., Farley, R. S., Kim, J. K. and Caputo, J. L. (2008) Oxygen consumption, heart rate, rating of perceived exertion, and systolic blood pressure with water treadmill walking. *Journal of Aging and Physical Activity* **16(1),** 14-23.

Farahani, A. V., Mansournia, M. A., Asheri, H., Fotouhi, A., Yunesian, M., Jamali, M. and Ziaee, V. (2010) The effects of 10-week water aerobic exercise on the resting blood pressure in patients with essential hypertension. *Asian Journal of Sports Medicine* **1(3),** 159-167.

Fisher, F., Brown, A. W., Brown, M. M. B., Alcorn, A., Noles, C., Winwood, L., Resuehr, H., George, B., Jeansonne, M.M. and Allison, D. B. (2015) High intensity interval- vs moderate intensity-training for improving cardiometabolic health in overweight or obese males: A randomized controlled trial. *PLoS ONE* **10(10),** e0138853.

Foster, C., Farland, C. V., Guidotti, F., Harbin, M., Roberts, B., Schuette, J.,Tuuri A., Dobersteub S.T. and Porcari, J. P. (2015) The effects of high intensity interval training vs steady state training on aerobic and anaerobic capacity. *Journal of Sports Science and Medicine* **14(4),** 747-755.

Gappmaier, E., Lake, W., Nelson, A. B. and Fisher, A. G. (2006) Aerobic exercise in water versus walking on land: Effects on indices of fat reduction and weight loss of obese women. *Journal of Sports Medicine & Physical Fitness* **46(4),** 564-569.

Hall, J., Grant, J., Blake, D., Taylor, G. and Garbutt, G. (2004) Cardiorespiratory responses to aquatic treadmill walking in patients with rheumatoid arthritis. *Physiotherapy Research International* **9(2),** 59-73.

Haykowsky, M. J., Brubaker, P. H., Stewart, K. P., Morgan, T. M., Eggebeen, J. and Kitzman, D. W. (2012) Effect of endurance training on the determinants of peak exercise oxygen consumption in elderly patients with stable compensated heart failure and preserved ejection fraction. *Journal of the American College of Cardiology* **60(2),** 120-128.

Heisz, J. J., Tejada, M. G. M., Paolucci, E. M. and Muir, C. (2016) Enjoyment for high-intensity interval exercise increases during the first six weeks of training: Implications for promoting exercise adherence in sedentary adults. *PLoS ONE* **11(12),** e0168534.

Hull, H. R., Morrow, M. L., Dinger, M. K., Han, J. L. and Fields, D. A. (2007) Characterization of body weight and composition changes during the sophomore year of college. *BMC Women's Health* **7(21),** 1-21.

Hunter, G. R., Bamman, M. M., Larson-Meyer, D. E., Joanisse, D. R., McCarthy, J. P., Blaudeau, T. E. and Newcomer, B. R. (2005) Inverse relationship between exercise economy and oxidative capacity in muscle. *European Journal of Applied Physiology* **94(5-6),** 558-568.

Hunter, G. R., Fisher, G., Neumeier, W. H., Carter, S. J. and Plaisance, E. P. (2015) Exercise training and energy expenditure following weight loss. *Medicine & Science in Sport & Exercise* **47(9),** 1950-1957.

Jenkins, G. P., Evenson, K. R., Herring, A. H., Hales, D. and Stevens, J. (2017) Cardiometabolic correlates of physical activity and sedentary patterns in U.S. youth. *Medicine & Science in Sports & Exercise* **49(9),** 1826-1833.

Kong, Z., Fan, X., Sun, S., Song, L., Shi, Q. and Nie, J. (2016) Comparison of high-intensity interval training and moderate-to-vigorous continuous training for cardiometabolic health and exercise enjoyment in obese young women: A randomized controlled trial. *PLoS ONE* **11(7),** e0158589.

Kraemer, R.R., Francois, M.R., Sehgal, K., Sirikul, B., Valverde, R.A. and Castracane, V.D. (2011) Amylin and selective glucoregulatory peptide alterations during prolonged exercise. *Medicine and Science in Sports and Exercise* **43(8),** 1451-1456, 2011.

