

ORIGINAL ARTICLE

Aquatic high-intensity interval training improves cardiometabolic profile and physical fitness in active middle-age and older adults: quasi-randomized clinical trial study

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Abstract

Introduction: aquatic exercises have been increasingly suggested to the population. Despite evidence on the benefits of high-intensity interval training in aquatic environments, scientific production still needs to be improved. Research involving middle-aged and older individuals usually seeks physiological responses from the assumption that they are sedentary.

Objective: to assess the physical fitness, lipid profile, and glycemic control of active middle-aged and older adults undergoing aquatic high-intensity interval training associated or not with intense water walking.

Methods: it is a quasi-randomized clinical trial composed of 45 active middle-aged and older adults subdivided into two groups with aquatic high-intensity interval training in the absence (AHIIT) or presence (AHIITW) of intense water walking. Participants were dosed with biochemical parameters, bioimpedance analysis, and physical and cardiopulmonary tests at the intervention's beginning and end.

Results: both groups showed increased HDL, reduced LDL, and hemoglobin glycated, with increased endurance and strength of upper and lower limbs. The AHIIT group showed a lean mass gain and fat mass decline compared to the AHIITW. The intense walking promoted an increase in oxygen ventilatory equivalent, maximum oxygen consumption, and the task metabolic equivalent at values like the AHIIT.

Conclusion: our findings indicate that high-intensity aquatic training holds the potential to enhance the lipid profile of individuals. However, the incorporation of pool walking into the training regimen did not lead to any notable differences in this regard. Conversely, the inclusion of pool aquatic exercises did result in improved functional capacity among participants.

Brazilian Registry of Clinical Trials (ReBEC): #RBR-99b6jr6

Keywords: exercise; walking; lipoproteins; oxygen consumption; aquatic high-intensity interval training

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Authors summary

Why was this study done?

This study was conducted to evaluate and compare the effects of high-intensity interval training in water, with and without intense walking, on metabolic health, functional capacity, and quality of life in individuals with type 2 diabetes mellitus, aiming to find effective and safe exercise strategies to improve the management of this chronic condition.

What did the researchers do and find?

The researchers conducted a study to investigate the effects of high-intensity interval training (HIIT) in water, with and without intense walking, in people with type 2 diabetes. They found that both types of training improved the metabolic health, functional capacity, and quality of life of the participants, but HIIT in water was slightly more effective.

What do these findings mean?

These findings suggest that high-intensity interval training (HIIT), especially when performed in water, may be an effective strategy to improve metabolic health, functional capacity, and quality of life in people with type 2 diabetes. This highlights the importance of physical exercise, especially modalities like HIIT in water, as an integral part of the management and treatment of this medical condition.

Highlights

High-intensity aquatic interval training (HIAIT) improved resistance and muscle strength in the upper and lower limbs.

The HIAIT group experienced lean mass gain and reduced fat mass compared to high-intensity aquatic interval training with additional intense walking (HIAITW).

Additional intense walking (HIAITW) improved maximal oxygen consumption (VO₂max) and functional capacity measured by the 30-second chair stand test, showing an additional benefit over HIAIT.

High-intensity interval aquatic training demonstrated potential to significantly improve lipid profile and functional capacity, regardless of the inclusion of intense aquatic walking.

INTRODUCTION

Physical activity is a fundamental ally for public health and can prevent and treat most noncommunicable diseases (NCDs)¹. More than 15 million deaths attributed to NCDs occur among people aged between 30 and 69 years², and 1.6 million deaths annually may be associated with poor physical exercise.

Evidence indicates that physical exercise can prevent chronic diseases and is a protective factor against the risk of cardiovascular diseases; it can also mitigate the physiological consequences of the human aging process³. Although any level of physical activity can be beneficial, there are still doubts in the scientific literature regarding the type, intensity, frequency, and duration of exercise prescription⁴.

Furthermore, physical exercise can increase the expression of receptors located in the liver (Liver X receptor - LXR- LXR), having a fundamental role in hepatic cholesterol metabolism through metabolic pathways that result in increased levels of HDL cholesterol subfractions plasmatic, essential framework to reduce risk factors for the development of cardiovascular diseases^{5,6}.

Evidence describing the benefits of high-intensity interval training has been associated with improved aerobic fitness, ejection fraction⁷, insulin sensitivity, reduced blood pressure, and body composition⁸. Aquatic exercises have been increasingly offered to the elderly population, as immersion reduces body weight overload on the joints and provides resistance to the movement of immersed limbs⁹⁻¹⁴.

