Aquatic Resistance Training: Acute and Chronic Effects

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ABSTRACT

THE WATER ENVIRONMENT HAS ADVANTAGEOUS PHYSICAL PROPERTIES FOR EXERCISE, AND IT IS AN ALTERNATIVE AND COMPLEMENTARY TOOL TO PERFORM RESISTANCE TRAINING (RT). RESEARCH IN WATER-BASED EXERCISE HAS BEEN FOCUSED ON AEROBIC EXERCISE, AND LITTLE IS KNOWN ABOUT THE EFFECTS OF RT IN WATER. THIS NARRATIVE REVIEW PROVIDES A COMPILATION OF THE STUDIES REGARDING ACUTE AND CHRONIC EFFECTS OF RT IN WATER AND INITIAL GUIDELINES BASED ON THE EVIDENCE. FOR A VIDEO ABSTRACT OF THIS ARTICLE, SEE VIDEO, **SUPPLEMENTAL DIGITAL CONTENT 1** HTTP://LINKS.LWW.COM/SCJ/A136.

INTRODUCTION

The benefits of resistance training (RT) have been well established during the past decade (1,2). Additionally, aquatic resistance exercise has been proposed as an ideal mode of RT in older adults to improve strength, power, cardiometabolic risk factors, bone mineral density, and psychological function and to reduce some of the risks of RT (1). Walking-running in deep water, walking-running in shallow water, aquatic bicycle, and RT exercises in a vertical position in water are the alternatives that are increasing their popularity in the sedentary population or in one without swimming abilities (43). Head-out aquatic exercises have also become a major element in rehabilitation programs for several diseases, for physical condition, and to enhance sport performance in athletes (7,8,37). The water environment has advantageous physical properties for exercise, and it is an alternative tool to perform RT.

The purpose of the present article is to give an overview of the existing literature with respect to several issues related to RT in water. This article will begin by providing the acute effects of RT in water, based on impact forces, muscular damage, hormonal responses, and muscle activation. The article will then provide the chronic effects of RT in water on strength, power, functional capacity, flexibility, balance, peak oxygen uptake ($\dot{V}O_2$peak), body composition, cardiometabolic risk factors, and other outcomes. Subsequently, effects of the equipment and water temperature will be reviewed. Based on these studies, the article will provide practical guidelines to prescribe RT programs in water.

ACUTE EFFECTS OF RT IN WATER

IMPACT FORCES

In the water environment, activities are performed with lower body-weight in relation to the degree of immersion, and therefore, it is an efficient and secure alternative to increase cardiorespiratory fitness and strength (15,56). Owing to the flotation component in water, the compressive forces in the joint articulations are weaker, and therefore, injuries and falls are minimal (19). For this particular reason, it is an ideal form of exercise for the obese, elderly, and patients with osteoarthritis, osteoporosis, or low back pain (9,43,56,60). Weightbearing exercise may not be the most appropriate for all the individuals because it may reveal contraindications or limitations toward the activities of this nature (43). Masumoto and Mercer (40) indicated that the reduction of body weight in relation to the immersion level is (a) 43% lower at the cervical vertebrae 7; (b) 29% lower at the

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xiphoid process, and (c) 15% lower at the anterior superior iliac spine.

Water is also an optimal environment for athletes performing jumps because impact forces are lower and peak concentric forces are higher than on dry land (21,57). In addition, performing jumps with single leg and with drag force equipment enhances peak concentric forces and reduces impact forces (30,57). During shallow water aerobic exercises, ground reaction forces (vertical peak and loading rate) are lower in water than on land (3,27) and the higher the level of immersion, the lower the magnitude of vertical peak forces (27,33). In water, forces applied to the body show a reduction of 40% at the anterior superior iliac spine and a reduction of 50% at the xiphoid process, in comparison with the land environment (27). However, running on a treadmill or shallow water running at waist depth produces similar spinal shrinkage changes after 30 minutes (31). These findings are of tremendous practical importance for power training because similar benefits to dry land training might be achieved with power training in water, with a lower risk for injury.

EFFECTS OF AQUATIC RT ON MUSCULAR DAMAGE AND HORMONAL VARIABLES

There are few studies on acute effects of RT in water regarding muscle damage and hormonal variables. To the best of our knowledge, there are only 2 studies about these topics.