Kruel, L. F. M, Beilke, D. D., Kanitz, A. C., Alberton, C. L, Antunes, A. H., Pantoja, P. D., da Silva E.M. and Pinto, S. S. (2013) Cardiorespiratory responses to stationary running in water and on land. *Journal of Sports Science and Medicine* **12(3),** 594-600.

Martinez, N., Kilpatrick, M. W., Salomon, K., Jung, M. E. and Little, J. P. (2015) Affective and enjoyment responses to high-intensity interval training in overweight-to-obese and insufficiently active adults. *Journal of Sport & Exercise Psychology* **37(2)**, 138-149.

Lopera, C.A., da Silva, D.F., Bianchini, J.A.., Locateli, J.C, Moreira, A.C., Dada R.P., Thivel, D. and Nardo, N. Junior. (2016) Effect of water- versus land-based exercise training as a component of a multidisciplinary intervention program for overweight and obese adolescents. *Physiology and Behavior* **165,** 365-373.

Menz, V., Strobl, J., Faulhaber, M., Gatterer, H. and Burtscher, M. (2015) Effect of 3-week high-intensity interval training on VO2max, total haemoglobin mass, plasma and blood volume in well-trained athletes. *European Journal of Applied Physiology* **115(11),** 2349-2356.

Montero, D., Diaz-Canestro, C. and Lundby, C. (2015) Endurance training and VO_2max: Role of maximal cardiac output and oxygen extraction. *Medicine & Science in Sports & Exercise* **47,** 2024-2033.

Murias, J. M., Kowalchuk, J. M. and Paterson, D. H (2010) Mechanisms for increases in VO2max with endurance training in older and young women. *Medicine & Science in Sport & Exercise* **42(10,** 1891-1898.

Padua, E., Campoli, F., Manzi, V., Panzarino, M., Lombardo, M., Melchiorri, G., Tancredi, V., Lebone P., Palazzo, F. and Annino, G. (2018) Water versus land-based exercises as physical training programs in elderly. *The Journal of Sports Medicine & Physical Fitness* **58(6),** 802-809.

Plotnick, G. D., Becker, L. C., Fisher, M. L, Gerstenblith, G., Renlund, D. G., Fleg, J. L., Weisfeldt, M.L. and Lakatta, E. G. (1986) Use of the frank-starling mechanism during submaximal versus maximal upright exercise. *American Journal of Physiology* **251(6 Pt2),** H1101-1105.

Reichert, T., Kanitz, A.C., Delevatti, R.S., Bagatini, N.C., Barroso, B.M. and Kruel, L.F. (2016) Continuous and interval training programs using deep water running improves functional fitness and blood pressure in the older adults *Age* **38(1),** 20.

Rynecki N.D., Siracuse B.L., Ippolito J.A. and Beebe K.S. (2019) Injuries sustained during high intensity interval training: are modern fitness trends contributing to increased injury rates? *Journal of Sports Medicine and Physical Fitness* 59(7), 1206-1212.

Ruoti, R. G., Troup, J. T. and Berger, R. A. (1994) The effects of non-swimming water exercise on older adults. *Journal of Orthopaedic & Sports Physical Therap* **19(3),** 140-145.

Schaal, C. M., Collins, L. and Ashley, C. (2012) Cardiorespiratory responses to underwater treadmill running versus land-based treadmill running. *International Journal of Aquatic Research and Education* **6,** 35-45.

Schuch, F.B., Pinto, S.S., Bagatini, N.C. Zaffari, P., Alberton, C.L., Cadore, E.L., Silva, R.F. and Kruel, L.F.M. (2014) Water based exercise and quality of life in women: The role of depressive symptoms. *Women & Health* **54(2),** 161-175.

Silfee, V., Lemon, S., Lora, V. and Rosal, M. (2017) Sedentary behavior and cardiovascular disease risk factors among Latino adults. *Journal of Health Care for the Poor and Underserved* **28(2),** 798-811.

Sosner, P., Gayda, M., Dupuy, O., Garzon, M., Lemasson, C., Gremeaux, V., Lalongé J., Gonzales M., Hayami D., Juneau M., Nigam A. and Bosquet, L. (2016) Ambulatory blood pressure reduction following high-intensity interval exercise performed in water or dryland condition. *Journal of the American Society of Hypertension* **10(5),** 420-428.