High-intensity interval training has emerged as an alternative for individuals to complete continuous training with better physical conditioning in a shorter time. Sometimes, conducting these routines in land settings is also an appropriate choice. Consequently, performing exercises in aquatic environments is an effective alternative that benefits older adults or people with physical impediments such as knee osteoarthritis^{11,12}.

Several studies have evaluated intense water walking with different methodologies and comparative analyzes in the presence of various comorbidities (Obesity, fibromyalgia, post-stroke, peripheral artery disease, COPD), and also related to improving functional and cardiorespiratory capacity, exercise tolerance, muscle strength, quality of life, mobility, balance, pain reduction, and low-impact aerobic exercise¹⁵⁻¹⁹.

Aquatic walking in a pool is a great exercise option for individuals with physical limitations because it minimizes stress on joints, bones, and muscles. This is why it is commonly integrated into rehabilitation programs. The practice offers various advantages: it helps maintain and build strength, lowers body weight's impact, enhances aerobic capacity, and contributes to cardiovascular well-being²⁰⁻²⁴.

The potential benefits of combining high-intensity interval training and aquatic walking remain unexplored. Investigating the effects of aquatic exercises can contribute to establishing public health interventions utilizing swimming pools, attracting individuals averse to gym settings or limited by musculoskeletal issues²⁵.

The hypothesis of our research states that supplementing high-intensity aquatic interval training with vigorous water walking could enhance physical fitness, lipid profile, and glycemic control among middle-aged and elderly adults. Hence, this study aims to assess the impact of high-intensity aquatic interval training, with or without intense water walking, on the physical fitness, lipid profile, and glycemic control of active middle-aged and elderly adults.

METHODS

Study design

A prospective Quasi-Randomized Clinical Trial identified with the number RBR-99b6jr6 at the Brazilian Registry of Clinical Trials (ReBEC) was conducted in

2018. The study received approval from the Ethical and Research Committee with Human Beings of the Centro Universitário de Patos - UNIFIP (#2,623,793). To minimize bias, the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool was employed.

The quasi-experimental research design was considered because the researchers did not have full control over the random allocation of participants into groups. This choice was made based on ethical considerations, as some participants expressed a desire to switch groups. It is important to note that while we could not achieve a fully controlled experiment, causal changes were still assessable. This research is categorized as quasi-experimental, rather than a “pure” randomized clinical trial, due to instances where individuals requested group changes upon learning about spending more time in the pool for walks.

Study population and eligibility criteria

Participants were selected from a university-initiated project aimed at benefiting the residents of Patos City, Paraíba state, and neighboring areas in northeastern Brazil. This project focuses on physical activities, health promotion, and well-being guidelines. To be eligible, individuals had to meet certain criteria: they needed to be part of the project, possess medical approval for participating in aquatic activities, engage in physical activities regularly (following the prescribed protocol of 2 to 3 times per week), and fall within the age range of 50 to 80 years.

Exclusion criteria encompassed individuals physically incapable of completing the initial and final assessment tests, including those with challenges in walking, dependence on walking aids, stroke sequelae, advanced osteoarthritis, or reliance on pacemakers. Participants with less than 75% attendance in weekly

activities, those experiencing infections during the study, or those unable to complete the initial and final assessments were excluded.

Randomization

An independent individual, not associated with the study, conducted the random assignment using sealed opaque envelopes containing group names. The data collection team conducting post-test assessments remained unaware of group assignments, maintaining single blinding. The same team was responsible for both pre-and post-protocol evaluations.

The volunteers were divided randomly into two groups: the Aquatic High-Intensity Interval Training Group (AHIIT), which followed a twice-weekly pool exercise regimen, and the Aquatic High-Intensity Interval Training and Intense Walking Group (AHIITW), which, in addition to the AHIIT protocol, included a third day of vigorous additional water walking session.

After explaining the research’s objectives and procedures, 75 eligible individuals consented to participate by signing an Informed Consent Form. Thirteen were excluded due to assessment test limitations. Ultimately, 62 participants were chosen, with 35 assigned to the AHIIT group and 27 to the AHIITW group. Some participants requested to switch groups when they learned about the additional pool walking time. These requests could not be denied, resulting in an uneven distribution of participants despite randomization. However, statistical analysis indicated no significant difference between the groups.

Among the 35 individuals in the AHIIT group, five dropped out, and one did not complete the final exercise test. Within the 27-member AHIITW group, 11 were withdrawn three dropped out, and eight did not complete all the final assessment sets (figure 1).

