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Original Research

The Effects of Combined Aquatic Exercise on Physical Performance and Metabolic Indices in Overweight Healthy Older Adults

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ABSTRACT

International Journal of Exercise Science 16(4): 1499-1513, 2023. Addressing overweight and obesity to promote healthy aging is essential. Exercise is an outstanding approach to manage metabolic and physical dysfunction. Aquatic exercise has been recommended for older individuals due to reduced weight pressure on joints. The aim of this study was to determine the effects of twenty-eight weeks of combined aquatic exercise (aerobic and resistance) in overweight healthy older individuals. Thirty-two subjects of both genders with mean age of 72.06 ± 5.8 years were randomly assigned into two groups: an aquatic exercise group (EG; n = 19) and a control group (CG; n = 13). Body composition, anthropometric measurements, blood pressure, lipid profile, fasting glucose, insulin, and leptin were assessed before and after the training program. The lipid profile, fasting glucose, leptin, insulin, and insulin resistance did not change between and within groups. The lipid profile worsened in the CG. Reduction in body fat mass, waist and leg circumferences, along with body mass gain in the aquatic exercise group was observed ($p \leq 0.05$). Systolic and diastolic blood pressure significantly improved in the exercise group ($P = 0.003$, $P = 0.001$). Significant differences were found in aerobic endurance ($P = 0.008$) and lower body flexibility ($P = 0.049$) of the aquatic exercise group compared with the control group. Also, upper body flexibility ($P = 0.001$, $P = 0.020$), lower and upper body strength ($P = 0.001$, $P = 0.031$), and handgrip ($P = 0.001$, $P = 0.006$), showed significant differences within the exercise group. Aquatic exercise may have a positive impact on the overweight aging population's metabolic and cardiovascular parameters, based on the observed improvements in blood pressure and body composition.

KEY WORDS: Glycemic control, leptin, obesity management, aquatic exercise therapy, physical fitness testing, elderly, subcutaneous fat, lipoproteins

INTRODUCTION

The topic of healthy aging has attracted extensive interest. The population of people aged 65 and over is growing rapidly and consequently, the prevalence of age-related chronic diseases poses more challenges for both individuals and the health care system (32). Fundamental changes including abdominal obesity, dysglycemia, dyslipidemia and hypertension, common factors for metabolic syndrome, are seen with advancing in age (9). Also, an inactive or sedentary lifestyle, which is prevalent among older people, increases the risk of insulin resistance and coronary artery disease (CAD) (11).

Overweight and obesity in elder population can be considered as an origin of metabolic and cardiovascular disorders and physical disfunction. Higher BMI and body fat percentage not only are associated with poor physical function but also potentiate individuals for metabolic alterations (28). Increased intramyocellular lipid and accumulation of its metabolites negatively impact the insulin-signaling pathway and promote insulin resistance in skeletal muscle. Moreover, obesity is often associated with alterations in lipid metabolism, leading to elevated levels of triglycerides, LDL cholesterol, and decreased levels of HDL cholesterol. These lipid imbalances can contribute to the development of atherosclerosis and cardiovascular disease (CVDs) (49).Furthermore, adipose tissue is a metabolically active tissue which secretes adipokines, and plays a significant role in energy metabolism and expenditure, inflammation and atherosclerosis. Among adipokines, dysregulated leptin has been correlated with pathogenesis of type two diabetes (T2D), CVDs and CAD (19). Leptin is associated with obesity and its indicators, including body mass index (BMI), visceral fat, waist circumference, and so on. In obese individuals, increased levels of leptin are linked with insulin resistance and disrupted glucose homeostasis. Leptin is an appetite suppressant, though people experiencing obesity are unsuccessful to reduce appetite and increase energy expenditure due to a leptin resistance state (2).

Aging is also characterized by decreased functionality to perform even routine daily tasks. Many studies have acknowledged disability in daily activities and decreased level of independence in aging populations. This inability to accomplish basic functional activities negatively affects quality of life. Indeed, the weak level of lower body strength which reflects in activities such as walking, going up and down stairs considerably limits daily mobility (16).

Among approaches tackling age-related diseases and disability, prescription of regular physical activity and exercise has an outstanding and critical role in disease prevention, as proposed by the American College of Sports Medicine as a form of "medicine" (6). It is a safe and economical way to control obesity and prevent related cardiovascular diseases (50). The curative and fortifying effects of exercise on physical fitness and performance not only decrease the risk of common geriatric diseases and dependency but also enhance the quality of life in older adults (25–27, 29). The term "aquatic program" refers to a set of exercises that are performed in water, usually in an upright position, with or without music, and in shallow and deep water, or even any type of physical activity that is conducted underwater (31). With this unique and safe exercise mode, older adults, obese/overweight individuals, and individuals with arthritis can benefit from concurrent aerobic and strength training (12, 22, 46). The results of a recent study indicated that older participants benefit more from water-walking due to lower impacts and decreased risk of falls, while still improving their cardiorespiratory fitness (39).

