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ACADEMIC LITERATURE REVIEW

Is water-based exercise training sufficient to improve physical fitness in the elderly?

A systematic review of the evidence

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Abstract The research on the effects of aquatic exercise is a field that has grown rapidly in the last decade. The majority of the available literature is focused on the benefits of water-based exercise programs for people with rheumatologic disease and back pain; however, there is a lack of evidence reporting the effects of exercise performed in an aquatic medium for healthy elderly adults. The purpose of this study was to critically review the existing evidence of a potential relationship between water-based exercise and improvement of physical fitness in healthy elderly subjects. A systematic database search for manuscripts and a quality control were performed. A system of rating was defined. Aerobic, muscular strength, flexibility and body composition outcomes were then extracted. Nine studies were analyzed after the screening for eligibility: five randomized controlled trials (RCT), three randomized uncontrolled trials (UT) and one controlled trial (CT). Four RCT and two randomized UT were classified as high quality studies. One RCT, one randomized UT and one CT were considered low quality studies. Strong evidence supports the use of water-based exercise for the improvement of aerobic capacity and strength. Moderate evidence highlights the benefits on flexibility, and inconclusive evidence was found supporting the modification of body composition.

Keywords Aquatic · Exercise · Older adults · Water-based · Review

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Introduction

In Western society, both medical and social institutions are paying increased attention to the health and well-being of the elderly and the impact of their growing numbers on society in future years. Both Europe and the United States are facing major changes in population age balance, which will likely reshape their demographic structure over the next 20 years. In fact, by the year 2050, one-tenth of the world's population will be over 65, and the age demographic including people over 80 years old will be the fastest growing segment of the population [1].

In recent years, there has been considerable interest in the benefits of physical activity in the elderly and the evidence regarding the benefits of regular exercise and physical activity for aged individuals are reported in the American College of Sports Medicine (ACSM) Position Stand 'Exercise and physical activity for older adults' [2] and the ACSM/American Heart Association (AHA) 'Physical activity recommendations for older adults' [3]. In the ACSM/AHA recommendations, aquatic exercise is considered beneficial, especially for people who have limited tolerance for weight-bearing activities. Water, as a medium, can be considered particularly useful with the elderly considering that it reduces the likelihood of acute injury and fear of falling and is known to improve participation and adherence [4].

A main problem with water-based aquatic exercise research is that it has primarily focused on the effects of aquatic exercise on rheumatologic disorders such as fibromyalgia [5], osteoarthritis [6, 7] and pain [8]. However, there is a lack of high level studies that primarily focused on the effects of exercise carried out in the aquatic medium by healthy older adult. The purpose of this study was to critically review the existing body of literature and find the relationship between water-based exercise and changes of physical fitness in healthy elderly.

Methods

Study design

This study is a systematic qualitative review of the literature, with the aim of analyzing and summarizing the changes of physical fitness in healthy older adults that underwent an exercise protocol in the aquatic environment.

Literature search

The researchers examined MEDLINE bibliographic online database, Bandolier®, ClinicalTrial.gov, PEDro and Web of Science®. Specific keywords were used, and only studies published in indexed journals between 1985 and 2009 and written in the English language were considered.

Inclusion criteria

Inclusion criteria for the systematic review comprehend: manuscripts classified as randomized controlled trials (RCT), controlled trials (CT) and uncontrolled trials (UT); published in an indexed journal and written in English. The study had to include an exercise or physical activity protocol. The age of the sample that underwent the exercise protocols had to be over 59 years old, and the participants involved in the study had to be healthy (without orthopedic-, cardiovascular- and cancer-related pathologies).

Exclusion criteria

Among the eligible works, studies that did not analyze changes on strength, aerobic capacity, flexibility and body composition were excluded.