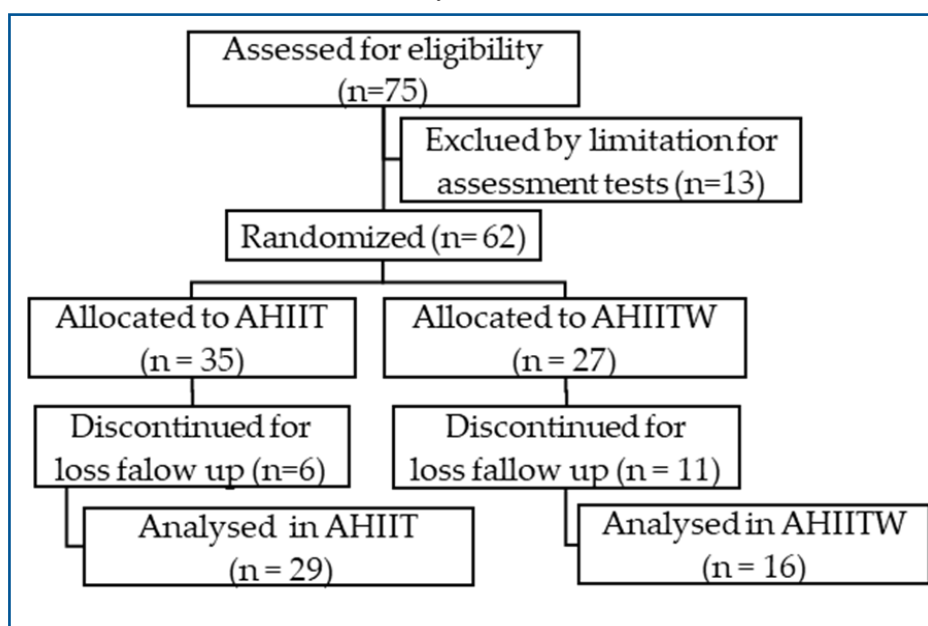


Figure 1: Flowchart of the participant’s selection

All participants underwent an assessment at the study's beginning and its conclusion, performing biochemical measurements, bioimpedance analysis, strength and endurance, flexibility, and cardiopulmonary function.

Throughout the research, no nutritional guidelines were given, and the use of medication did not have any impact on the study's proceedings.

Questionnaires

To characterize the participant group better, a sociodemographic questionnaire designed by the researchers was administered. This survey encompassed queries regarding age, ethnicity, gender, education, family income, medical history including prior ailments and surgeries, utilization of prescribed medications, and personal habits such as tobacco and alcohol consumption.

Moreover, the International Physical Activity Questionnaire (IPAQ) was also applied. This tool is specifically tailored and validated for the older adult population in Brazil^{26,27}. The IPAQ estimates the weekly level of physical activities. Structured around four domains- work, commuting, household tasks, and leisure time- it inquires about the duration of moderate and vigorous activities. The outcome of the IPAQ categorizes participants into different activity levels: continually active, active, irregularly active A and B, or sedentary.

Data Collection

Laboratory Test

Blood samples for biochemical analysis were taken twice during the study – once at the study's commencement and then again at its conclusion. The samples were collected in the morning after the participants had fasted for around 10 to 12 hours overnight.

All individuals followed an identical procedure and had their tests carried out at the same laboratory. The measurements taken included fasting blood glucose levels, glycated hemoglobin levels, total cholesterol levels, and fractions (HDL - high-density lipoprotein and LDL - low-density lipoprotein).

Physical assessment and bioimpedance analysis

Anthropometric measurements were conducted using a specific scale (Welmy 110 CH - 150Kg). Participants were instructed to step onto the scale barefoot and stand upright, while their weight in kilograms (Kg) was recorded. Additionally, they were asked to take a deep breath so that their height in centimeters (cm) could be measured accurately.

For the bioimpedance analysis, participants were given specific instructions: they were required to wear comfortable clothing without any metal accessories (belt, necklace, bracelet, ring, wristwatch), refrain from moderate/intense physical activity for the past 12 hours, abstain from eating for 2 hours and without drinking, alcohol, coffee, teas, or diuretics for 24 hours before the analysis. It was important for them to have an empty bladder and bowels during the evaluation^{28,29}. The Maltro-BF906 device, which employs tetrapolar bioelectrical impedance, was used to assess body mass distribution.

This method's accuracy was compared to the hydrostatic weighing technique³⁰.

Participants were positioned in a supine position on a non-conductive stretcher. Electrodes were placed on the right hand and foot. These electrodes, consisting of a black pole (Voltage Electrode) near the hand and a red pole (Current Electrode) near the third finger²⁹, were preceded by cleaning the contact points with alcohol-soaked cotton wool. After turning on the device and inputting weight and height data, various body composition parameters were measured. These included body mass index (BMI) in kilograms per square meter (Kg/m²), lean body mass, body fat mass, and body water percentage.

