Effects of a Short-Term Aquatic Resistance Program on Strength and Body Composition in Fit Young Men

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Abstract

Colado, JC, Tella, V, Triplett, NT, and González, LM. Effects of a short-term aquatic resistance program on strength and body composition in fit young men. *J Strength Cond Res* 23(2): 549–559, 2009—This study was designed to analyze the effects of a short-term periodized aquatic resistance program (PARP) on upper-limb maximum strength, leg muscular power, and body composition (BC) in fit young men. Twenty subjects (21.2 ± 1.17 years) were randomly assigned to an exercise or control group; 12 subjects completed the study. The aquatic exercise group (AEG; $n = 7$) participated in an 8-week supervised program of 3 d·wk^{-1}, and the control group (CG; $n = 5$) maintained their regular activities. The PARP consisted of a total-body resistance exercise workout using aquatic devices that increased drag force, with a cadence of movement controlled and adjusted individually for each exercise and subject. The volume and intensity of the program were increased progressively. Submaximal tests were carried out to determine the change in upper-limb maximum strength, as well as a squat-jump test to determine the change in leg muscular power. Four skinfold sites, 6 circumference sites, body weight, and stature were used to determine changes in BC. A significant increase in upper-limb maximum strength and leg muscular power was observed for the AEG. A significant increase also was noted in the circumference and muscular area of the arm, and there were significant decreases in pectoral and abdominal skinfolds. Nevertheless, the circumference, muscular area, and local fat of the lower limbs did not change. There were no significant changes in any variables in the CG. These results indicate that the PARP produces significant improvements in muscular strength, power, and fat-free mass and, thus, seems to be a very effective form of resistance exercise.

Key Words drag force, monitored cadence of movement, periodized

Introduction

Both the number of physical conditioning activities carried out in water and the number of those exercising have significantly increased in the United States and Europe in recent decades. The physiological and articular benefits offered by the specific properties of this medium (7,38) may have promoted this increase. These activities have traditionally been aimed at and prescribed for those populations with some kind of disability. However, they are currently used both to improve the physical condition of healthy individuals who regularly take part in recreational training (9) and as a complement to improve the performance of athletes (5,16,25,27,33). Although the physiological responses, effects, and benefits offered by performing aerobic exercises in water are well known (8,15), studies are lacking on the potential effects of a program of resistance exercises in water (32). The absence of methodological criteria with which to control resistance objectively and progressively while performing these exercises (30,31) may be one of the reasons for this, and as a result this type of training has not been recommended by academic professionals or used by practitioners.

In general terms, the same program design recommendations should be followed for the specific application of strength training programs in water (31,36). Therefore, to design a strength training program in the aquatic medium, studies (6,7,9,10,12,17,23,28,30–32,36,38) have recommended that it is essential to achieve the combined control of i) the pace of the movement, ii) the size of the aquatic devices that increase the drag force, iii) the length of the lever of the limb being exercised, iv) the hydrodynamic position of the segment mobilized and the aquatic devices used, and v) the

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performance of a targeted number of repetitions based on the desired goal. In addition, it should be pointed out that in all cases the individuals exercising carry out the movements with the aquatic devices at a pace determined by a cadence of beats per minute that has been previously identified on the basis of the predicted targeted number of repetitions. It has been shown that the workload in water is always similar as long as the movement is performed at the same pace and under the same exercise conditions (7,12). Thus, to increase the resistance offered by the water, either the pace per minute must be increased or the area of the aquatic device must be increased (7). Therefore, objective criteria exist with which to quantify the progressive increase in the "load" or resistance, marked by the proposed pace per minute and the aquatic device used (7). The moment when neither the pace nor correct performance can be maintained defines when muscular actions are inadequate for the stimulus (29).

No scientific studies have examined the basic aspects of the design of resistance programs in combination with the use of adequate aquatic devices and the performance of movements according to a previously evaluated pace. Although several studies have confirmed the positive adaptations caused by aquatic resistance exercises (3,37,39), many of them display methodological shortcomings when it comes to controlling the resistance generated by the exercises both immediately and in the long term, as well as usually being applied to untrained middle-aged or older subjects with whom it is easier to cause certain adaptations in the early stages of strength training programs. Therefore, to analyze the effects that an aquatic resistance program can have on fit young men regarding maximum strength, muscular power, and body composition (BC), a randomized and supervised study was carried out for which a method was designed to adapt and control exercise intensity objectively. The hypothesis of the current study was that aquatic resistance training can generate positive neuromuscular adaptations in fit men if the resistance applied to the training movements is controlled by a specific cadence of movement for each exercise and subject according to the targeted number of repetitions initially prescribed.