Muscle damage may be absent after RT performed in water. Pantoja et al. (44) have compared muscle damage after similar RT performed on dry land versus in a water environment. The RT protocol consisted of 3 sets of maximum elbow flexion and extension. A 10-repetition maximum (RM) test was used to load the control group on land with free weights. In water, the exercise was performed at maximal velocity with aquatic drag resistive equipment. The duration of the exercise was the same on land and in water to reproduce the same metabolic response. Plasma creatine kinase was significantly greater (about double) after 48 hours on land, and no significant differences were found in water. Thus, the authors concluded that RT in water can be performed with greater frequency than on land because of a more rapid recovery.

RT in water may stimulate salivary testosterone both in young and older adults (14). Water-based exercise with emphasis on strength development was found to stimulate a more acute increase in salivary testosterone than water-based aerobic exercise, probably as a result of the higher intensity used in that training protocol (14). Thus, it is important to prescribe training sessions that are sufficiently intense to optimize the stimulus to anabolic hormones, especially to increase strength and perhaps muscle mass in elderly subjects.

MUSCLE ACTIVATION IN WATER ENVIRONMENT

Surface electromyography (EMG) is the most common way to analyze muscle activation during the performance of exercises (55). Investigators assume that exercises that produce higher EMG signal amplitudes also generate larger strengthening effects (6,29). EMG in water is a reliable technique to analyze muscle activation whenever a proper waterproofing procedure is implemented (17,48,49,54).

During repeated trials in water, concentric agonist activity decreases with a simultaneous increase in antagonist muscle activity during the final range of movement during knee flexion and extension (51). This is because of the movement of the leg, which continues to move because of the flow of the water as a result of the inertia. It is necessary to decelerate the movement with an anticipatory change of direction, thus the early eccentric activity of the antagonist. This can also be defined as a stretch-shortening cycle type of exercise. However, in a single trial effort in water, antagonist activity is low and agonist activity is high and prolonged during the whole range of movement. Additionally, angular velocities show similar values between single and repeated exercises. Therefore, repeated movements in water involve both concentric and eccentric muscle actions, and single movements in water involve concentric muscle actions purely and have similar EMG patterns to isokinetic machines because the action of gravity is minimal, and angular velocity is fairly constant (51).

Few studies have evaluated EMG during the performance of RT exercises in water. Pinto et al. (46) analyzed 15 women performing stationary aquatic jogging combined with elbow flexion and extension without devices, with drag device, and with floating device at submaximum (80 and 100 beats per minute) and maximum cadences. For all muscles, the exercise performed at maximal cadence showed significantly higher values than those performed at submaximal cadences, except for the triceps brachii. For submaximal cadences, the results indicated a similar pattern for all muscles, without significant differences between 80 and 100 beats per minute, except for the biceps femoris.

Some of the studies involving EMG during RT exercises in water have evaluated trunk muscles that stabilize the spine (also called core). RT should include core training to prevent and rehabilitate low back disorders, frequently in the sedentary population, healthy trained people, and elite athletes (9). Erector lumbar spinae muscle activation is higher in water than on dry land when performing the same exercise of horizontal shoulder abduction and adduction and at the same intensity controlled with the rate of perceived exertion scale (23). Additional instability caused by water currents significantly increases erector lumbar spinae activation (23).

When performing an aquatic resistance exercise at maximal velocity, different devices (i.e., small/large and drag forces/floating) generate similar core muscle activation (20). Bressel et al. (12) analyzed the performance of 4 trunk abdominal exercises in water and on land, finding out that the activation of most core muscles was greater in all the exercises performed on land compared with water. The authors explained it by the flotation component and recommended the performance of these exercises in water in the first phases of low back disorder rehabilitation. Furthermore, aquatic exercises, such as abdominal bracing, stability ball push-downs, and lateral push-downs, maximize trunk muscle activity, whereas abdominal hollowing and pelvic tilt minimize muscular activation (13).