Flexibility was assessed using the Sit and Reach test³¹, where participants sat on a Wells Instant Flex (Sanny[®]) bench with legs and arms extended. They were instructed to flex the trunk without bending the knees during exhalation and to push the marker, followed by a tape measure fixed to the bench with the fingertips. The best distance among the three repetitions was recorded in centimeters (cm).

Two tests were used to measure endurance and muscle strength: the Arm Curl test and the 30-second chair-stand test³¹. In the Arm Curl test, participants used dumbbells of 2 kg for women and 3 kg for men. Using a stopwatch (RS-013, Incoterm[®]), the number of controlled repetitions performed within 30 seconds was recorded. It is worth noting that all participants in the program underwent a medical check-up before participating in aquatic pool physical activities.

Cardiopulmonary testing

Two distinct protocols were employed for the ergo spirometric test: the Bruce protocol, modified for individuals up to the age of 60, and the Naughton protocol, designed for those over 60. The Naughton approach involved slower speeds and higher treadmill inclines, accommodating older adults with some degree of arthrosis.

To conduct the tests, the MedGraphics 2000 metabolic analyzer and the Super ATL-Ibramed multi-programmable ergometer were utilized, connected to a computer. The Breeze Software initiated the protocols and promptly captured metabolic measurements approximately every 7 to 13 seconds.

The testing environment was maintained at a controlled temperature ranging between 18°C and 22°C using a thermometer and air conditioning. Participants were instructed to wear comfortable clothing and sneakers, avoid moderate or intense exercise within the last 24 hours, and consume a light diet on the test day while refraining from consuming food, coffee, or alcohol within three hours prior to the test. Medication usage remained uninterrupted³².

Upon arrival, individuals were outfitted with a Polar M460 watch and remained seated for ten minutes to measure their resting blood pressure and heart rate. The device was then calibrated through a self-calibration system, and a facial mask was fitted to measure their baseline oxygen consumption (VO₂).

Subsequently, participants began the treadmill

test with continuous monitoring of their heart rate. The exercise was halted when individuals signaled their maximum limit, leading to the recording of peak heart rate (HR) and blood pressure. Five minutes after concluding the test, heart rate and blood pressure were rechecked before individuals were released from the assessment.

For statistical analysis, variables including peak HR, resting HR, peak, and baseline VO₂, and the ventilatory oxygen equivalent (VE/VO₂) were employed.

Intervention

The intervention program lasted for a total of eighteen weeks, with the initial two weeks dedicated to acclimating to pool exercises of low intensity (around 30% of MHR). Subsequently, the main training phase spanned sixteen weeks. The participants were divided randomly into two groups: one group followed Aquatic High-Intensity Interval Training (AHIIT) twice a week, while the other group engaged in the same AHIIT sessions but with the addition water walking session once a week (AHIITW).

The water temperature in the pool was maintained between 30 to 32°C and monitored using a thermometer. The pool was indoors and had a depth ranging from 1.00 to 1.50 meters. Each training session lasted from 50 to 60 minutes and was structured as follows: a 10-minute warm-up routine, followed by strength and power exercises, cardiorespiratory training, and concluding with

a 10-minute segment of stretching and balance exercises.

This intervention observed the Moreira *et al.* protocol^{33,34} comprised of four-week mesocycles each. Volunteers, encouraged by the instructor (physical education teacher and physiotherapist), executed each set with the maximum effort to meet the maximum potential movement speed.

The mesocycles progressed in terms of exercise complexity and set duration: starting with two sets of 30-second exercises each (weeks 1-4), progressing to three sets of 20 seconds (weeks 5-8), then four sets of 15 seconds (weeks 9-12), and finally, five sets of 10 seconds (weeks 13-16). The participants reported muscle fatigue due to exertion after completing the exercise routines.

To control the intensity of cardiorespiratory exercises, the Borg CR10 Scale³⁵ was employed, which rates perceived exertion on a scale from 0 (no exertion) to 10 (maximum effort). The participants used a visual poster with facial expressions representing different effort levels. Following the Borg CR10 Scale, the effort levels increased progressively through the mesocycles: level 6 (approximately 60% of MHR) for 16-minute sessions during weeks 1 to 4, level 7 (approximately 70% of MHR) for 13-minute sessions in weeks 5 to 8, level 8 (approximately 80% of MHR) for 9-minute sessions in weeks 9 to 12, and level 9 (approximately 90% of MHR) for 7-minute sessions in weeks 13 to 16 (table 1).