Considering all of the above, aquatic exercise programs appear to be a feasible alternative to exercise on land, and it is crucial to continue studying its potential in order to determine its benefits and effects. We hypothesized that 28 weeks of combined aquatic exercise could attenuate metabolic indices and enhance daily physical performance in overweight healthy older adults. Thus, the purpose of this study was to investigate the effect of head-out aquatic exercises on metabolic indices, leptin, insulin resistance and physical performance in overweight older adults.

METHODS

Participants

Participants were recruited in Portugal's central region, specifically in the region of Sertã. This study was a randomized pretest-postest design with a control group aiming to investigate the effects of aquatic training on metabolic indices, leptin, and physical performance in overweight healthy older adults. All variables were evaluated before and after a 28-week aquatic training program. In each evaluation, two stages were conducted: Stage 1 - Analyzing anthropometry and physical functions; Stage 2 - Determining biochemical markers. A sample size was determined using the G*Power software considering the following parameters: F test (ANOVA); effect size: 0.25; α-level: 0.05; statistical power: 0.80; number of groups: 2; number of measures: 4. A sample size estimated was 12 participants in each group (EG vs. CG). To make the recruitment process more convenient, the sample was recruited using a non-probabilistic method. One hundred and twenty individuals from the community were personally invited, but only 82 agreed to participate in the study. After applying the inclusion and exclusion criteria, 40 participants were randomly assigned to two groups: an exercise group (EG: n = 22) and a control group (CG: n = 18). During the intervention, 8 participants dropped out (personal motives, participated in less than 50% of the interventions sessions, injury not related with intervention and disease). The final sample analyzed was 32 participants (EG: n = 19; CG: n = 13). In our experience, as well as based on previous research (36), older persons tend to drop out of exercise programs at a high rate, so we recruited more participants. Participants were randomly assigned to groups by an external researcher using a computer-generated list of random numbers. For the purpose of ensuring randomization, the researchers were blinded. Figure 1 shows the study flowchart. The inclusion criteria were as follows: individuals older than 65 years of both genders, community-dwelling and living independently, sedentary (with no regular exercise participation in the last 6 months), and overweight (BMI 25.0 to < 30 or waist-to-height ratio ≥ 0.5 to < 0.6. According to the physician and information obtained from the health questionnaire, individuals were excluded based on specific factors to ensure a systematic approach and minimize bias. Individuals were excluded from participation if they were diagnosed with diabetes; had a history of severe arrhythmia, acute myocardial infarction for at least 6 months, severe aortic stenosis, and uncontrolled systemic arterial hypertension (systolic blood pressure > 180mmHg and diastolic blood pressure > 110mmHg); any medical conditions that endanger the health of participants while performing aquatic exercises; receiving any sort of medication that could interfere with the study evaluations. Before the study was initiated, all participants provided full informed consent. They were free to leave the study at any time.

Results from those participants with less than 50% sessions attendance were also removed from the study analysis. Protocols and experimental design followed the principles of the Declaration of Helsinki and were approved by the Ethics Committee of the Faculty of Sport Sciences and Physical Education (FCDEF) - University of Coimbra (Reference: CE/FCDEF-UC/00462019). This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science, 12(1): 1-8, 2019 (38).