With regard to water immersion depth, xiphoid depth optimizes muscle activation of the agonist muscle in comparison with clavicle depth (20). Additionally, different depths do not modify core muscle activation significantly, although there is a tendency for lower immersion depth to increase core muscle activation (20). Thus, if maximum activation of the prime mover is required, lower immersion is a better choice (20).

Based on the review of the scientific evidence of acute effects of RT in water, the Table summarizes relevant intervention studies.

CHRONIC EFFECTS OF RT IN WATER

EFFECTS OF RT IN WATER ON STRENGTH

RT in water is effective to improve strength in both men (10,24,35) and women (26,42,47,52,58), and both young (24,47,52) and older adults (10,26,32,42,56). Strength has been measured with different methods (i.e., 1RM, 3RM, 10RM, isokinetic and isometric tests, and functional tests), and improvements are present when RT is integrated in the water-based exercise or when RT is performed unaccompanied. Pinto et al. (47) showed that intrasession exercise order during concurrent training in a water environment is important, and they concluded that RT must be performed before aerobic training to optimize strength and muscle thickness gains.

EFFECTS OF RT IN WATER ON PHYSICAL CAPACITY

Power (24,56,58), functional capacity to perform daily living activities (10,36,56,58), flexibility (11,26,35,58), and $\dot{V}O_2$peak (42,47,56) seem to increase after water-based exercise, which involves RT. However, Jones et al. (34) found no significant improvement in $\dot{V}O_2$peak after 12 weeks of combined moderate-intensity water-based exercise. Only 1 study measured balance, and no differences were found in comparison to baseline (36). In the studies where RT was performed unaccompanied, power, functional capacity, and flexibility improved; nevertheless, $\dot{V}O_2$peak only improved in combined exercise training. More studies are required to analyze the influence of RT in water performed unaccompanied on $\dot{V}O_2$peak and balance. It seems that intrasession exercise order during concurrent training does not influence $\dot{V}O_2$peak improvements (47). Additionally, RT in water is as effective as training on dry land with elastic bands or weight machines to improve strength and functional capacity to perform daily living activities (22).

EFFECTS OF RT IN WATER ON BODY COMPOSITION

Water-based exercise, including RT, shows similar effects to land-based exercise. RT performed unaccompanied or in combination with aerobic exercise leads to decreased fat mass and some reduced circumferences and skinfolds (22,34,42,59) and also leads to increased muscle mass (24,26,47,52). However, studies that show improvement in muscle mass have not used dual x-ray absorptiometry, which is the "gold standard" because it is the most highly developed technique and the most thoroughly validated biologically. Body mass index and total weight decreased in some studies (26,59), whereas no changes were found in other studies (34,42,56). Interestingly, Colado et al. (24) found a significant increase in body weight after only 8-week intervention in fit young men performing RT alone, as a result of the improvement in fat-free mass. Further studies with "gold standard" equipment are needed to assess the effects of RT in water on body composition.

EFFECTS OF RT IN WATER ON CARDIOMETABOLIC RISK FACTORS

Some studies found significant improvement in triglycerides (59), total cholesterol (56,59), low-density lipoprotein cholesterol (LDL-c) (56), fasting glucose and insulin levels in impaired glucose tolerance subjects (34), and diastolic blood pressure (26). However, other studies found no change in triglycerides (26,56), total cholesterol (26), LDL-c (26,59), high-density lipoprotein cholesterol (26,56,59), fasting glucose in subjects with normal glucose tolerance (26,34), fasting insulin in subjects with normal glucose tolerance (34), and diastolic (56) and systolic (26,56) blood pressure. Interestingly, Colado et al. (26) showed a significant increase in cholesterol, LDL-c, and glucose in the control group, and experimental group remained unchanged. Most of these studies performed a combination of aerobic training and RT. Effects of RT in water on cardiometabolic risk factors are blurred; thus, more research is needed.