Table 1: Exercise intensity protocol over the 16 weeks

Mesocycles (weeks)	number series (repetitions of each exercise)	Runtime	recovery time	Intensity of execution (Borg)
1° - 4°	2	25"	1'	6
5° - 8°	3	16"	1'20"	7
9° - 12°	4	12"	1'30"	8
13° - 16°	5	10"	1'40"	9

Over the course of 16 weeks, the participants performed exercises standing in chest-deep water in the following order: elbow flexion/extension with shoulder abduction, hip abduction/adduction, shoulder horizontal flexion/extension with the elbow extended, and hips and knees flexion/extension alternate.

The AHIITW group used the same workout twice a week along with an additional intense walk in the pool once a week. During the walking sessions, the individuals had a 10-minute period for getting accustomed to the water and performing stretching exercises. Following that, they were instructed to walk in a circular motion. Subsequently, they were asked to change their walking direction every whenever the water favored a change. The drag generated in the direction change increased the water resistance.

The intensity of walking in the water varied between moderate and vigorous levels, and this was determined using the Borg CR10 scale as a guideline for a duration of 30 minutes. The aquatic walking routine encompassed the following components: a 5-minutes period of regular walking for warming up, followed by 20 minutes of walking that was tailored to the specific

functional capacity of each participant, guided by their Borg CR10 scale rating. The Borg scale was chosen because it was not possible to monitor all individuals (in water) and base their training heart rate on the measured VO₂. This protocol was based on previous studies of Lobanov *et al.*³⁶, Sklempe *et al.*³⁷, and Peyré-Tartaruga³⁸. The instructor consistently motivated the participants verbally. The session concluded with five minutes of relaxation using floats after the 30-minute session was completed.

Statistical analysis

Qualitative variables were described in absolute and relative frequency. The Chi-square test and the t-student test compared the categorical variables. Data are presented as group mean values and standard deviations. Excel[®] and SPSS[®] (Statistical Package for Social Research) 20.0 (Chicago, IL, USA) software for statistical analysis were used to create the database.

Descriptive statistics were conducted to calculate measures of central tendency and dispersion. The Shapiro–Wilk test was used to verify data normality. ANOVA analysis of dependent variables was used for the

AHIITW and AHIIT across different moments (initial vs final) with repeated measures on the final factor. Post-hoc comparisons were carried out using the Bonferroni test. The significance level was set at $p < 0.05$.

Centro Universitário de Patos - UNIFIP (#2,623,793). Informed consent was obtained from all subjects involved in the study.

RESULTS

A total of 45 individuals divided into two groups were evaluated. Both groups showed similar sociodemographic characteristics (table 2).

Ethical and legal aspects of the research

The study contents were approved by the Ethical and Research Committee with Human Beings of the

Table 2: Comparison of sociodemographic variables between groups

Variables	Group		p*
	AHIIT n (%)	AHIITW n (%)	
Sex			
Female	25 (86.21)	16 (100)	0.126
Male	4 (13.79)	-	
Breed			
White	21 (72.41)	12 (75.00)	0.851
Brown	8 (27.59)	4 (25.00)	
Marital status			
Married	14 (48.27)	8 (50.00)	0.757
Single	2 (6.90)	1 (6.25)	
Widover	7 (24.14)	2 (12.50)	
Divorced	6 (20.69)	5 (31.25)	
SAH			
No	15 (51.72)	6 (37.50)	0.360
Yes	14 (48.28)	10 (62.50)	
Med_SAH			
No	16 (55.17)	8 (50.00)	0.739
Yes	13 (44.83)	8 (50.00)	
DM			
No	25 (86.21)	11 (68.75)	0.161
Yes	4 (13.79)	5 (31.25)	
IPAQ			
Active	8 (27.59)	5 (31.25)	0.742
Very active	21 (72.41)	11 (68.75)	
Education			
Literacy	1 (3.44)	0 (0%)	0.856
Basic education	7 (24.14)	5 (31.25%)	
Incomplete high school	7 (24.14)	3 (18.75%)	
Complete high school	4 (13.79)	4 (25%)	
Incomplete higher education	1 (3.45)	1 (6.25%)	
Complete higher education	7 (24.14)	3 (18.75%)	
Postgraduate studies	2 (6.90)	0	
Family income			
Less than a minimum wage	3 (10.35)	3 (18.75%)	0.599
From 1 to 3 minimum wages	22 (75.86)	11 (68.75%)	
From 3 to 6 minimum wages	4 (13.79)	2 (12.50%)	
	Mean (Minimum - Maximum)	p**	
Age (years)	64.43 (47.00 – 83.00)	62.37 (52.00 - 78.00)	0.451

*Chi-square and **Student's t-test; (AHIIT) Aquatic High-Intensity Interval Training Group; (AHIITW) Aquatic high-intensity interval training and Intense Walking Group; (SAH) Systemic Arterial Hypertension; (Med_SAH) Systemic Arterial Hypertension with Medication; (DM) Diabetes Mellitus; (IPAQ) International Questionnaire for Physical Activity.