Methods

Experimental Approach to the Problem

In accordance with the methodology proposed by Kraemer et al. (23) for using elastic devices for strength training, in this study a specific cadence of movement using the same aquatic device to increase drag force was used to complete an 8- to 12-repetition maximum (RM) range with a 10-repetition target. To this end, a cadence of movement was identified for each subject in the aquatic exercise group (AEG) that allowed the subject to achieve the amount of resistance needed to maintain the targeted number of repetitions (RM zone $\pm$ 2 rep) while using good technique. The subjects trained using an acoustic metronome throughout the training program, with each individually following the initially identified cadence of movement for each exercise. Whenever necessary, greater resistance was provided by using a faster cadence of movement to maintain the targeted number of repetitions. At least 1 trained monitor was always present to corroborate the correct application of this methodology. Muscle function and BC were tested before and after the resistance training program to determine its effects. All measurements and practical procedures were always carried out by the same researchers, all of whom had experience with this kind of trial. All subjects were continually encouraged, and the laboratory conditions were always the same. Pre- and posttests were filmed, and the film was then checked to ensure the validity of the procedures followed. The study was approved by a research commission and by the Department of Physical Education and Sports from the University of Valencia (Spain).

Subjects

Twenty men volunteers from third-year students at the Faculty of the Sciences of Physical Activity and Sports at the University of Valencia (Spain) were randomly assigned into a control group (CG; 8 subjects) and an AEG (12 subjects), with no significant differences ($p > 0.05$) in any intergroup baseline measurement. All subjects were physically active as they performed 5.08 $\pm$ 1.5 d·wk^{-1} of varied physical training at moderate intensity for at least 20 minutes, and all had done so for at least 6 months before the study. They did not normally perform resistance exercises on dry land, and they never had performed aquatic resistance exercises. All subjects signed an agreement by which they committed themselves, for the duration of the study, not to carry out any specific physical activity for strength training in their free time, to maintain their habitual lifestyle and eating habits, and not to take performance-enhancing substances (after prior corroboration that they never had taken these substances). The subjects did not suffer any cardiovascular, neuromuscular, orthopedic, or psychological disorders. All subjects were informed of the nature of the study before volunteering to take part in it. To evaluate any possible interference with the training program followed in the study, and to better understand certain results obtained, each subject was supplied with a diary in which he listed the type of physical activity he had carried out during the day, his diet, his rest periods, and his feelings during the aquatic resistance training sessions. Finally, after the usual withdrawals and eliminations associated with any unremunerated experimental study, the final make-up of the groups was as follows: a) AEG: $n = 7$, 21 $\pm$ 1 years, 173.96 $\pm$ 4.97 cm, 73.43 $\pm$ 7.97 kg; b) CG: $n = 5$, 21.4 $\pm$ 1.34 years, 178.12 $\pm$ 4.08 cm, 76.38 $\pm$ 5.03 kg.

Body Composition

All measurements were carried out by the same fully trained individual under identical environmental conditions using exactly the same instruments. A Harpenden skinfold caliper was used to measure skinfolds, and the average of 2 trials was used except in the case in which the measurements differed by more than 2.0 mm. In this case, a third measurement was obtained, and the mean value was used. The skinfolds measured were those of the right-hand side of the chest, abdomen, and thigh, following the usual protocol (18). In addition, a skinfold was taken from the brachial triceps region of the right arm for later analysis. Body density was calculated (21), and the value was used to determine body fat percentage by applying the Siri formula (35) for Caucasian men; subsequently, fat-free mass was determined. In addition, the circumferences of the relaxed right arm, the internal and thoracic region at shoulder height at maximum inspiration, the relaxed hip, and the upper thigh were measured. We also measured fasting body weight and height using the spinal column extension method and normal procedures for these measurements (18). Finally, the muscle area of the arm and thigh were determined by using the above measurements and applying the formulas used by Huygens et al. (20).

Procedures

It was scrupulously ensured that the correct range and technique were used for each exercise during the tests. All subjects were required to perform a standardized warm-up. Two measurement sessions with 48 hours of separation between them were carried out for both the initial and final tests, and there were 72 hours separating the final training session from the first posttest evaluation. The best result for each variable measured was taken for analysis. The intraclass correlation coefficient was calculated from the measurements of the pre- and posttests of the control group. For the anthropometric and strength variables, the intraclass correlation coefficient values for our protocols ranged between 0.87 and 0.98 and between 0.82 and 0.87, respectively.

Maximum Strength. The exercises chosen for the dry-land evaluation involved the same muscle groups and working angles exercised during the periodized aquatic resistance program (PARP) in as similar a fashion as possible. The exercises used and the order of evaluation were always the same, which prevented any possible interference with performance that could be a result of the order in which the exercises were carried out. The order was as follows: a) vertical row, b) horizontal bench press, c) horizontal bench row, d) arm lateral raise, and e) squat-jump. Previously calibrated standard materials were used, consisting of bars with diameters of 2.5 cm and weights of 11 kg, dumbbells with diameters of 2.5 cm and weights of 2.5 kg, weight plates with standard features, collars, and standard supports. Subjects were familiarized with each exercise, and their technique was checked before the performance of each test. A submaximal test only allowing a maximum of 6 repetitions until muscular failure with correct technique was used (14). A submaximal test was used because a large number of muscle groups were evaluated by means of different tests, and it was necessary to the quality and validity of the tests to minimize fatigue of the subjects. If a subject exceeded the number of repetitions, he rested and then tried again with a higher load. The Brzycki formula (4) was used to calculate maximal strength from the submaximal repetitions.