EFFECTS OF RT IN WATER ON OTHER OUTCOMES

Rotstein et al. (53) showed that an experimental group maintained or improved bone status in spinal vertebrae L2-L4, whereas in a control group bone status declined. The training protocol was composed of a combination of 20 minutes of aerobic training and 20 minutes of RT with different exercises and devices during 7 months. On the contrary, Bravo et al. (11) found no improvements in bone mineral density at L2-L4 and femoral neck in 77 postmenopausal women. Patients with coronary artery disease can participate in water-based exercise 4 times per week with similar improvement as land-based exercise (59). Interestingly, these patients have improved exercise tolerance and circulatory stress in comparison with a control group. Kargarfard et al. (35) showed significant improvements

Table Effects of resistance training in water environment							
Study	Population	Age (y)	Length (wk)	Exercise description	Use of equipment	Outcome measures	Physiological responses
Bento et al. (10)	Elderly (N = 37)	60–76	12	CG EG = 3 sessions/wk of 60 min: 20 min of aerobic exercise at 12–16 in Borg Scale (6–20) and 20 min of RT for the lower limbs: 40-s exercise and 20-s rest increasing speed progressively using Borg Scale (6–20) from 12 to 16, in progression Water at xiphoid process	Water-resistive devices	Strength: peak torque, rate of torque development. Functional tests.	↑ Peak torque and rate of torque development for most of the muscles. ↑ Functional tests (sit and reach, 8-ft up and go test, and 6-min test), except 30-s chair stand test.
Bravo et al. (11)	Postmenopausal women (N = 77)	59.4 ± 5.5	52	SWT 3 sessions/wk of 60 min. 40 min of jumping and RT: 6 exercises, 1 set of 15–20 repetitions Water at waist height of the smallest subjects	None	BMD: L2 to L4 and femoral neck with DEXA. Flexibility. Agility. Coordination. Strength. Endurance. Psychological well-being.	↓ BMD at the lumbar spine. ≈ BMD at the femoral neck. ↑ Flexibility, agility, strength, endurance, and psychological well-being. ↓ Coordination.
Cardoso et al. (16)	Adult women (N = 34)	35–75	12	DWT 2 sessions/wk in progression, 2–6 sets, 10–30 s per exercise and 1 min to 1 min 40 s rest 4 EG: EG1 and EG2 = Emphasis on muscle strength using Borg Scale (6–20) in progression from 12 to 19 EG3 and EG4 = Without emphasis on muscle strength	EG1 and EG3 = resistive equipment in lower limbs (unspecified). EG2 and EG4 = resistive equipment in upper limbs (unspecified)	1RM: elbow flexors; elbow extensors; hip adductors (exercises performed in the program).	↑ Strength in all groups and all muscles without differences between EG, except for EG3 and EG4 in the hip adductor muscle. Emphasis on muscle strength is necessary for lower limbs to provoke significant increase. The use of equipment did not interfere in muscle strength.

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Colado et al. (22)	Sedentary postmenopausal women (N = 77)	53 ± 2	10	CG	Drag forces devices	Physical capacity: knee push-up, 60-s squats, abdominal crunch. Body composition.	↑ Physical capacity in all EG. ↓ Decreased fat mass in all EG. ↑ Fat-free mass in all EG, except for EG2, where fat-free mass was unchanged. In general, the effects of the training procedure were similar in the 3 EG.
				Same design for all EG, 2 sessions/wk, 1–3 sets, 20 repetitions, 30-s active rest and intensity with OMNI scale (0–10) from 5 to 7, in progression. EG1 = Elastic bands on dry land			
				EG2 = Shallow water			
				EG3 = Weight machine on dry land			
Colado et al. (24)	Fit young men (N = 20)	21.2 ± 1.17	8	CG	Drag forces devices	Body composition. Strength: 1 RM. Power: squat jump test.	↑ Strength, power, fat-free mass. ↓ Fat mass and some circumferences and skinfolds, especially in abdominal and pectoral regions.
				EG = SWT 3 sessions/wk in progression. 8–15 repetitions and 3–5 sets per exercise. Cadence of movement was adjusted individually for each exercise and subject			
Colado et al. (26)	Sedentary postmenopausal women (N = 46)	54 ± 2	24	CG	Drag forces devices	Physical capacity: sit and reach, knee push-up, 60-s squats, abdominal crunch. Body composition. Blood perfil.	↑ Physical capacity (except for abdominal crunch in EG2) in both EGs. ↑ Fat-free mass in both EG. ↓ Fat mass, BMI and waist circumference in both EG. ↑ HDL-c and ratio of total cholesterol to HDL-c only in EG2. ↑ Cholesterol, LDL-c, glucose, and waist circumference in CG, with both EG keeping constant. ↓ Diastolic BP in both EG.
				Same design for both EG in progression: 2–3 sessions/wk, 1–3 sets, 15–20 repetitions. Intensity with OMNI scale (0–10) from 5 to 7. EG1 = SWT			
				EG2 = elastic bands exercise on dry land			