Figure 2 illustrates the inter- and intra-group comparisons for measures related to Low-density lipoprotein cholesterol (LDL), High-density lipoprotein cholesterol (HDL), and glycated hemoglobin (HbA1c) parameters. There was a reduction in LDL and HbA1c,

as well as an increase in HDL in both groups, but there was no statistical difference when comparing the groups. Fasting blood glucose (FBG) and Total cholesterol were also evaluated but there was no statistical difference between the initial and final moments.

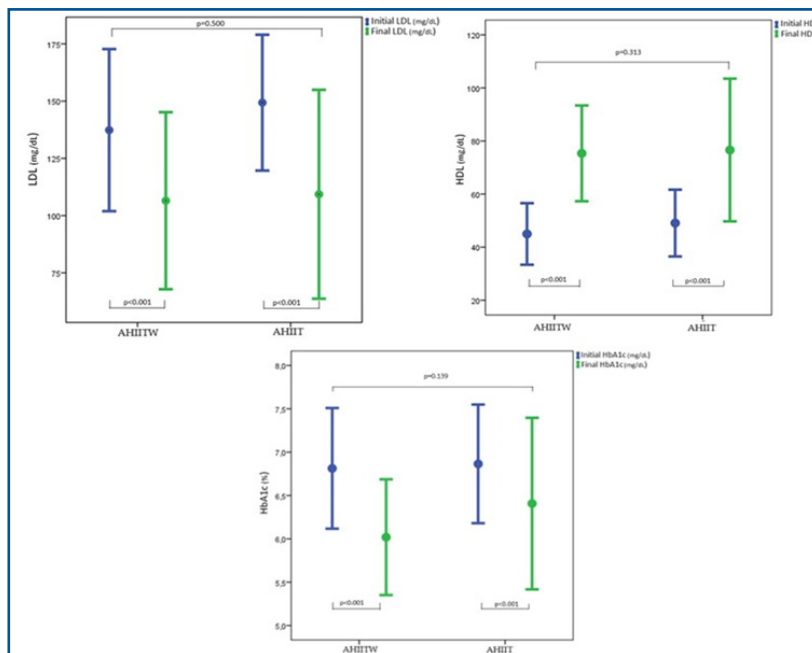


Figure 2: Biochemical parameters intra and intergroup comparison

ANOVA (Values were expressed as mean and standard deviation); (AHIT) Aquatic High-Intensity Interval Training Group; (AHITW) Aquatic high-intensity interval training and Intense Walking Group; (LDL) Low-density lipoprotein cholesterol; (HDL) High-density lipoprotein cholesterol; (HbA1c) Glycated hemoglobin.

The inclusion of walking intensity alongside high-intensity aquatic exercises contributed, at the end of the activities, to an increase in maximum oxygen consumption (VO₂max) (figure 3). However, there were no differences between the two groups and between time points (initial vs final) in terms of resting heart rate, oxygen ventilatory equivalent (V_e/VO₂), and the metabolic equivalent of the task (MET) (Figure 3).

Figure 4 shows the inter and intragroup comparison for the 30-s chair-stand test. Notably, both groups exhibited an increase in the number of repetitions. However, a statistically significant difference (p=0.022) emerged, indicating that the group incorporating intense walking demonstrated a more significant improvement. While the Sit and Reach test and Arm Curl test were also evaluated, no significant statistical differences were observed between the initial and final moments (Figure 4).

The implementation of high-intensity aquatic interval training did not result in any discernible alteration in bioimpedance markers. No distinctions were observed between the two groups or across different moments (initial vs final) concerning body lean mass, body fat mass, body water, and body mass index.

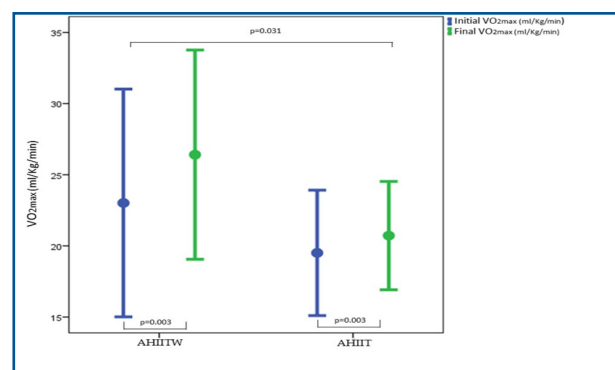


Figure 3: Maximum Oxygen Consumption (VO₂max) intra, and intergroup comparison.