Study quality assessment

The quality of the studies was assessed applying the nine criteria checklist provided by the Cochrane Collaboration Back Review Group [9]. Each criterion of the list was evaluated for all studies. When showing a satisfactory description, a positive value was assigned (+). If the criterion description was considered absent, unclear or with a lack of contents, a negative value was assigned (−). The first criterion, the randomization procedure, was used only in RCTs. A study was qualitatively judged as being of high quality if it showed a positive score on 5 to 9 of the criteria; otherwise, it was considered a low quality study. The overall level of evidence of the selected variables (aerobic capacity, strength, flexibility and body composition) was calculated according to Proper et al.'s systematic review [10]. For each of the analyzed outcomes (aerobic capacity, strength, flexibility and body composition), five levels of evidence were categorized according to the statistical significance of the evaluated variables: “strong evidence” required at least two high quality RCTs showing statistically significant results for the analyzed variables; “moderate evidence” required one high quality RCT and at least one low quality CT/RUT, or two low quality RCTs or at least two high quality CT/RUT showing statistically significant changes; “limited evidence” required one high quality RCT and at least one low quality CT/RUT, or at least two low quality RCTs, or more than one CT/RUT of high quality that reported statistically significant results for the analyzed variables; “inconclusive evidence” required one or more CT/RUT of low quality with contradictory results in the analyzed variable and the criterion was classified as “no evidence” if more than one study did not describe statistically significant change in the considered variable [10].

Data extraction and synthesis

Two authors examined the abstract of each study. After which, they independently decided the eligibility of each study for inclusion. In case of disagreement, a third author was consulted.

Three authors carried out the quality check according to the Cochrane methodological quality criteria. They independently assigned a positive or a negative score to each item. Finally, they analyzed and discussed the individual ratings assigning a final positive or negative score. Then, the final rating for each study was calculated by analyzing all items.

Results

Search results

The flow chart of the literature search is represented in Fig. 1. The research returned 276 studies. Of these, 209 were primarily rejected for manuscript type or because they