Power. To identify the evolution of lower-limb muscle power, the static vertical jump or squat-jump test was used because it also exclusively assesses the concentric muscle action that characterized the PARP used in this study. It was performed using the recommendations of Lehmkuhl et al. (24). The muscular power of each vertical jump was estimated by applying the prediction equation of Sayers et al. (34).

Periodized Aquatic Resistance Training Program

Exercises. Because the subjects were not used to aquatic resistance exercises, they were taught the correct technique for performing them before starting the training program. The researchers explained the exercises to the group, and each subject then carried them out under supervision. The criteria for correct technical performance were those described by Colado (9), and the exercises are described in Table 1. The temperature of the water in the swimming pool where the training program took place was 28 ± 1° C, and the depth of immersion was always such as to allow the exercises to be carried out in a technically correct fashion. Standard materials were used during the training program. For example, the gloves had a projected area of 293 cm^2, the fins had a projected area of 430 cm^2, and the boards had a projected area of 874 cm^2. Noodles were used to maintain the horizontal flotation position in the exercises training the abdominal musculature.

Resistance Identification. A Wittner metronome and a digital audio editing program were used to record a compact disc with 12 tracks corresponding to different paces and ranging from 46 beats per minute to 102 beats per minute. Each of the tracks was thoroughly checked to guarantee that they did not contain alterations to the preset pace. The subjects initially used the aquatic devices to carry out the basic exercises prescribed at a pace determined by a cadence of beats per minute chosen on the basis of pilot tests and the prior experience of the researchers. This meant that the subjects had to match their movements to the individual beats of the tracks recorded on the compact disc. Those subjects who were not able to generate enough resistance from the water to reach muscle failure with the preset number of repetitions at the pace initially planned and without varying their technique took a rest period and then increased the pace by choosing the next track. Similarly, the subjects for whom the pace was too difficult to reach the prescribed number of repetitions chose the previous track after the rest period. This allowed them to obtain the initial "load" after identifying the track offering the optimal pace to be used by each subject for each of the exercises. From then on, the "load" was adjusted to the aquatic movement by changing the track. The subjects repeated the process after resting for 2 hours to ensure that the track chosen for each exercise was correct. This test was carried out 48 hours after having carried out the dry-land pretests to determine maximum strength and muscular power. Table 1 also shows the beats per minute (pace) most commonly used for each of the basic training program exercises.

TABLE 1. Exercises used in the different cycles of the periodized aquatic resistance program (PARP).

Device name	Exercise name		Pace*	Description of the joint movements
Gloves	Horizontal shoulder ab-adduction	H.Sh Ab/d	69	Horizontal abduction and adduction of the shoulders
	Oblique shoulder ab-adduction	O.Sh Ab/d	69	Oblique abduction and adduction of the shoulders
	Vertical shoulder ab-adduction	V.Sh Ab/d	72	Abduction and adduction of the shoulders
	Elbow flexion-extension	Elb F/E	72	Flexion and extension of the elbows
Boards	Horizontal press-pull	H P/P		On a horizontal plane: flexion and extension of the shoulders and elbows
	Oblique press-pull	O P/P		In an oblique direction: flexion and extension of the shoulders and elbows
	Vertical press-pull	V P/P		On a frontal plane: abduction and adduction of the shoulders and flexion and extension of the elbows
	Arms press-pull	A P/P		Flexion and extension of the elbows
Fins	Frontal kick	FK	60	Flexion and extension of the knee with a small supported flexion of the hip
	Great frontal kick	GFK	46	Flexion and extension of the knee and hip
Fins and boards	Dorsal resisted batter	DRB		Dorsal resisted batter with the boards in every hand and below the body
	Lateral resisted batter	LRB		Lateral resisted batter with the board held with the hands over the head
Noodles	Frontal top crunch	FTC		Frontal top crunch in horizontal position and with a noodle in lengthwise direction
	Frontal low crunch	FLC		Frontal low crunch in horizontal position and with a noodle in longitudinal direction

*Cadence of movement (bpm) most typically applied to each of the basic exercises of the training program.

Training Program. One member of the research group was always present during the training sessions to ensure that the program was performed correctly. Training compliance for the subjects was 95%. The exercises performed during warm-up and cool-down were standardized to avoid any possible interference with the aims of the study. Despite the fact that a short-term program was used to maximize training effects, and given that the subjects were physically active, a periodized model for strength training was used, with a total duration of 8 weeks, divided into 2 consecutive 3-week cycles and a final 2-week cycle, with a frequency of 3 sessions a week. To vary the training stimulus, the volume was modified in each cycle by an overall increase in the sets and the exercises. Table 2 shows the methodological criteria followed to perform the different cycles and the exercises according to the specific association with the technique of preexhaustion overloading of agonist muscle groups. The exercises for dynamic training of the abdominal musculature were performed following a repetition speed of 1 second for the outward stage and 2 seconds for the return stage to the initial position.

As mentioned previously, a very high volume was applied in this PARP. With the use of aquatic resistance devices, all movements are concentric only, such that the opposing muscles around a joint are primarily trained in the concentric manner in each direction of joint movement, which serves to increase the overall training volume compared with that of dry-land training. The recovery time between sets was always 90 seconds, which is typical of the 8- to 12-repetition range. These rest periods, combined with the significant length of the sessions, meant that the subjects carried out slow jogging movements and/or slow active range-of-motion exercises of different joints during the recovery periods to avoid the risk of suffering from hypothermia, with some subjects even training while wearing thin thermal garments.