ANOVA (Values were expressed as mean and standard deviation); (AHIT) Aquatic High-Intensity Interval Training Group; (AHITW) Aquatic high-intensity interval training and Intense Walking Group; (VO₂max) Maximum Oxygen Consumption.

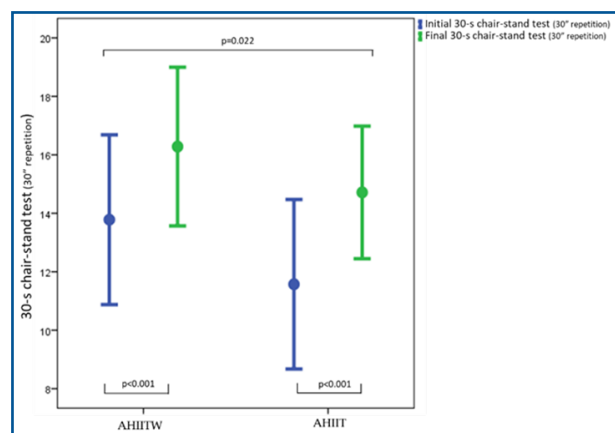


Figure 4: 30-s chair-stand test intra, and intergroup comparison.

ANOVA (Values were expressed as mean and standard deviation); (AHIT) Aquatic High-Intensity Interval Training Group; (AHITW) Aquatic high-intensity interval training and Intense Walking Group.

DISCUSSION

Our research showed that high-intensity aquatic training had a positive effect on the lipid profile of individuals. However, the addition of pool walking to the training regimen did not lead to any noticeable changes in LDL, HDL, or glycated hemoglobin levels. Conversely, the inclusion of walking did result in maximal oxygen consumption, leg strength, and endurance.

Interestingly, the high-intensity aquatic interval training did not bring about any alterations in bioimpedance markers. Although both groups exhibited a decrease in LDL cholesterol and an increase in HDL with statistically significant differences, these changes were not mirrored in total cholesterol and the overall lipid profile. Similar outcomes were reported in a study by Kim *et al.*³⁹, involving elderly women, where aquatic exercise notably improved LDL and HDL while not significantly impacting total cholesterol. This aligns with the findings of the meta-analysis by Igarashi & Yoshie Nogami⁴⁰, which emphasized the positive effects of aquatic exercise on blood lipid profiles. The limited duration of our intervention and the lack of dietary restrictions in our exclusion criteria might have influenced the outcome concerning total cholesterol reduction.

Our study also observed that high-intensity interval training conducted in an aquatic environment did not lead to a reduction in serum fasting blood glucose levels. However, both proposed training programs reduced the percentage of glycated hemoglobin. Despite the well-established minimal impact of physical exercise on this marker, particularly in diabetics subjects⁴¹, the literature is divergent regarding the effects of aquatic exercise on serum fasting blood glucose levels.

Research involving patients with type 2 diabetes has yielded varying results in terms of the impact of aquatic exercise on serum fasting blood glucose levels. For instance, certain studies have demonstrated a noteworthy reduction in levels⁴², while others have not observed a significant difference, both with elderly patients⁴³ and individuals with type 2 diabetes⁴⁴. Like our study, which had a concise duration, Gonçalves *et al.*⁴⁴ explained that the duration of the intervention was a pivotal factor influencing the absence of differences in serum fasting blood glucose levels.

Depiazzi *et al.*¹⁴ conducted a systematic review with a meta-analysis to examine the effectiveness of high-intensity interval training in an aquatic setting. They concluded that this form of training enhances the muscle strength of the lower limbs. This observation underscores the role of exercise intensity and contraction pattern in shaping the remodeling of skeletal muscles through aerobic training⁴⁵. Another study involving postmenopausal women who underwent a 24-week high-intensity interval water training regimen, like the current study's protocol, reported improvements in strength, flexibility, and balance³⁴.

Several studies have reported that aquatic high-intensity training can lead to a reduction in body fat percentage in sedentary young adults²⁶ and elderly women with osteoarthritis¹¹. Lambert *et al.*⁴⁶ proposed that the decrease in body fat percentage could be attributed to

increased energy expenditure during the intervention period.