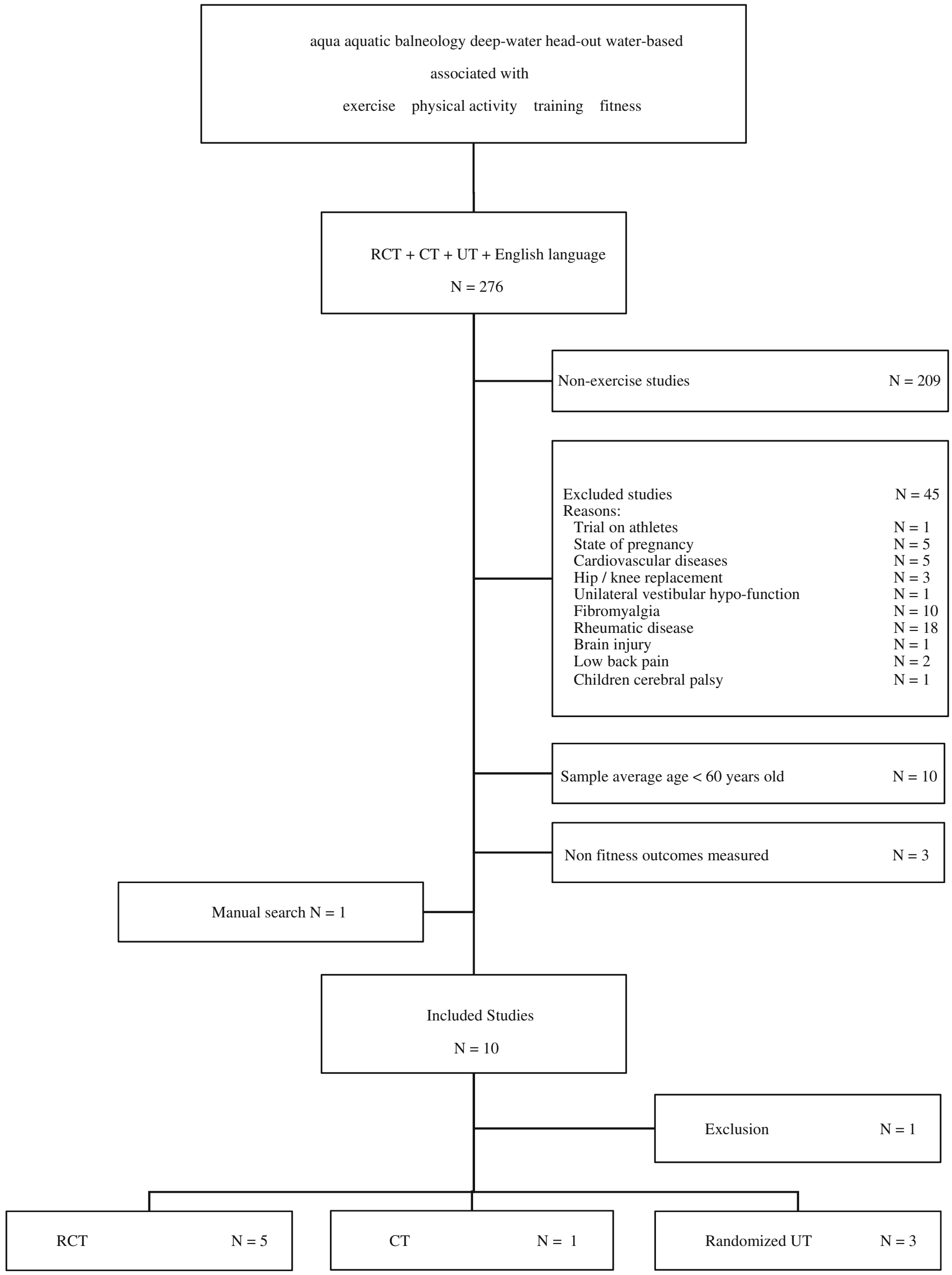

Fig. 1 Flow chart of the literature search

did not carry out an exercise intervention. Further, 45 manuscripts were excluded because of sample characteristic issues; some involved athletes and others had subjects with diseases or physical impairment.

After the final screening, there were ten eligible studies. One additional study [11] was excluded because muscle strength of the expiratory and inspiratory muscles was not consider as an index of aerobic or endurance capacity. Among the included studies, five were RCTs [12–16], three studies were randomized UTs [17–19] and one study was a CT [20].

Quality assessment

Quality assessment conducted assigned a score from two to six among the nine criteria of the Cochrane checklist. Four RCT [12–15] and two RUT [17, 18] were classified as high quality studies.

One RCT [16], one RUT [19] and one CT [20] were considered low quality studies. Global scores are represented in Table 1.

None of the studies described the items “blinding” procedure and the “intention to treat” procedures. Only one

Table 1 Quality assessment of the studies

Citation	Randomization procedure	Similarity of study groups	Inclusion or exclusion criteria	Dropouts	Blinding	Compliance	Intention-to-treat analysis	Timing of outcomes assessment	Follow-up	Results
Katsura et al. (2009)	+	+	+	+	−	+	−	−	−	5/9
Vale et al. (2009)	−	+	+	−	−	−	−	−	−	2/9
Bocalini et al. (2008)	+	+	+	+	−	+	−	−	−	5/9
Cancela Carral et al. (2007)	+	−	+	+	−	+	−	−	−	4/9
Broman et al. (2006)	+	+	+	+	−	+	−	−	+	6/9
Tsourlou et al. (2006)	+	+	+	+	−	+	−	−	−	5/9
Takeshima et al. (2002)	+	+	+	+	−	+	−	−	−	5/9
Taunton et al. (1996)	+	+	+	−	−	−	−	+	−	4/9
Ruoti et al. (1994)	+	−	−	+	−	+	−	−	+	4/9

Item A is only applicable for RCTs

study reported the timing of outcome assessments satisfactorily [19] and two described the follow-up [13, 16].