Statistical Analyses

The data gathered were analyzed using the SPSS program. The homogeneity of the dependent variables was checked using the Levene test ($p > 0.05$), and their normality was evaluated using Kolgomorov-Smirnov statistics ($p > 0.05$). Descriptive statistics were then calculated. t-Tests were used for within-group differences, and ANOVA was used to analyze independent (between-group) samples. All differences were accepted as statistically significant at $p \leq 0.05$ and as very significant at $p \leq 0.01$.

Table 2. Periodized aquatic resistance program (PARP) followed in the study.

Cycle number		Exercises and workout order	Sets per exercise	Repetitions per set 1	2	3
1	1°	Horizontal shoulder ab-adduction	3	8–12		
	2°	Oblique shoulder ab-adduction	3	8–12		
	3°	Vertical shoulder ab-adduction	3	8–12		
	4°	Elbow flexion-extension	5	8–12		
	5°	Frontal kick	5	8–12		
	6°	Great frontal kick	5	8–12		
	7°	Frontal top crunch	4	15		
2	1°	(1) Oblique shoulder ab-adduction + (2) oblique press-pull	3	8–12	15	
	2°	(1) Vertical shoulder ab-adduction + (2) vertical press-pull	3	8–12	15	
	3°	(1) Horizontal shoulder ab-adduction + (2) horizontal press-pull	3	8–12	15	
	4°	(1) Elbow flexion-extension + (2) arms press-pull	5	8–12	15	
	5°	(1) Great frontal kick + (2) lateral resisted batter	5	8–12	15	
	6°	(1) Frontal kick + (2) dorsal resisted batter	5	8–12	15	
	7°	(1) Frontal low crunch + (2) frontal top crunch	4	15	15	
3	1°	(1) Vertical shoulder ab-adduction + (2) vertical press-pull + (3) vertical shoulder ab-adduction	4	8–12	15	8–12
	2°	(1) Horizontal shoulder ab-adduction + (2) horizontal press-pull + (3) horizontal shoulder ab-adduction	4	8–12	15	8–12
	3°	(1) Elbow flexion-extension + (2) arms press-pull + (3) elbow flexion-extension	5	8–12	15	8–12
	4°	(1) Frontal kick + (2) dorsal resisted batter + (3) frontal kick	5	8–12	15	8–12
	5°	(1) Great frontal kick + (2) lateral resisted batter + (3) great frontal kick	5	8–12	15	8–12
	6°	(1) Frontal top crunch + (2) frontal low crunch + (3) frontal top crunch	5	15	15	15

Rest interval between sets: 90 seconds.

Results

Tables 3 and 4 show the effects caused by the PARP on muscular fitness and global BC, stating the baseline value and final absolute change after comparing the initial value with that obtained after the 8 weeks of training. Additionally, Figures 1 and 2 show the individual values of the AEG for the variables indicated.

The PARP led to significant improvements in both the maximum strength of the upper limbs and in the power of the lower limbs (Table 3). The PARP also led to significant increases in fat-free mass (Table 4) and arm/hip circumference (Table 5). In addition, the PARP significantly reduced local fat in the abdominal and pectoral region (Table 5) together with overall fat mass (Table 4), there being a significantly positive correlation in the AEG between weight increase and reduction of body fat mass ($p \leq 0.01$). However, the PARP did not lead to any modification of lower-limb BC.

Discussion

Except for the study carried out by Pöyhönen et al. (32) analyzing the effects caused by a PARP with movements performed with aquatic devices on the strength and BC of young, physically active women, there are no other scientific studies focusing on the effects that a total-body workout PARP using aquatic devices could have on other populations, especially where intensity is controlled objectively. Therefore, in the current investigation it was necessary to create a methodology that had been lacking up to now. The method used here to control intensity in aquatic strength training through joint control of the pace of movement and target number of repetitions is in agreement with current recommendations for controlling training against resistance (29). The results highlight the fact that the PARP developed was effective in increasing both strength and fat-free mass with only 8 weeks of training, despite the fact that there are aquatic devices available that are more appropriate because they are larger and more ergonomically designed than those used in the current investigation, and even though the subject attrition reduced the final statistical power, which is accounted for when making generalizations about the results obtained in this investigation.

The results provided by this study show a clear increase in the maximum strength of upper-limb muscle groups in young, healthy, physically fit men with an intermediate level of muscular fitness. Faced with the lack of equivalent studies in

TABLE 3. Change in maximum strength.