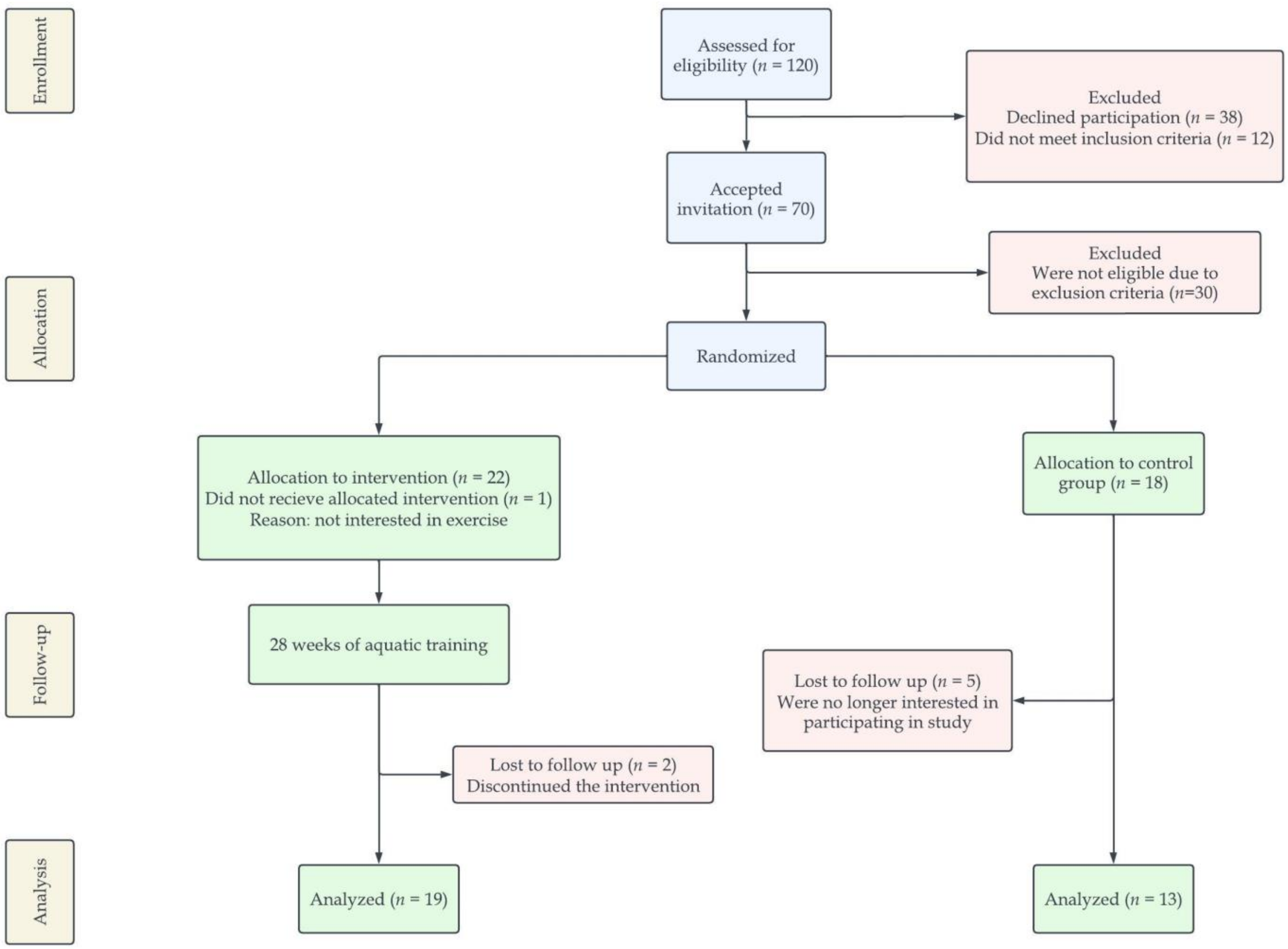

Figure 1. Flowchart of participant recruiting.

Protocol

Instruments and measurements: Height was assessed using a portable Seca Bodymeter® stadiometer (model 208, Hamburg, Germany) with an accuracy of 0.1 cm. Data including age, stature, and gender were entered in the TANITA BC-601 impedance scale (Tokyo, Japan), then participants were placed on a scale with minimal clothing, without shoes, metal, and electrical equipment to calculate body mass, body mass index (BMI), visceral fat, percentage of fat, and muscle mass. Waist, arms and legs circumferences were measured as previously described according NIHR Southampton Biomedical Research Centre Procedure for Measuring ADULT CIRCUMFERENCES (37). A specialist measured heart rate and blood pressure with

Sphygmomanometer (Riester, Model RI-championN®). The Senior Fitness Test (SFT) was used to indirectly assess the main physical parameters associated with functional and motor ability, and to identify whether an older adult might be at risk of functional inability. The SFT is a safe and easy-to-administer test that has been validated in several countries (15). It includes simple and practical tests of moderate intensity that can be used by older adults of all levels of ability. The strength of the lower and upper limbs was assessed using the chair stand test and arm curl test respectively (repetitions/30 s); aerobic capacity was assessed using the two-minute step test (number of steps); flexibility of lower and upper limbs was tested with the chair sit and reach test, and back scratch test, respectively (centimeters); agility and dynamic balance were assessed through the timed up and go (TUG) test (seconds). Hand strength was measured through the handgrip test using the Jamar hand dynamometer (Lafayette Instrument Company, Lafayette, IN, USA) (kg) (44). All assessments were repeated after the exercise intervention.

Blood collection and biochemical analysis: Participants were asked to refrain from exercise 72 hours prior to blood sampling, as well as to maintain their normal diet. Participants were asked to present in the sampling location at 8 o'clock in the morning. After a 10-minute rest, a fasting (12 h) blood sample (7 mL) was collected from participants through the brachial vein. Following collection into a serum tube and an ethylenediaminetetraacetic acid (EDTA) containing tube, they were centrifuged at 3500 rpm for 10 min, then stored in aliquots and kept at −80°C until time of analysis. Total cholesterol, Triglyceride, LDL-cholesterol, and HDL-cholesterol were analyzed with an enzymatic method using an automatic analyzer (Auto-analyzer Hitachi 7150, Japan) (3). Blood glucose was measured using an automatic blood glucose analyzer (YSI 2300, NH, USA) (34). Homeostatic Model Assessment for Insulin Resistance (HOMA IR) was calculated using the formula: fasting insulin concentration (IU/mL) × fasting plasma glucose (mmol/L)/22.5. Leptin and insulin were measured with ELISA kits (Crystal Chem, USA) with sensitivities of 0.42 ng/mL and 25 mU/L, respectively. Measurements were conducted according to the manufacturer's instructions that accompanied the kits, with no changes in technique (10). After 28 weeks of aquatic training, blood was collected from both the participants in the control and the experimental groups, in a similar manner to the first stage. Blood was collected 48 h after the last training session. The control group did not participate in any of the exercise sessions and was instructed to keep their usual daily habits.