Studies description

Table 2 shows the experimental design of the included studies, while Table 3 describes their results.

Aerobic capacity

Three high quality studies showed statistically significant improvements in various parameters expressing aerobic capacity: +42% and +10% of VO_2 max [12, 13], +20% of VO_2 at lactate threshold and +12% of VO_2 peak [15]. Moreover, the RCT of Ruoti et al. [17] revealed improvements between and within groups in VO_2 max and heart rate (HR), while Taunton et al. [19] highlighted a 11.7% of improvements in VO_2 max of the water-based exercise group, but the improvement was statistically significant only in the within group analysis. Finally, only the RUT of Cancela Carral et al. [18] did not find any statistically significant change in VO_2 max and in the 2,000-m walk time. From the available literature and the criteria set in this review, it appears that the utilization of water exercise as a method to improve aerobic (cardiovascular) capacity in healthy elderly is supported by strong evidence.

Muscular strength

Among the nine studies included in the review, eight evaluated strength using various modalities. One high quality RCT showed a statistically significant increase in the within- and between-group comparisons in the arm curl test [12]. Two high quality RCTs [14, 15] found statistically significant improvements in most of the examined strength variables: maximal isometric torque of knee flexors (+13.4%, +12.7%) and extensor (+10.5%, +8.4%) [14, 15], one repetition maximum (1-RM) at the knee extension (+29.4%) and leg press (+29.5%) [14], chest press (+25.7%, +7.2%) [14, 15], and hand grip (+12.8%) [14], except for the 1-RM at the lat pull down (−1.7%) [14] and low back flexion (−3.7%) [15]. In the Ruoti et al. study [16], a statistically significant increase in work capacity of shoulder abduction–adduction and flexion–extension was reported (+34.8% and +10.7%, respectively). Significant improvements in all analyzed strength variables (right handgrip +13.1%, left handgrip +10.5%, leg strength +19.6% and abdominal resistance strength +12.1%) were also reported in the study by Cancela Carral et al. [18]. Finally, in the RUT by Katsura et al. [17], a statistically significant change in planter–flexion muscular strength was found (+35.6%). One study did not detect any statistical change in the upper limb strength [19]. All results are summarized in Table 3. Overall, data reported in the selected studies support with strong evidence that water-based exercise is effective to improve strength in healthy elderly.

Flexibility

Six studies examined flexibility; five of them [12, 14, 17–19] used the sit and reach test [21] to assess lower body, while Bocalini et al. [12] performed the back scratch test [21] in order to measure upper body flexibility; differently, Takeshima et al. [15] measured trunk extension and flexion starting from a standing position. The water-based exercise group of Bocalini et al. [12] reported significant upper (+40%) and lower body (+50%) flexibility improvements in the between- and within-group comparisons; the aquatic training group of Tsourlou et al. [14] showed a +12% increase, and both exercise groups (resistance and nonresistance) of