Variable	Group	Previous value and change		$SD(\pm)$	$(p)^1$	$(p)^2$
Horizontal bench press (kg)	CG	Pre	64.31	6.77	0.209	0.004†
		Change	−2.12	3.17		
	AEG	Pre	62.28	9.50	0.003†	
		Change	+3.19	1.76		
Arm lateral raise (kg)	CG	Pre	25.77	2.99	0.686	0.465
		Change	−0.01	2.55		
	AEG	Pre	23.74	3.37	0.044*	
		Change	+2.30	2.40		
Horizontal bench row (kg)	CG	Pre	69.67	5.02	0.541	0.154
		Change	+0.95	3.18		
	AEG	Pre	72.38	13.32	0.033*	
		Change	+4.46	4.29		
Vertical row (kg)	CG	Pre	44.82	2.42	0.235	0.028*
		Change	+1.44	2.1		
	AEG	Pre	44.70	10.91	0.018*	
		Change	+4.88	2.35		
Squat-jump (W)	CG	Pre	4694.95	437.54	0.658	0.210
		Change	−89.51	419.07		
	AEG	Pre	4471.07	581.37	0.045*	
		Change	+135.62	141.84		

$(p)^1$ = Statistical intragroup significance; $(p)^2$ = posttest statistical intergroup significance with regard to the change.
CG = control group; AEG = aquatic exercise group.
*Significant statistical difference ($p \leq 0.05$); †very significant statistical difference ($p \leq 0.01$).

the aquatic medium with which to compare the results, in this analysis the results can only be compared with those from other programs carried out on dry land, in which the testing and training were done with the same exercise. The results obtained with the PARP are similar to those obtained in other studies using resistance devices on dry land, although they were applied using methods and subjects with slightly different characteristics to the AEG. For example, the first 8 weeks of the study of Hostler et al. (19) used traditional training methods for improving maximum strength in the horizontal bench press exercise (2–3 $\text{d}\cdot\text{wk}^{-1}$, 3 sets of 7 RM). The young men chosen were physically active and had not carried out any specific strength training in the previous 6 months. The relative strength of the 2 groups of men analyzed was significantly higher than that of the subjects of the AEG (1.22 and 1, respectively, vs. 0.85 for the AEG). The subjects of the Hostler et al. study improved their 1RM by 4.1 and 5.1 kg in 8 weeks (increases of 4.89 and 6.47%, respectively), and the AEG subjects improved by 3.19 kg (an increase of 5.12%), with the dry-land groups showing respective relative strength improvements of 3.28 and 5.82% compared with an improvement of 4.70% for the AEG. Thus, the studies analyzed show how the improvement in the maximum strength of the AEG in the bench press exercise is similar to that obtained by those participating in dry-land programs, even though the subjects in the current investigation performed the horizontal press-pull during part of the aquatic training program, which is only moderately equated to the bench press. This may have limited the strength gains in the bench press test of the subjects in the current investigation.

However, as was previously mentioned, it is very important to point out that concentric muscle actions were prioritized in the PARP, whereas tests were carried out that required combined concentric and eccentric muscle actions to evaluate the change in maximum strength in the AEG. It is generally accepted that gains in strength shown in a test are greater when the test exercise, training exercise, type of muscle action required, and type of resistance to be overcome are similar. Therefore, the most appropriate evaluation test for assessing the current program adaptations should focus exclusively on the concentric phase of maximum dynamic strength (32,37). However, the effects on maximum strength caused by participation in this study were evaluated using exercises of a combined concentric and eccentric nature, using weight equipment that is typically used in dry-land programs Although this is a possible limitation to the current investigation in defining the real improvements of the program followed, it was necessary because improvements in muscular fitness achieved with aquatic exercise programs will usually be transferred and applied to performance on dry land.

Regarding the training effects on muscular power of the lower limbs, the AEG showed a significant improvement of 3.03% over its initial value of 4471.07 W. Although existing studies have shown that the power of the lower limbs is improved by following aquatic training programs (25,27,33), these studies are solely based on carrying out multijump exercises, unlike the PARP followed in our study where only traditional open–kinetic-chain resistance exercises were performed. The dry-land studies of Coutts et al. (13) and Lehmkuhl et al. (24) can be used to compare the results of our PARP with their programs because they also used the squat-jump as the evaluation test, trained the strength of the lower limbs by using common open– and closed–kinetic-chain strength exercises, and at no time used multijump training

TABLE 4. Change in overall body composition.

Variable	Group	Previous value and change		SD(±)	$(p)^1$	$(p)^2$
Fat-free mass (kg)	CG	Pre	69.58	3.03	0.043*	0.000†
		Change	−1.42	0.48		
	AEG	Pre	66.01	7.53	0.000†	
		Change	+1.28	0.47		
Percentage of body fat (%)	CG	Pre	8.78	3.24	0.875	0.092
		Change	+0.12	1.59		
	AEG	Pre	10.13	2.25	0.019*	
		Change	−1.32	1.10		
Fat mass (kg)	CG	Pre	6.80	2.90	0.893	0.194
		Change	−0.02	1.44		
	AEG	Pre	7.42	1.71	0.023*	
		Change	−0.91	0.79		
Body weight(kg)	CG	Pre	76.38	5.03	0.112	0.029*
		Change	−1.44	1.59		
	AEG	Pre	73.43	7.98	0.374	
		Change	+0.37	0.88		

$(p)^1$ = Statistical intragroup significance; $(p)^2$ = posttest statistical intergroup significance with regard to the change.
CG = control group; AEG = aquatic exercise group.
*Significant statistical difference ($p \leq 0.05$); †very significant statistical difference ($p \leq 0.01$).