Exercise protocol*:* In our study, we opted for moderate combined aquatic exercise for a longer duration to address the lack of such interventions in the scientific literature (31). We considered factors like exercise intensity, safety, and feasibility for our overweight healthy older adult participants. In accordance with the recommendations of the American College of Sports Medicine (43), all physical exercise programs were conducted by qualified physical exercise technicians (with a degree in sports science) who specialize in hydrogymnastics (instructor course-level 1). The experimental group performed the head-out aquatic exercise in a swimming pool with water level between 0.80 m and 1.20 m and temperature of 30-32 degrees Celsius for 28 weeks, regularly for 2 sessions per week (non-consecutive days), adjusted with health guidelines. Each session was formed by three parts: warm-up, main activity and cool down. The warm-up had a duration of 10 minutes and included movements such as walking, pushing and

pulling for the purpose of adaptation to the water environment, muscular acclimatization and preparation for metabolic demands as well as articular mobilization. The main section lasted for 20-30 minutes and was made up of a combined exercise protocol (aerobic and resistance).
In the continuous aerobic phase, individuals performed exercises at the intensity of 60 to 65 % of the maximum heart rate reserve (HRR) (weeks 1 to 12). The chosen heart rate reserve range aligns with a moderate-intensity level, known for its effectiveness and safety, particularly in providing potential cardiovascular benefits (43). From week 13 to 28, intensity increased to reach the target of 65 to 70 % HRR. By selecting this moderate intensity, we aimed to offer a practical and well-tolerated exercise program that encouraged adherence over the 28-week intervention period. Basic water aerobic exercises were carried out with some variations (running, bouncing, kicking, pendulum jumping, skiing, twister, and horse). Due to the effect of water immersion on HR at maximal effort and anaerobic threshold, the rate of perceived exertion (RPE) was also used alongside HRR to control training intensity (The Borg Scale 6-7). The resistance phase included 4 to 6 different strengthening exercises of the upper, lower body and torso. In this phase, the participants used auxiliary equipment, such as hand weights and pool noodles (e.g., elbow extension/flexion, shoulder extension/flexion, shoulder abduction/adduction, hip abduction/adduction, hip flexion/extension, knee flexion/extension, dorsal and plantar flexion of the ankle.). The Borg Scale (6-7) was used to control the intensity. The exercises were performed in 2 series of 12 repetition each (from weeks 1-12) and in 3 series with 16 repetitions each (from weeks 13-28). The exercises continuously alternated between the muscle groups with no resting time between series in other to avoid decreases in body temperature.

The cool-down part had a duration of 5 to 10 minutes; with two stages: primarily relaxing exercises were applied to return the participants' heart rate (HR) to a resting value. The second stage included stretching movements in which exercised muscle groups underwent stretch to decrease the level of lactic acid and the possibly post-exercise pain. For the purpose of safety track and intended intensity control, participants were monitored by Polar heart rate monitors (R800CX) during exercise sessions. The intensity was indirectly calculated using the following equation (21):

Target HR = ((MaximumHR - Resting HR) % intensity) + Resting HR (1)

Besides, to calculate the maximal heart rate (HR), the Franklin, Whaley and Howley (2000) formula for the older population was used (Franklin, Whaley, Howley, & Medicine, 2000):

Maximal HR = 207 beats per minute - (0.7 x chronological age) (2)

Statistical Analysis
Descriptive statistics were computed and normal distributions of all variables were assessed with the Shapiro-Wilk test and the homoscedasticity was assessed with the Levene test. The two groups were compared using the Univariate Analysis of Variance (ANOVA). The Paired t-test was used to compare paired data. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) statistical software, version25.0. The level of significance used was

$p \leq 0.05$. The mean values between and within groups were shown in a table and bar chart in the pre-post setting.

RESULTS

The participants characteristics are presented in Table 1. There are no significant differences between the two groups in terms of body composition indices and anthropometric variables at baseline. After 28 weeks of aquatic exercise, body fat percentage [$t_{(18)} = 3.95$, $P = 0.001$], waist circumference [$t_{(18)} = 4.19$, $P = 0.001$] and leg circumference [$t_{(18)} = 2.11$, $P = 0.04$] significantly decreased, and fat-free body mass percentages [$t_{(18)} = -3.46$, $P = 0.003$] increased in the EG (Table 2).

Table 1. Baseline characteristics of sample.