Table 2 Characteristics of the studies

Author	Subjects	Age	Grouping	Training modality	Program and intensity	Frequency	Duration
Katsura et al. (2009)	20 (16 F, 4 M)	>64	Resistance group	Combined strength and endurance exercises (with water resistance equipment)	Moderate to strong levels of RPE scale; resistance training using water resistance equipment	3	8 weeks
			Non-resistance group	Aquatic exercise training without water resistance equipment	Moderate to strong levels of RPE scale		
Vale et al. (2009)	35 F	>60	SG—strength training group (N=12)	Progressive resistance training	4 weeks: 10 min warm-up+35 min progressive resistance training at 50% of 1-RM 8 weeks 10 min warm-up+35 min progressive resistance training at 75–85% of 1-RM	3	12 weeks
			AG—aerobic training group (N=13)	Progressive aerobic aquatic training	4 weeks at 2 and 3 Borg's CR10 Perceived Exertion Scale 8 weeks at 3 and 4 Borg's CR10 Scale		
			CG—control group (10)		Daily living activity—not engaged in any physical activity		
Bocalini et al. (2008)	72 F	>61	WE—Water-based exercise (N=27)	Combined aquatic aerobic and resistance training	Aerobic exercise at 70% of age predicted maximum HR	3	12 weeks
			WL—walking on land (N=25)	Walking exercise	60 min exercise each session at 70% of age predicted maximum HR	5	
			S—sedentary group (N=20)				
Cancela Carral et al. (2007)	62 F	>64	G1—group 1 (N=31)	4 months: exercise in water; 5 months subsequent: exercise in water (twice per week) and strength exercise (three times per week)	Strength training at 75% of 1-RM; Exercise in water: 45 min.	5	9 months
			G2—group 2 (N=31)	4 months: exercise in water; 5 months subsequent: exercise in water (twice per week) and calisthenic exercise (three times per week)	Calisthenic exercise: First microcycle 15 min (6 strength exercise + 9 general movement). First microcycle main activity 15 min (6 strength free body exercises and 9 aerobic). The remaining microcycles 30 min of main exercises; The fourth and last microcycle 30 min (strength exercise + 20 min general movement)		
Broman et al. (2006)	29 F	>64	Training group (N=18)	High intensity deep water interval training with wet vest	3 phases: A (10 min) from 75% to 80% maximum HR B (10 min) from 75% to 85% maximum HR C (10 min) from 75% to 85% maximum HR	2	8 weeks
			Control group (N=11)				
Tsourlou et al. (2006)	22 F	>59	AT—aquatic training (N=12)	Combined aerobic and resistance aquatic exercise	25 min aerobic-type exercise, 20–25 min of resistance exercise Aerobic exercise intensity progress from 65% to 80% maximum HR	3	24 weeks

Table 2 (continued)

Author	Subjects	Age	Grouping	Training modality	Program and intensity	Frequency	Duration
					Resistance exercise program included 15 for 2/3 sets at progressive training from 60 to 120 b min^{-1}. 20/30 s recovery time between the sets		
			C—control group (*N*=10)				
Takeshima et al. (2002)	30 F	>59	TR—training group (*N*=15)	Combined aerobic and resistance aquatic exercise	Endurance training: 30 min per session at the correspondent HR to lactate threshold	3	12 weeks
					Resistance exercise: 10 min each session with each body exercise performed 12/15 per 1 set at maximum velocity of execution		
			Nonexercise control group (*N*=15)				
Taunton et al. (1996)	41 F	>64	Water-based exercise program (*N*=23)	Combined aerobic and resistance aquatic exercise	Aerobic exercise 20 min each session at 60–65% of maximum HR	3	12 weeks
			Land-based exercise program (*N*=18)	Combined aerobic and resistance exercise	Strength and resistance 8 min		
					Flexibility and balance 7 min		
					LBE and WBE programs were matched as closely as possible in content		
Ruoti et al. (1994)	20 (12 F, 8 M)	>59	Exercise group (*N*=12)	Nonswimming water exercise	Structured physical activity protocol, 1 set each exercise with time of execution from 30 min to 60 min at 80% of maximum HR	3	12 weeks
			Control group (*N*=8)				