resources. The 2 groups of subjects in the Coutts et al. (13) study trained for the first 6 weeks at 3 d·wk^{-1}, with a total-body workout of 7 exercises including one for the lower limbs (back squat), carrying out multiple sets of 10–16 repetitions at an intensity of 55–73.5% 1RM, with a 1-minute rest interval. The load was modified when it was perceived as too heavy or too light. Applying the Sayers et al. (34) formula to the results of the study shows that 1 group improved its initial value of 4382.12 W by 2.8%, and the other group improved its initial value of 4575.64 W by 4.96%. The Lehmkuhl et al. (24) study used a combined sample of men and women athletes who were given performance-enhancing supplements. Their training program lasted 8 weeks and consisted of a total-body workout prioritizing maximum strength training for 3 d·wk^{-1} and using multiple sets. As before, if the Sayers et al. (34) formula is applied, it can be shown that the placebo group improved its initial jump value of 4642.22 W by 1.5%. As previously stated, the 3.0% improvement in lower-limb power by the AEG in the current study was significant, although there were no significant differences in power when compared with the CG. This can be explained by the use of nonspecific aquatic devices such as the fins. This material modified the movement pattern of the basic frontal kick and great frontal kick exercises, meaning that the subjects struck the bottom of the swimming pool as a result of the increased length of the limb caused by using this device. This made it difficult to carry out the exercise in technically correct fashion while stabilizing the body. One additional problem of this material used for the lower extremities was that it could have caused some ankle joint pain, and this fact could have limited the intensity, and maintained performance of the movements as the joint was subjected to significant stress. Another factor that could have had a negative effect was the type of test used, despite following the suggestions of previous studies (37) and the fact that the squat-jump really provided evaluation appropriate to the muscle action trained. However, the movement

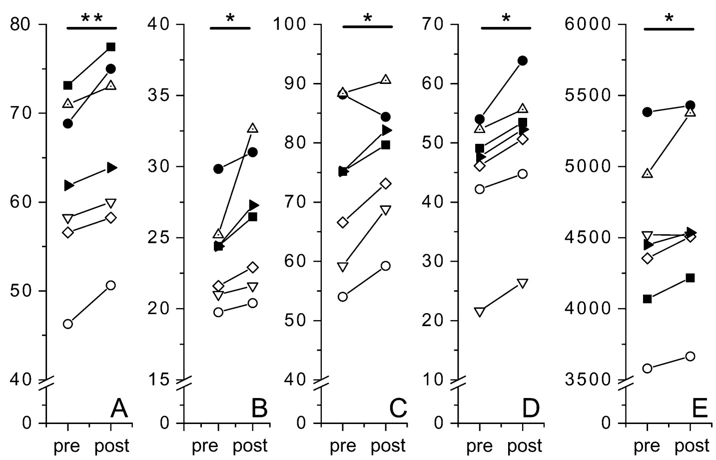

Figure 1. Individual values of the aquatic exercise group for maximum strength before and after 8 weeks of aquatic resistance training. From left to right, the panels represent A) horizontal bench press (kg), B) arm lateral raise (kg), C) horizontal bench row (kg), D) vertical row (kg), and E) squat-jump (W). The significant differences between the pre- and posttests are indicated by *($p \leq 0.05$) and **($p \leq 0.01$).

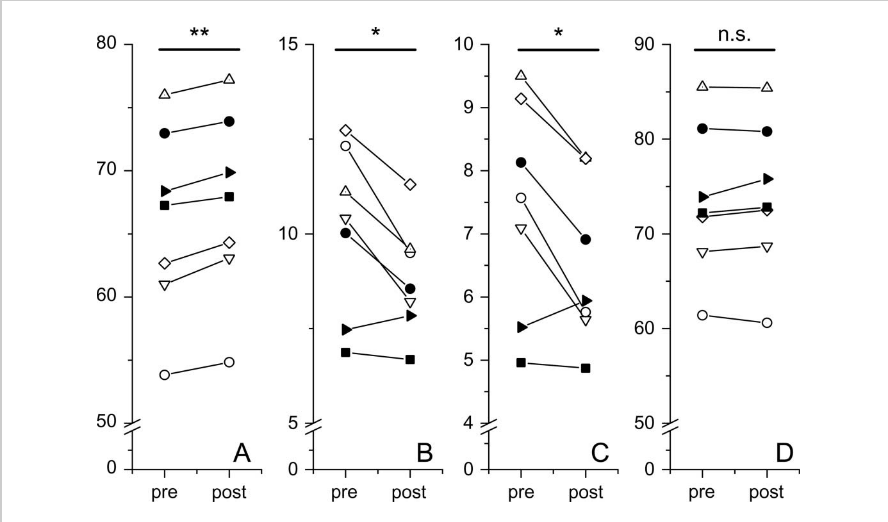

Figure 2. Individual values of the aquatic exercise group for overall body composition before and after 8 weeks of aquatic resistance training. From left to right, the panels represent A) fat-free mass (kg), B) percentage of body fat (%), C) fat mass (kg), and D) body weight (kg). The significant differences between the pre- and posttests are indicated by *($p \leq 0.05$) and **($p \leq 0.01$). n.s. = no significant difference.

pattern and the type of strength trained showed significant differences. These limiting factors were not present in the Pöyhönen et al. (32) study because Hydro-tone boots were used. These devices do not prevent correct execution of the exercise and do not overload the ankle joint. They also have a greater surface area that allows them to generate greater drag force. The leg extension test used by Pöyhönen et al. (32) was also better suited to the movement pattern trained. It is therefore likely that the limitations of the present investigation contributed to the lack of intergroup differences and the absence of change in the BC of the thigh segment. Thus, there is a need to carry out further studies in which these factors are taken into account, allowing future PARPs to be designed and evaluated more precisely.