However, systematic reviews with meta-analyses present different findings. These reviews suggest that aquatic high-intensity interval training might not significantly affect body composition^{14,15}. The authors of these reviews attribute these mixed findings to the limited number of studies evaluating these parameters and the insensitivity of the measurement methods used. Furthermore, the effects of high-intensity interval training on body composition are influenced by several factors, including the duration and intensity of training, methods of body composition assessment, and dietary interventions⁴⁷.

It is important to highlight that the participants in our study, who were middle-aged and older adults, were categorized as highly active according to the IPAQ. This distinction is crucial as it influences the processes of body mass loss and cardiorespiratory fitness, differentiating these individuals from sedentary or obese counterparts as seen in previously mentioned interventions. The aging process tends to have a negative impact on cardiorespiratory function, particularly raising cardiovascular disease risks among older adults, especially those with a high body mass index (BMI)⁴⁸.

In our study, there were no significant differences in cardiorespiratory function between the groups. This observation is noteworthy because the participants were already active or highly active individuals. The slight alterations in cardiorespiratory parameters for the intense walking group were due to their higher training load. However, it is important to highlight that the combination of aquatic high-intensity interval training and intense walking was instrumental in increasing maximal oxygen consumption (VO₂max).

Under these circumstances, the study highlights the potential benefits of aquatic high-intensity interval training for active middle-aged and older adults. This form of training could help mitigate cardiovascular risks and enhance functional capacity which is often compromised by the aging process.

Nevertheless, the study's main limitations were the inability to control the calories consumed by the participants in each group. In addition, dropout rates and group changes upon individual requests resulted in differing sample sizes between groups.

CONCLUSIONS

Our findings indicate that high-intensity aquatic training holds the potential to enhance the lipid profile of individuals. However, the incorporation of pool walking into the training regimen did not lead to any notable differences in this regard. Conversely, the inclusion of pool aquatic exercises did result in improved functional capacity among participants.

Author Contributions

All authors contributed to the manuscript. Rayne Borges Torres Sette: Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation. Tassiane Cristina Morais: Writing—Original Draft Preparation. Andrea Cristina de Sousa Rocha do Rêgo

Costa: Methodology, Investigation. Luiz Vinicius de Alcantara Sousa: Software, Formal Analysis, Writing—Review and Editing. Juliana Zangirolami-Raimundo: Validation. Blanca Elena Guerrero Daboin: Resources, Writing—Original Draft Preparation. Matheus Paiva Emidio Cavalcanti: Data Curation, Writing—Original Draft Preparation, Writing—Review and Editing. Rodrigo Daminello Raimundo: Conceptualization, Methodology,

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Resumo

Introdução: os exercícios aquáticos têm sido cada vez mais sugeridos à população. Apesar das evidências sobre os benefícios do treinamento intervalado de alta intensidade em ambientes aquáticos, a produção científica ainda precisa ser aprimorada. Pesquisas envolvendo indivíduos de meia-idade e mais velhos geralmente buscam respostas fisiológicas a partir do pressuposto de que são sedentários.

Objetivo: avaliar a aptidão física, o perfil lipídico e o controle glicêmico de adultos ativos de meia-idade e idosos submetidos a treinamento aquático intervalado de alta intensidade associado ou não à caminhada aquática intensa.

Método: trata-se de um ensaio clínico quase randomizado composto por 45 adultos ativos de meia idade e idosos subdivididos em dois grupos com treinamento aquático intervalado de alta intensidade na ausência (TAIAI) ou presença (TAIAIC) de caminhada aquática intensa. Os participantes receberam parâmetros bioquímicos, análise de bioimpedância e testes físicos e cardiopulmonares no início e no final da intervenção.

Resultados: ambos os grupos apresentaram aumento de HDL, redução de LDL e hemoglobina glicada, com aumento de resistência e força de membros superiores e inferiores. O grupo TAIAI apresentou ganho de massa magra e declínio de massa gorda em comparação ao TAIAIC. A caminhada intensa promoveu aumento do equivalente ventilatório de oxigênio, do consumo máximo de oxigênio e do equivalente metabólico da tarefa em valores assim como o TAIAI.

Conclusão: nossos achados indicam que o treinamento aquático de alta intensidade tem potencial para melhorar o perfil lipídico dos indivíduos. No entanto, a incorporação da caminhada na piscina no regime de treino não levou a quaisquer diferenças notáveis a este respeito. Por outro lado, a inclusão de exercícios aquáticos na piscina resultou em melhora da capacidade funcional dos participantes.

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Palavras-chave: exercício, andando, lipoproteína, consumo de oxigênio, treinamento intervalado aquático de alta intensidade.

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