	EG (*n* = 19)	CG (*n* = 13)	*P*-value
Sex			
Men	5(26)	6(46)	0.26
Women	14(74)	7(54)	
Age (years)	71.16 ± 5.91(65-86)	73.38 ± 5.81(65-82)	0.30
Weight (kg)	72.77 ± 10.49	70.96 ± 12.36	0.66
BMI (kg/m^2)	29.48 ± 4.22	27.51 ± 4.0	0.19
Heart rate (Beats/min)	75.10 ± 13.02	71.30 ± 10.88	0.39

Values expressed as (%), mean ± SD (range), EG: exercise group; CG: control group; BMI: body mass index.

Table 2. Intra-group and inter-group comparison of the means for body composition and anthropometric variables.

Variables	Groups	Pre-test	Post-test	Intragroup differences		Differences between groups		
				t	*P*	*F*	*P*	*ES*
Weight (kg)	EG	72.77 ± 10.49	72.49 ± 10.12	1.033	0.315	0.04	0.834	
	CG	70.96 ± 12.36	71.87 ± 12.39	-1.985	0.07			0.001
BMI (kg/m^2)	EG	29.48 ± 4.22	29.45 ± 4.06	0.24	0.813	0.034	0.854	
	CG	27.51 ± 4	27.86 ± 4.01	-1.882	0.084			0.001
Body fat (%)	EG	39.40 ± 9.48	37.66 ± 9.92	3.958	0.001*	0.192	0.663	
	CG	32.77 ± 7.81	33.02 ± 7.12	-0.774	0.454			0.003
Fat Free Body mass (%)	EG	25.6 ± 4.19	26.91 ± 4.77	-3.466	0.003*	0.511	0.477	
	CG	28.77 ± 3.45	28.6 ± 3.39	0.905	0.383			0.008
Visceral fat (%)	EG	12.57 ± 3.65	12.47 ± 3.33	0.697	0.494	0.002	0.961	
	CG	12.23 ± 5.11	12.23 ± 5.13	0.0	1.0			0.000
Waist circumference(cm)	EG	104.13 ± 9.66	99.23 ± 9.14	4.199	0.001*	0.874	0.354	
	CG	97.63 ± 15.70	98.45 ± 14.51	-0.534	0.603			0.014
Right arm circumference(cm)	EG	32.15 ± 3.09	31.74 ± 2.64	1.212	0.241	0.044	0.834	
	CG	30.81 ± 3.06	30.70 ± 2.36	0.233	0.82			0.001
Left arm circumference(cm)	EG	31.64 ± 2.64	31.24 ± 2.63	1.342	0.196	0.039	0.845	
	CG	30.61 ± 2.48	30.46 ± 2.25	1.052	0.314			0.001
Right leg circumference(cm)	EG	53.98 ± 5.70	52.52 ± 5.71	1.893	0.074	0.084	0.773	
	CG	51.96 ± 4.76	51.25 ± 3.05	0.545	0.596			0.001
Left leg circumference(cm)	EG	53.62 ± 5.91	51.93 ± 6.13	2.117	0.048*	0.159	0.692	
	CG	51.0 ± 4.23	50.37 ± 3.61	0.725	0.482			0.003

*Indicates $P < 0.05$; ES: effect size; BMI: body mass index; EG: exercise group; CG: control group.

As reported in Table 3, no significant differences were found in glucose, insulin, insulin resistance, leptin, lipid profile indices (Total cholesterol, HDL cholesterol, LDL cholesterol, Triglyceride) and systolic and diastolic blood pressure between the groups following the exercise intervention ($p > 0.05$). However, total cholesterol showed a trend towards a decrease in the EG ($p = 0.053$) and a significant increase in the CG ($P = 0.015$). Overall, the lipid profile showed a tendency to improve in the EG while in the CG values showed the opposite trend. Both systolic [$t_{(18)} = 3.43$, $P = 0.003$] and diastolic [$t_{(18)} = 3.86$, $P = 0.001$] blood pressure significantly improved after 28 weeks of aquatic exercise. As shown in Figure 2, after 28 weeks of the combined aquatic exercise protocol, significant differences were found in physical function indices including aerobic endurance [$F_{(1,60)} = 7.521$, $P = 0.008$, $\eta^2 = 0.111$] and lower body flexibility [$F_{(1,60)} = 3.991$, $P = 0.049$, $\eta^2 = 0.062$], [$F_{(1,60)} = 7.015$, $P = 0.010$, $\eta^2 = 0.015$] when compared with the CG. Also, upper body flexibility ($P = 0.001$, $P = 0.020$), lower and upper body strength ($P = 0.001$, $P = 0.031$) and handgrip ($P = 0.001$, $P = 0.006$), showed significant differences within the EG.

Table 3. Intra-group and inter-group comparison of the means of biomarkers blood levels and blood pressure.