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Graef et al. (32)	Elderly women (N = 27)	60–74	12	CG	Foam resistive equipment	1RM: pectoral fly machine.	↑ Strength only in EG1.
				EG1 = SWT with emphasis on strength: 35 min of aerobic training at intensity Borg scale (6–20) of 12–13 and 15 min of RT in progression, 4–5 sets, 8–15 repetitions, 90- to 120-s rest, performing exercises at maximal velocity at xiphoid process			
				EG2 = SWT without emphasis on strength: 50 min of aerobic training at intensity Borg scale (6–20) of 12–13			
				Both EG: 2 sessions/wk			
Jones et al. (34)	Overweight women (N = 15)	57 ± 4	12	DWT, 3 sessions/wk, 60 min, combination of aerobic (70–75% mode-specific maximum heart rate) and RT (60–90 s interspersed)	Resistive properties of the medium or foam dumbbells	Glucose and insulin responses. Anthropometry: weight, BMI, hip and waist circumferences, and waist-to-hip ratio. Aerobic fitness: DWR maximal test.	↓ Waist circumferences and waist-to-hip ratio in EG1. ↓ Waist circumference in EG2. ↑ Insulin and glucose responses in EG2.
				EG1 = subjects with normal glucose tolerance			
				EG2 = subjects with impaired glucose tolerance			
Kargarfard et al. (35)	Men with moderate hemophilia (N = 20)	20 ± 9	8	CG	None	Strength: Biodex isokinetic dynamometer. Flexibility: range of movement.	↑ Strength of flexion and extension of knees in both legs and range of movement in the knees, elbows, and ankles.
				EG = water, 3 sessions/wk, 40–60 min, combination of aerobic, flexibility, and RT, in progression. RT was performed at maximal velocity			

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Katsura et al. (36)	Healthy elderly individuals (N = 20)	69.1 ± 4.5	8	SWT, 3 sessions/wk, 90 min, flexibility, endurance, and RT based on walking at "moderately strong RPE levels" at 2 EG: EG1 = with equipment EG2 = without equipment	Drag forces device and rubber-tube devices	Physical characteristics: BMI, body mass, systolic and diastolic BP. Fitness test: flexibility, strength, functional tests, balance. Profile of mood state.	↑ Sit and reach, muscle strength of the triceps surae, TUG, 5-m maximum walking speed in EG1. ↓ Score of fatigue in EG1. ↑ Sit and reach, muscle strength of the triceps surae, and TUG in EG2. The 5-m maximum walking speed, 10-m obstacle walking time, and length with eye open exhibited significant improvements in EG1 compared with EG2. ≈ Physical characteristics, balance, and profile of mood state in both EG.
Kruel et al. (38)	Adult women (N = 17)	38–67	11	SWT 2 sessions/wk. 20-min endurance and 15 min of RT in progression, 3–5 sets, 10–15 repetitions performed in 20–30 s at intensity Borg scale (6–20) of 15–19. 4 EG: EG1 = RT in lower limbs with resistive equipment EG2 = RT in lower limbs without resistive equipment EG3 = RT in upper limbs with resistive equipment EG4 = RT in upper limbs without resistive equipment	Foam resistive equipment only in EG1 and EG3	1RM: elbow flexors, elbow extensors, hip adductors (exercises performed in the program).	↑ Strength in all EG. No significant differences were found among all the EG in all the muscle groups evaluated.