One other important factor that should be highlighted is the fact that no relevant eccentric muscle actions have appeared in PARPs carried out using aquatic devices (31,32), which has created questions as to whether aquatic resistance programs can result in increases in strength and muscle mass of young, healthy, physically active subjects. However, physiological adaptations should result whenever the magnitude of muscular stress generated by the muscle action is greater than the normal level of stress to which the muscle group is subjected. The results of the current study support the statement that those PARPs using aquatic devices that prioritize concentric muscle action are effective in increasing both strength and fat-free mass. The fact that this kind of program was based on single-joint movements has possibly favored the very early gains in fat-free mass (32). Despite the fact that dietary modification as a basic factor for increasing fat-free mass was not manipulated while the PARP was being carried out, it should be noted that this kind of PARP did include typical program variables aimed at favoring muscle hypertrophy, such as the rest interval and the number of repetitions performed, the large number of sets per muscle group, the use of preexhaustion methods, the weekly training frequency, and the anabolic environment usually created by programs combining these aspects that also involve many large muscle groups.

Although the diet was not manipulated, the subjects agreed not to change their dietary practices and filled in daily questionnaires during the duration of the study to reduce any confounding effects with the PARP, as was the case with previous studies (37). These were checked every week to ensure that their habits before starting the study had not changed. Thus, the PARP applied led to a significant improvement of 1.285 kg of fat-free mass in only 8 weeks. This increase is even more significant considering that there was a significant reduction in physical activity (outside of the PARP in the AEG) during the course of the semester, which would normally lead to a reduction in fat-free mass, as was seen in the CG. In general terms, the improvements of the AEG are in line with those obtained in other dry-land programs following a similar methodology, obviously excepting the specific aquatic applications. It has been reported that fat-free mass increases by about 2.0 kg after 10–16 weeks of total-body resistance training (2). In another study, Mazzetti et al. (26) submitted young trained men to a classical linear periodized resistance training program emphasizing strength and hypertrophy phases for 12 weeks. In this study, the initial 68.22 kg of fat-free mass in the supervised group increased by 1.38 kg–an improvement of 2.02% that is very similar to the 1.95% increase in the AEG studied here.

Despite the small reduction in the body fat percentage of the AEG, which is within the error range associated with the determination of body fat via skinfold methods (26), the results also suggest that the PARP applied was significantly effective in the reduction of body fat, despite not being designed for this purpose. The PARP involved extra expenditure of calories that, because it was not compensated for by an increase in the calories provided by the daily diet, caused a negative balance that led to a slight reduction in the fat mass of subjects with very low percentages of body fat. These results are therefore very positive because the PARP created a stimulus that both increased muscle mass and favored an overall reduction in fat–more specifically, that

TABLE 5. Change in body composition by segments.

Variable	Group	Previous value and change		SD(±)	(p)¹	(p)²
Arm circumference (cm)	CG	Pre	30.48	1.81	0.142	0.000†
		Change	−0.10	0.12		
	AEG	Pre	30.03	2.18	0.000†	
		Change	+1.33	0.22		
Arm skinfold (mm)	CG	Pre	7.92	2.23	0.288	0.589
		Change	−0.56	1.02		
	AEG	Pre	10.63	4.56	0.095	
		Change	−0.94	1.26		
Arm muscular area (cm2)	CG	Pre	52.48	6.27	0.524	0.000†
		Change	+0.37	1.19		
	AEG	Pre	47.11	6.97	0.000†	
		Change	+5.49	1.99		
Thigh circumference (cm)	CG	Pre	60.48	2.66	0.181	0.71
		Change	−1.12	1.55		
	AEG	Pre	59.57	4.39	0.286	
		Change	+0.64	1.45		
Thigh skinfold (mm)	CG	Pre	11.88	2.85	0.542	0.294
		Change	+1.00	3.36		
	AEG	Pre	12.06	4.53	0.356	
		Change	−0.57	1.51		
Thigh muscular area (cm2)	CG	Pre	291.53	25.28	0.185	0.71
		Change	−10.65	14.89		
	AEG	Pre	283.72	41.92	0.278	
		Change	+6.24	13.84		
Thoracic internal circumference (cm)	CG	Pre	102.88	3.59	0.269	0.948
		Change	−0.90	1.57		
	AEG	Pre	100.84	5.37	0.121	
		Change	−0.96	1.40		
Thoracic external circumference (cm)	CG	Pre	119.20	3.66	0.533	0.880
		Change	−1.12	3.68		
	AEG	Pre	117.64	6.74	0.413	
		Change	−0.84	2.54		
Pectoral skinfold (mm)	CG	Pre	7.04	2.38	0.102	0.113
		Change	−0.52	0.50		
	AEG	Pre	8.77	3.44	0.039*	
		Change	−1.51	1.14		
Waist circumference (cm)	CG	Pre	83.88	3.89	0.004†	0.013†
		Change	−2.56	0.99		
	AEG	Pre	82.60	3.07	0.398	
		Change	−0.54	1.24		
Abdominal skinfold (mm)	CG	Pre	13.32	6.72	0.964	0.052*
		Change	−0.04	1.86		
	AEG	Pre	15.97	4.42	0.009†	
		Change	−2.17	1.50		
Hip circumference (cm)	CG	Pre	100.06	5.25	0.345	0.040*
		Change	−1.78	3.21		
	AEG	Pre	96.49	4.20	0.049*	
		Change	+1.51	1.63		