Variables	Groups	Pre-test	Post-test	Intragroup differences		Differences between groups	
				t	*P*	*F*	*P*
						ES	
Glucose (mg/dl)	EG	87.0 ± 16.6	85.0 ± 11.9	-0.846	0.397	0.345	0.559
	CG	94.6 ± 15.6	97.3 ± 19.5	-0.617	0.106	0.006	
Insulin (mU/L)	EG	4.3 ± 2.1	4.7 ± 3.2	-0.644	0.519	0.369	0.546
	CG	5.2 ± 4.3	4.6 ± 3.0	0.979	0.328	0.006	
Leptin (ng/ml)	EG	37.6 ± 32.0	38.1 ± 34.0	-0.161	0.872	0.008	0. 928
	CG	17.0 ± 11.9	16.4 ± 12.4	0.754	0.314	0.001	
Insulin resistance	EG	0.97 ± 0.5	1.0 ± 0.8	-0.684	0.754	0. 244	0. 623
	CG	1.2 ± 1.1	1.1 ± 0.8	0.874	0.382	0.004	
Total cholesterol (mg/dl)	EG	190.52 ± 28.77	180.31 ± 20.60	2.067	0.053	1.89	0.174
	CG	177.15 ± 28.05	185.92 ± 31.68	-2.835	0.015*	0.031	
HDL cholesterol (mg/dl)	EG	58.05 ± 9.33	57.94 ± 10.28	0.074	0.942	0.567	0.454
	CG	58.84 ± 12.83	54.61 ± 11.19	3.134	0.009*	0.009	
LDL cholesterol (mg/dl)	EG	109.94 ± 27.78	106.42 ± 20.78	0.796	0.436	0.177	0.675
	CG	99.38 ± 27.36	101.23 ± 27.29	-0.389	0.704	0.003	
Triglycerides (mg/dl)	EG	100.73 ± 34.08	93.94 ± 35.87	0.979	0.34	0.575	0.451
	CG	109.76 ± 26.6	115.15 ± 24.28	-0.741	0.473	0.009	
Systolic blood pressure (mmHg)	EG	135.73 ± 16.20	128.84 ± 15.15	3.433	0.003*	0.382	0.539
	CG	132.92 ± 14.94	131.15 ± 19.12	0.557	0.588	0.006	
Diastolic blood pressure (mmHg)	EG	79.84 ± 8.11	73.52 ± 8.28	3.867	0.001*	2.448	0.123
	CG	77.53 ± 7.58	77.53 ± 7.43	0.0	1.0	0.039	

*Indicates $P < 0.05$; ES: effect size; BMI: body mass index; EG: exercise group; CG: control group