Sylvester, B. D., Standage, M., McEwan, D., Wolf, S. A., Lubans, D. R., Eather, N., Kaulius M., Ruissen G.R., Crocker P.R., Zumbo B.D. and Beauchamp, M. R. (2016) Variety support and exercise adherence behavior: Experimental and mediating effects. *Journal of Behavioral Medicine* **39(2),** 214-224.

Taunton, J. E., Rhodes, E. C., Wolski, L. A., Donelly, M., Warren, J., Elliot, J., McFarlane L., Leslie J., Mitchell J. and Lauridsen, B. (1996) Effect of land-based and water-based fitness programs on the cardiovascular fitness, strength and flexibility of women aged 65-75 years. *Gerontology* **42(4),** 204-210.

Thum, J. S., Parsons, G., Whittle, T. and Astorino, T. A. (2017) High-intensity interval training elicits higher enjoyment than moderate intensity continuous exercise. *PLoS ONE* **12(1),** e0166299.

Trost, S. G., Owen, N., Bauman, A. E., Sallis, J. F. and Brown, W. (2003) Correlates of adults' participation in physical activity: Review and update. *Medicine & Science in Sports & Exercise* **34(12),** 1996-2001.

Vasić, D., Novaković, M., Božič, M.M., Barbič, Ž. B. and Jug, B. (2019) Short-Term Water- and Land-Based Exercise Training Comparably Improve Exercise Capacity and Vascular Function in Patients After a Recent Coronary Event: A Pilot Randomized Controlled Trial. *Frontiers in Physiology* **16(10),** 903.

Vella, CA and Robergs, RA. (2005) A review of the stroke volume response to upright exercise in healthy subjects. *British Journal of Sports Medicine* **39(4),**190-195.

Vieira, R. S., Gallo, A. M, Carvalho, C. J. A., Araujo, J. P., Cabral, R. and Eler, G. J. (2016) Risk factors for developing cardiovascular

disease in women. *Investigacion y Educacion en Enfermeria* **35,** 35-47.
Vincent, J. L. (2008) Understanding cardiac output. *Critical Care* **12(4),** 174.
Walia, S. (2012) A comparison between land-based and water-based balance training exercise program in improvement of balance in community dwelling elderly population. *Indian Journal of Physiotherapy & Occupational Therapy* **6(3),** 221-227.
Waller, B., Munukka, M., Rantalainen, T., Lammentausta, E., Nieminen, M. T., Kiviranta, I., Kautiainen H., Häkkinen A., Kujala U.M. and Heinonen, A. (2017) Effects of high intensity resistance aquatic training on body composition and walking speed in women with mild knee osteoarthritis: A 4-month RCT with 12-month follow up. *Osteoarthritis and Cartilage* **25(8),** 1238-1246.
Wang, T. J., Belza, B., Thompson, F. E., Whitney, J. D. and Bennett, K. (2006) Effects of aquatic exercise on flexibility, strength and aerobic fitness in adults with osteoarthritis of the hip or knee. *Journal of Advanced Nursing* **57(2),** 141-152.
Wei, B., Kilpatrick, M, Naquin, M. and Cole, D. (2006) Psychological perceptions to walking, water aerobics and yoga in college students. *American Journal of Health Studies* 21(3), 142-147.
Whaley, D. E. and Schrider, A. F. (2005) The process of adult exercise adherence: Self-perceptions and competence. *The Sport Psychologist* **19,** 148-163.
Wilmore, J. H., Stanforth, P. R., Gagnon, J., Leon, A. S., Roa, D. C., Skinner, J. S. and Bouchard, C. (1996) Endurance exercise training has a minimal effect on resting heart rate: The HERITAGE study. *Medicine & Science in Sport & Exercise* **28(7),** 829-835.

Key points

- Aquatic calisthenic high intensity exercise, when used in a progressive fashion, is tolerated by sedentary, overweight individuals.
- Aquatic calisthenic high intensity exercise, when used in a progressive fashion, is effective in improving cardiorespiratory fitness and body composition.
- Effective aquatic calisthenic high intensity exercise can be conducted without aquatic treadmills or cycles.

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