(p)¹ = Statistical intragroup significance; (p)² = posttest statistical intergroup significance with regard to the change.
*Significant statistical difference ($p \leq 0.05$); †very significant statistical difference ($p \leq 0.01$).
CG = control group; AEG = aquatic exercise group.

located in the pectoral and abdominal region (13.59%)–in fit subjects with excellent BC who only trained at a frequency of 3 d·wk^{-1}. Colado et al. (11) observed that aquatic resistance exercises using aquatic devices showed a certain tendency towards creating greater cardiovascular and metabolic response than dry-land resistance exercises with elastic bands, something possibly caused by the continuous participation of concentric muscle actions and, possibly, by the greater muscular demands made on stabilizing muscles in the aquatic medium. The PARP also used a progressive overload method based on increasing volume by grouping exercises that not only increased the total involvement of the number of muscle groups but also increased the duration of the effort and the number of muscle actions per session. In typical dry-land training, the load is constant for both the eccentric and concentric phases of movement. Conversely, with PARP and aquatic devices, the muscle actions are predominantly concentric for all movements, which may actually result in a higher growth hormone response (22). Therefore, this hormonal response could have a positive effect on improving BC, given the role played by growth hormone in the mobilization of fatty acids for use as an energy substrate, and it could be one of the causes underlying the results regarding the improvements in BC among the AEG. However, specific studies should be carried out to confirm this.

Body composition did not change equally in the upper and lower body, with no significant changes in BC seen in the lower body among the AEG. It is possible that the local training volume applied was too low when compared with that applied to the upper limbs. It is also possible that more time than that used in this program is needed to achieve muscle adaptations in the lower limbs, this not being the case for the upper limbs (1).

Nevertheless, despite the positive effects that can be provided by training programs that prioritize concentric muscle actions, we should be cautious with regard to the fact that eccentric actions do not play a major role in PARPs using aquatic devices, which are typical of sport and of daily life and are usually combined with concentric actions in many motor situations. Thus, it should be recommended that any overall neuromuscular conditioning program should include dry-land exercises that demand such actions for those taking part in a PARP. However, Colado (9) suggests that the fact that eccentric actions are minimized and training is carried out using muscle pairs (agonist/antagonist) could favor a reduction in delayed muscle pain, less risk of injury, greater calorie consumption, and reduced training time. These factors would increase adherence to the programs, routines for functional pairs that are easier to balance, and, as has been shown in this study, fat-free mass and strength.

An important contribution of the current investigation is that it offers a practical solution to one of the main drawbacks of strength training in the aquatic medium, which is control over the intensity of work (7,31) and, consequently, the possibility of objectively quantifying the resistance used. Prior methods were dependent on the subjective criteria of those exercising, who had to perform the exercises to a high speed depending on their effort perception (32,37); such methods therefore offered little control. Through quantification of the pace of movement per minute, with adjustments to a specific targeted number of repetitions according to the specific needs of each exercise and each subject, control of the intensity applied to each set, exercise, and training session could be maintained at all times. This method has provided tangible, objective, and practical criteria with which to monitor aquatic resistance exercises. Finally, it is very important to point out that quantification of the "load" for strength training in water using the methodology proposed here could allow the individual to target any particular program goal (hypertrophy, strength, muscle endurance, power). In conclusion, the present results indicate that a PARP with a cadence of movement monitored and adjusted individually for each exercise and subject using a metronome produces significant improvements in muscular strength, power, and fat-free mass and, thus, seems to be a very effective form of resistance exercise.

Practical Applications

As well as being an effective training method for increasing maximum strength and fat-free mass, the aquatic resistance program has a positive effect on reducing body fat. As with dry-land exercises, these effects appear when the correct, progressive program design is established, meaning that the resistance offered by the water in each of the sets and exercises must be controlled. In the aquatic medium, progressive and well-adapted increases of the "load" or resistance can be applied as long as the subjects use aquatic devices with which they already have been evaluated to find a pace of movement per minute for each exercise that allows them to perform a certain number of repetitions at the initially prescribed perceived intensity. However, for this resource to be valid, we also must ensure that the subjects always maintain the same arm and lever length and the same position of the segments and the aquatic devices that increase the drag force. Therefore, if similar findings are made, we are witnessing a new future for strength training in such different fields as rehabilitation, sports performance, health, and aesthetics.

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