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Meredith-Jones et al. (42)	Sedentary overweight women (N = 18)	59 ± 8.6	12	EG = DWT 3 sessions/wk, 60 min per session	Foam dumbbells and the resistance of the medium itself	$\dot{V}O_2$peak. Strength: Biodex isokinetic dynamometer. Body composition.	↑ $\dot{V}O_2$peak. ↑ Lower-body and upper-body strength. ↓ Waist and hip circumference and waist-to-hip ratio. ≈ BMI.
				Aquatic circuit training. Combination of 3-min aerobic and 1 min of 30-s RT. RT exercises performed at maximal velocity			
Petrick et al. (45)	Healthy young women (N = 37)	18–35	8	EG1 = water RT	Plastic bottles (floating equipment)	Strength: isokinetic and 10RM of quadriceps. Questionnaire of pain.	↑ 10RM test in both EG. ≈ Isokinetic test in both EG. No differences were found between the EG. Subjects in EG2 complain of more pain than EG1.
				EG2 = land RT			
				5 sessions/wk. 2 sets of 10 repetitions from 50 to 100% of 10RM, knee extension only, at 60°/s			
Pinto et al. (47)	Healthy young women (N = 26)	25 ± 3	12	CG = 11 subjects evaluated 4 wk before the training program	None	Cardiorespiratory fitness: $\dot{V}O_2$peak. Strength: 1RM, isometric peak torque, and electromyography. Muscle thickness: ultrasound.	↑ $\dot{V}O_2$peak in both EG. ↑ 1RM, isometric peak torque, and electromyographic maximal amplitude in both EG, with similar gains. Greater improvements were found in EG1 for knee extensors 1RM. ↑ Knee extensors and elbow flexors thickness, while the increase observed in EG1 was greater than EG2.
				EG1 = SWT resistance training before aerobic training			
				EG2 = SWT aerobic training before resistance training			
				Both EG performed 2 sessions/wk. Aerobic training at second ventilator threshold during 18–36 min, in progression. RT consisted of 3–6 sets of 10- to 20-s duration and 80- to 100-s rest at maximal velocity, in progression			

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Pöyhönen et al. (52)	Healthy women (N = 24)	34.2 ± 3.9	10	CG	Drag forces device: boots	Strength: isometric and isokinetic torque production. EMG. Muscle mass: computed tomography.	↑ Static and dynamic torques, and muscle mass and activity.
				EG = SWT 2-3 sessions/wk, 40–60 min per session including 30–45 min of RT in progression. 2–3 sets, 12–25 repetitions, 30–50 seconds rest. RT exercises performed at maximal velocity with drag device increased from small to large			
Rotstein et al. (53)	Postmenopausal women (N = 34)	50–65	31	CG	Drag forces and floating devices	BMD and content with DEXA in spinal vertebrae L2-L4 and femoral neck.	↑ BMD in spinal vertebrae. Bone status improved modestly because no main effects were found.
				EG = SWT 3 sessions/wk, 60 min per session, including 20 min of aerobic training at 12–16 on Borg scale (6–20) and 20-min RT in progression. Water at chest level			
Takeshima et al. (56)	Older women (N = 30)	69.3 ± 3.5	12	CG	Finbell water-resistance products (soft cushioned hand bars and leg pads)	Body composition. Cardiorespiratory fitness. Strength. Power. Agility. Blood lipids. Flexibility.	≈ Resting heart rate, systolic and diastolic BP, HDL-c, triglycerides, trunk flexion, and body weight in either group. ↑ Vertical jump, side stepping, trunk extension, pulmonary function, $\dot{V}O_2$ and heart rate at lactate threshold, $\dot{V}O_2$peak, and muscle strength (lower and upper body). ↓ Total cholesterol, LDL-c, skin-fold thickness.
				EG = SWT 3 sessions/wk, 70 min per session including 30 min of endurance (light to moderate) and 10 min of RT. RT exercises performed at maximal velocity at xiphoid depth			