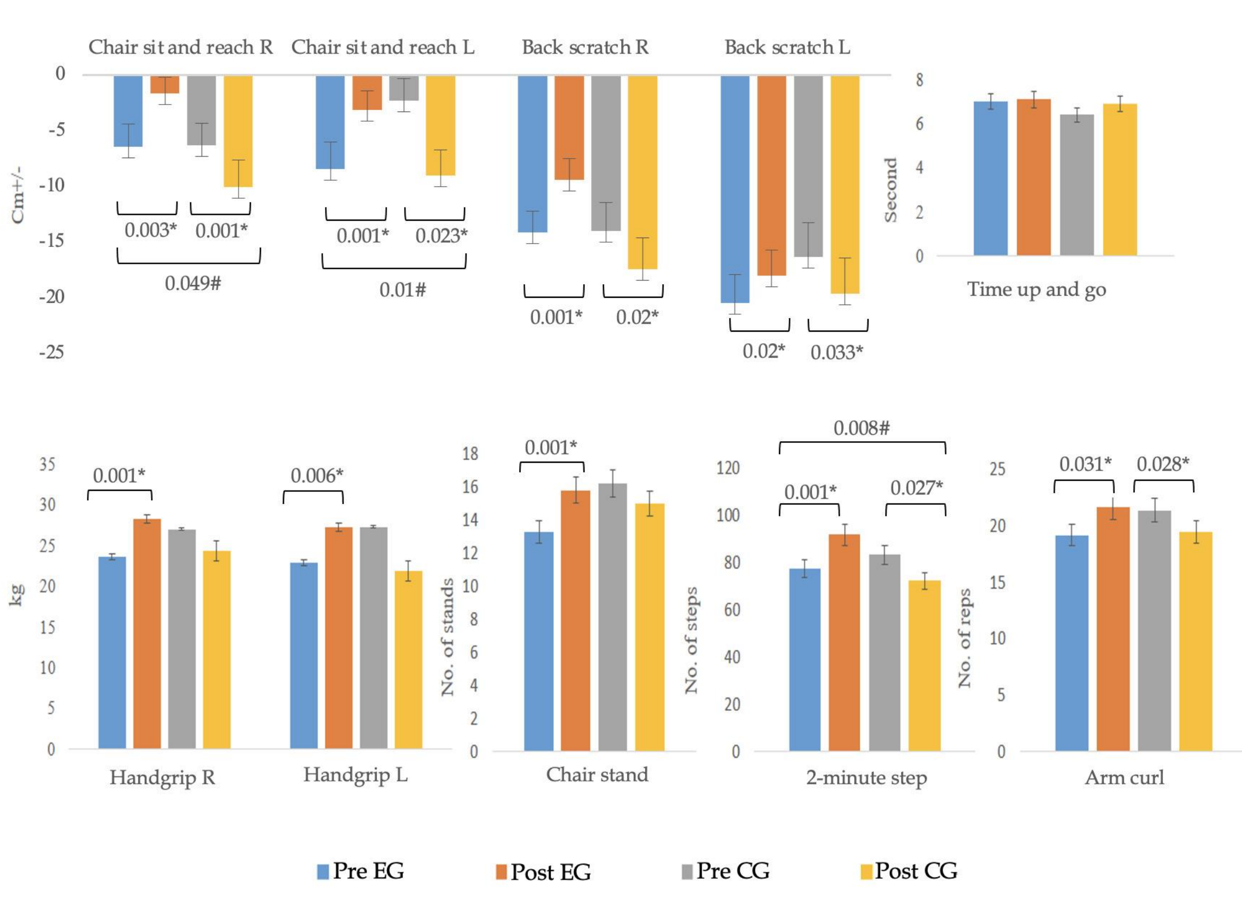

Figure 2. Comparing physical function variables among aging subjects within and between groups.

DISCUSSION

Our results showed that 28 weeks of water-based training greatly improved the physical performance of the overweight older participants. Also, significant improvements were found in body fat and fat-free body mass percentages and in blood pressure.

The present study showed that combined aquatic exercise did not significantly alter serum leptin concentrations. Research suggests that leptin plays a crucial role in glucose and energy balance. But, the response of circulating leptin to exercise training has been contradictory (13, 41). It seems that factors such as age, gender, training status, and exercise modality and intensity contribute to the divergent results. The present study, which investigated the effects of aquatic exercise, differs from the study conducted by Rezaeimanesh and Farsani (2019) that has been on leptin among adults who have type two diabetes. The authors reported a significant decline in leptin levels after 8 weeks of moderate aquatic aerobic exercise (42). Aquatic exercise may be advantageous as it has been shown to have a great drag force and viscosity that contributes to energy expenditure. In agreement with our results, Fico et al. (2020) and Markofski et al. (2014) did not observe significant changes in serum leptin levels in adults and older adults (33).

Markofski and colleagues evaluated the effect of 12 weeks of exercise training (treadmill walking at 60%–70% of heart rate reserve followed by two sets at 80% 1RM of resistance exercises) on adipokines and assessed the possible relationships with inflammatory markers. No significant change was found in leptin (33). A recent study reported that in absence of weight loss and body fat changes, exercise might have a minor to no effect on leptin (18). In our study, though a significant decrease was seen in body fat of the EG (4.4%), it was not significant enough to induce leptin changes. A review suggests that a minimum of 10% weight loss is necessary to induce those effects (24). Furthermore, caloric restriction (> 800 kcals) is essential for exercise to induce a significant reduction in leptin (7). It is also known that leptin has a strong positive correlation with BMI and waist circumference. In overweight individuals, leptin levels increase with BMI and waist circumference suggesting that the amount and size of fat depots need to decrease if change in leptin levels is to occur (35). In the present study, the insulin and insulin resistance values did not change. This absence of change may be due to the fact that participants were healthy and had desirable insulin sensitivity. The unchanged resting insulin levels could also be due to the lack of alteration in serum leptin. Furthermore, no significant improvements were seen in glycemic control, although a trend for a decrease in fasting glucose levels in the EG was present. The insignificant change in the present study is consistent with the studies conducted by Lopes et al. (2015), and Fico et al. (2020) in obese individuals. In these studies, neither swimming nor walking in the water with moderate intensity improved glucose and insulin levels (13, 30). In contrast, Karimi et al in 2018 reported that an aquatic exercise program, at an intensity of 60% - 70% of maximum heart rate lasting for 60 to 70 minutes significantly decreased glucose plasma levels in men with obesity (20). The glucose counterregulatory response which adjusts blood glucose at a constant level is done by the secretion of hormones like glucagon, adrenaline, cortisol, and growth hormone. This adjustment, which is linked with autonomic and neuroendocrine responses, is under the effect of exercise that contributes to energy expenditure. It seems that the lack of change in glucose levels could be due to balancing metabolic hormones and shifts in the activity of the autonomic nervous system under the effect of the combined exercise(48, 51).