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Tsoulou et al. (58)	Healthy elderly women (N = 22)	60–75	24	CG	DEHAG water-resistance products (noodle and cuff devices)	Muscle strength (isometric and dynamic). Flexibility. Functional mobility. Body composition.	↑ Isometric (knee flexors and extensors, grip strength) and dynamic strength (3RM of 4 exercises including upper and lower body), sit and reach test, squat jump, TUG, and lean body mass.
				EG = SWT 3 sessions/wk, 60 min per session including 25 min of endurance (65–80% heart rate max) and 20–25 min of RT in progression. RT exercises were performed at a given pace from 60 to 120 bpm, from xiphoid to axillary depth. 2–3 sets of 12–15 repetitions and 20- to 30-s rest			
Volaklis et al. (59)	Patients with coronary artery disease (N = 34)	48–61	18	CG	Specialized equipment to increase resistance (unspecified)	Body composition. Exercise stress test. Strength. Blood profile.	↓ Body mass, sum of skinfolds, total cholesterol, triglycerides similarly in both EG. ↑ Exercise tolerance in both EG. ↓ Circulatory stress in both EG. ≈ HDL-c and LDL-c
				Same design for both EG: 4 sessions/wk, 2 aerobic sessions and 2 RT sessions. 60 min per session. EG1 = land exercise. Aerobic intensity: 60–80% heart rate max. RT: 2–3 sets, 12–15 repetitions, 60% 1RM, 30-s rest between exercises and 5 min between sets			
				EG2 = SWT. Aerobic intensity: 50–70% heart rate max. RT: 60–80% of the maximal repetitions performed at baseline; the progression was ensured by increasing the amount of sets, the number of repetitions, and the speed of the exercises			

BMD = bone mineral density; DEXA = Dual-energy X-ray absorptiometry; DWR = Deep Water Running; DWT = deep water training; SWT = shallow water training; RT = resistance training; EG = experimental groups, CG = control groups; BMI = body mass index; HDL-c = high-density lipoprotein cholesterol; LDL-c = low-density lipoprotein cholesterol; BP = blood pressure; bpm = beats per minute; RM = repetition maximum; TUG = test up and go.

in strength and range of movement in only 8 weeks of RT in water in hemophilia patients.

EFFECTS OF THE EQUIPMENT

There are 2 primary types of aquatic devices that take advantage of the physical properties of the water environment: floating and drag forces equipment (25). Floating equipment is characterized by a density considerably lower than the water fluid; thus, the main property of this material is to increase the buoyancy load. In addition to the buoyancy load, floating devices have a frontal surface area creating drag. The resistance is the sum of buoyant and drag forces (39). There are some movements that are difficult to perform in a comfortable position to take advantage of the property of this equipment (25,45).

The other primary device is drag forces equipment, which increases the resistance only by the frontal surface area, because this device has a similar density to the water fluid, and therefore, buoyant force is negligible. Colado and Triplett (25) recommend drag forces devices for RT in water.

Interestingly, when maximal velocity of the movement is performed with different kind of aquatic equipment, different size, or/and different properties (i.e., drag forces or flotation), muscle activation is similar (20). Pinto et al. (46) analyzed 15 women performing 15 seconds of stationary jogging combined with elbow flexion and extension without devices, with drag forces device, and with floating device at maximum cadence, and the results showed no significant differences between the execution of the exercise with or without device for most of the muscles evaluated. Similarly, performing knee flexion and extension at maximal velocity barefoot versus with additional drag boot produces similar EMG amplitude and patterns (50). Intervention studies are in accordance with the descriptive studies, indicating that performing a RT program with or without equipment generates similar strength gains (16,38). Therefore, EMG results are in accordance with the intervention studies, and this phenomenon is explained by the general fluid equation ($F_d = ½ \cdot \rho \cdot A \cdot C_d \cdot v^2$) (4). With maximal velocity movement performed with different equipment, the bigger the device, the lower the angular velocity and vice versa (52).

Additionally, when comparing different properties of aquatic equipment (drag forces versus floating), floating equipment resistance is the sum of buoyant and drag forces (39); thus, maximal velocity achievable might be lower, and the final EMG amplitude is similar with floating equipment and with drag equipment (46). Further research is required to know the effects of different equipment during RT programs in water.

During RT in water, the use of drag forces equipment generates greater oxygen uptake ($\dot{V}O_2$), energetic expenditure, and postexercise oxygen consumption than performing the exercise without equipment, when both protocols are performed at maximal velocity (28). Additionally, when comparing 2 identical protocols performing 3 × 20 or 6 × 10, both generate the same $\dot{V}O_2$ per minute, the same energetic expenditure per minute, and the same postexercise oxygen consumption (28).

WATER TEMPERATURE DURING RT

Water temperature of 35°C is considered as thermoneutral during water immersion at rest; however, during dynamic exercise, water temperature between 29°C and 34°C is required for thermoneutrality (18). Water immersion above or below thermoneutral temperature leads to physiological and rectal temperature changes, which are not optimal for training purposes (7,18,41).

For aquatic fitness programs, the Aquatic Exercise Association (5) has established a water temperature ranging from 28°C to 30°C. However, the temperature needs to be adapted to the specific situation. For example, older adults required higher temperature than young adults, and if the aim of the activity is relaxation, the improvement of range of motion or flexibility, water temperature should be increased to a thermoneutral value (7).

GENERAL GUIDELINES FOR RT IN WATER

Because there are a few studies comparing optimal progression models of RT in water, these general guidelines are based on the most common protocols used in different studies and on the authors' experience.

At the beginning, 2 sessions per week, with a duration of 10–15 minutes performing 3–6 exercises involving large muscle groups per session and 1–2 sets of 20–25 repetitions per exercise is enough.

After a correct progression, 3 sessions per week or more with a duration of 15–45 minutes performing 6–12 exercises involving large muscle groups per session and 3–5 sets of 8–15 repetitions per exercise are optimal.

FREQUENCY

≥ 2–3 sessions/week (22,52,56).

DURATION

15–45 minutes for 3–12 exercises.

TYPE

All large muscle groups.

INTRASESSION ORDER

RT before aerobic exercise (47).

EQUIPMENT

No equipment seems to be necessary (16,20,38), although equipment can be used to increase energy expenditure (46).

IMMERSION DEPTH

Shallow water at xiphoid process (20).

VOLUME

2–5 sets of 8–15 repetitions.

Volume guidelines must be similar to those used in dry land RT (25). The number of repetitions should lie within the optimal range for the goals of the person exercising (strength, hypertrophy, or local muscular endurance) (25).

REST PERIODS

Rest time is specific to the targeted number of repetitions (1), and it would consist of inactive movements at low intensity for maintaining thermoneutral temperature and blood distribution in the active areas.

INTENSITY

Two different ways for monitoring intensity have shown to be effective.

Maximal velocity of the movement. Maximal velocity of the movements for a specific number of repetitions is the most common way to control intensity (32,42,47,56). Although it seems that intensity is not controlled for each individual, the intensity cannot be over the capabilities of each individual because of water properties. Unlike on land where the weight is the same throughout all the repetitions of a set and it could be excessively heavy, in water, the maximal velocity is adjusted to the fatigue and to the strength condition of each individual, and thus muscle failure cannot be reached.

Fundamental criteria to control intensity using the rate of perceived exertion scale:

1. The movement pace or cadence (sound or lights) (25).
2. Size of the equipment
3. Length of the extremity used
4. Hydrodynamic position of the moving segment and equipment used
5. Perception of effort at the predetermined number of repetitions (5–9 with OMNI scale [0–10] or 12–19 with Borg scale [6–20]).

FUTURE RESEARCH

RT in water is effective; however, little is known about the optimal training protocol. Will different devices and immersion depths lead to different physiological effects in an intervention study? When maximal velocity of movement is performed, do we need to prescribe training volume with repetitions or with time per set? Is plyometric training in water really safer for injury prevention? What are the effects of different training protocols on muscle damage, hormonal responses, strength, physical capacity, body composition, cardiometabolic factors, bone mineral density, and muscle mass in different populations?

LIMITATIONS

The exercise performed in most of the studies is a combination of aerobic and RT exercises; thus, the specific effects of RT unaccompanied need further research. It is important to clarify that these general guidelines are not definitive and must be adapted to each individual depending on his potential and goals. Furthermore, in specific populations (e.g., low back pain or osteoporosis patients with poor balance), RT in water may be a useful option or first step before performing exercises on dry land.

PRACTICAL APPLICATIONS

RT in water is safe and effective to improve strength, power, flexibility, and physical capacity to perform daily living activities. Controversy exists regarding the effects on $\dot{V}O_2$peak, balance, body composition, cardiometabolic risk factors, and bone mineral density, although positive effects are common. RT in water should follow similar prescription to dry land training. More research is required to establish proper RT guidelines in water and to compare effectiveness with traditional land-based exercise programs.

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