The results of this study demonstrated that 28-weeks of whole-body combined aquatic exercise significantly improved certain measures of functional ability (e.g., aerobic endurance and lower body flexibility). Our study results revealed that when adjusting for baseline levels, the aquatic group significantly increased aerobic endurance, and lower body flexibility compared to the control group. The baseline mean values of the 2-Minute Step Test in our groups were higher than the cut-off point for the risk of functional loss (65 steps) (40), indicating that our population had a good level of physical fitness. After implementing the aquatic program, the intervention group demonstrated a significant improvement in aerobic endurance. It was found that 84% (16 participants) of those in the EG group exceeded the cutoff value (data not shown). Conversely, the control group experienced a statistically significant decrease in the test scores, with approximately 30% of the participants' test values falling below the recommended functional threshold. Previous aquatic exercise interventions have demonstrated the benefits of water-based impact on a variety of populations(23, 52). Fiksen et al., (2015) and Silva et al., (2019) studied a group of older adults who aquatically trained over twelve weeks and found similar results to those in this study for aerobic endurance, and lower body flexibility variables (2min step tests, sit and reach test(14, 45). In Silva et al, study, the aquatically trained individuals significantly increased flexibility, TUG and Balance variables, whereas the control group failed to yield significant improvements in any of the variables. In the present study, the aquatic exercise also elicited significant improvements in upper body flexibility measured by scratch test. Furthermore, the EG showed significant improvement in arm curl and the chair sit and stand test. This suggests that the combined components integrated into the aquatic exercise program not only increased leg strength but also increased upper body strength. In contrary to Fiksen's study, the maximum isometric strength of hand and forearm muscles which were assessed by handgrip improved significantly (19.5%) (14). The cutoff points of handgrip strength, balancing sensitivity and specificity for mobility limitation, were reported to be 25.8 kg for men and 17.4 kg for women (47). In our study, the mean handgrip strength for the EG group (comprising 74% women) was initially 22.9 kg, which significantly improved to 27 kg after the completion of the aquatic exercise program. Particularly, 89% (17 participants) of the EG group exceeded the cutoff value (data not presented). These muscle improvements were confirmed by a significant increase in fat free body mass in the exercising group. The findings of this study did not demonstrate a significant difference in TUG scores between the EG and the CG. Both groups increased in their TUG measures, but the EG only worsened by 1.4% when compared to the 7.8% in the CG which is consistent with the findings of Hale et al., (2012) (17). Many studies have verified the potential of water properties, such as buoyancy, viscosity and immersion to induce a vast array of effects on musculoskeletal, neurological, and cardiopulmonary systems. It is a unique exercise mode that provides an environment for concurrent aerobic and strength training which could be the safest environment for overweight and older persons (4). In our study, the aquatic program was designed so that exercises mimicked everyday activities. The aquatic environment up to the xiphoid allowed participants to exercise at an increased velocity and with a full range of motion while controlling weight-bearing on joints. As a matter of fact, shallow water decreases the buoyancy and raises ground reaction force resulting in changes in the neuromuscular pattern of active muscles at different water levels. Additionally, buoyancy can provide all three methods of exercise; assistance, support, and resistance. Also, water viscosity commanded more involvement of the motor cortex, consequently increasing motor neurons firing, reflecting the increase in muscular strength and possibly the physical function (1). Hence, the mechanism behind physical function improvement was helped by water properties. Moreover, in the current study, both systolic and diastolic pressure significantly improved in the exercise group. The hydrostatic pressure is capable of facilitating venous return, aids fluid returning to the heart and lymph which triggers the increase in cardiac filling volume and reduces heart rate and blood pressure (8). In addition, heated water ranging from 30 to 32°C, the same as in our study, stimulates a reduction in peripheral vascular resistance due to dilatation of arterioles (5). Finally, in our study, no significant difference was detected in the lipid profile of the older people. It appears that major changes in cholesterol levels may also require dietary changes. However, an insignificant decrease (5.3%) in total cholesterol in the EG ($P = 0.053$) and a significant increase in the CG implies the protective effect of aquatic on total cholesterol.

The study's limitations include a small sample size and unbalanced gender participation, which may have potentially influenced the results. The lack of external validity in this study calls for caution when interpreting the benefits of aquatic exercise, as the findings are confined to a limited sample size of participants and may be influenced by gender biases. Another limitation of the study was an absence of a dietary plan to regulate caloric intake. Future studies should measure other adipokines (like adiponectin) and inflammatory markers to provide a better perception of the effect of the exercise intervention and potential mechanisms in the prevention of metabolic and cardiovascular diseases.

In summary, the previous literature and the data collected in this study suggest that combined aquatic exercise can be beneficial in preventing hypertension, enhancing functional abilities, and reducing disabilities among overweight older individuals. However, it is important to note that the study did not result in significant changes in resting serum leptin levels, glucose levels, and insulin resistance under stable weight conditions. Nonetheless, the positive impact of exercise on health parameters remains evident, making it a worthwhile area of research, especially for the specific population of overweight older adults. It is recommended that future studies should include the incorporation of a training program with varying levels of intensity and duration. Moreover, it would be beneficial to involve participants from different age groups, and fitness levels to gain a more comprehensive understanding of the effects. Additionally, to enhance the study's validity, controlling for diet and nutrition factors should be taken into consideration.

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