Table 3 Results

Author	Group	Aerobic or endurance capacity	Strength and muscular endurance	Flexibility	Body composition
Katsura et al. (2009)	Resistance group (N=12)		Leg extension force (N m): 339.0±61.1 to 340.5±53.0 Muscle strength of planter flexion (kg)*: 32.3±6.8 to 43.8±6.5 Muscle strength of dorsi flexion (kg): 22.7±3.3 to 23.1±5.4	Sit and reach test (cm): 27.9±8.3 to 31.3±6.7*	
	Nonresistance group (N=8)		Leg extension force (N m): 382.8±95.2 to 391.1±78.3 Muscle strength of planter flexion (kg)*: 40.4±6.7 to 48.1±9.6* Muscle strength of dorsi flexion (kg): 24.5±5.0 to 27.5±3.8	Sit and reach test (cm): 23.6±5.0 to 28.0±4.8*	
Vale et al. (2009)	SG—strength training group (N=12)		Bench press (kg): 16.50±4.27 to not reported (+42.4%)* Leg press 45° (kg): 51.67±1.02 to not reported (+71.0%)*		
	AG—aerobic training group (N=13)		Bench press (kg): 24.46±3.84 to not reported (1.02%) Leg press 45° (kg): 77.81±3.06 to not reported (26.17%)*		
	CG—control group (10)		Bench press (kg): 21.08±1.03 (4.40%) Leg press 45° (kg): 67.30±2.45 (3.26%)		
Bocalini et al. (2008)	WE—water based exercise (N=27)	VO_2 max (ml kg^{-1} kg^{-1}): 20±3 to 35±3 (42%)*,**,***	Arm curl test (number to exhaustion): 17±3 to 25±1*,**,***	Back scratch test (cm): −10±2 to −6 ±2*,**,*** Sit and reach test (cm): 24±3 to 36±2*,**,***	
	WL—walking on land (N=25)	VO_2 max (ml kg^{-1} kg^{-1}): 19±4 to 28±2 (32%)*,**	Arm curl test (number to exhaustion): 20±2 to 22±3	Back scratch test (cm): −11±1 to −10±1 Sit and reach test (cm): 21±2 to 28±2*,**	
	S—sedentary group (N=20)	Not reported	Arm curl test (number to exhaustion): 19±1 to 21±2	Back scratch test (cm): −11±2 to −10±1 Sit and reach test (cm): 22±2 to 23±2	
Cancela Carral et al. (2007)	G1—group 1 (N=31)	VO_2 max (ml kg^{-1} kg^{-1}): 19.39 ±5.85 to 18.80±6.00 Time 2,000 m (min): 22.12±1.95 to 21.48±1.41	Right hand grip (kg): 19.58±5.74 to 22.14±6.26* Left grip (kg): 18.78±5.76 to 20.76±5.62* Leg strength (kg): 51.08±27.55 to 61.10±22.84* Abdominal resistance strength (number to exhaustion): 55.03±26.24 to 61.71±14.00*	Sit and reach test (cm): 23.21±7.43 to 24.82±7.24*	

Table 3 (continued)

Author	Group	Aerobic or endurance capacity	Strength and muscular endurance	Flexibility	Body composition
	G2—group 2 (*N*=31)	VO_2 max (ml kg^{-1} kg^{-1}): 17.50 ±9.87 to 17.58±9.81 Time 2,000 m (min): 22.02±3.01 to 22.39± 3.02	Right hand grip (kg): 18.21± 5.08 to 18.32±5.01 Left hand grip (kg): 17.76±5.33 to 17.48±5.36 Leg strength (kg): 43.83±18.04 to 45.72±17.30 Abdominal resistance strength (number to exhaustion): 50.92±25.08 to 50.89±23.85	Sit and reach test (cm): 23.18±5.44 to 26.47±7.59*	
Broman et al. (2006)	Training group (*N*=18)	Work rate (W): 120±20 to 132±20* VO_2 (l min^{-1}): 1.74± 0.25 to 1.92±0.28* VO_2 (ml kg^{-1} kg^{-1}) 25.5±2.3 to 27.2±2.1*			
	Control group (*N*=11)	Work rate (W): 111±27 to 116±22 VO_2 (l min^{-1}) 1.65± 0.29 to 1.72±0.27 VO_2 (ml kg^{-1} kg^{-1}) 22.5±4.3 to 23.3±4.0			
Tsourlou et al. (2006)	AT—aquatic training (*N*=12)		Knee extension (N m): 80.8± 8 to 89.3±7.9*,** Knee flexion (N m): 54.3±5.5 to 61.6±5.4*,** 1-RM knee extension (kg): 41.70±2.5 to 53.97±2.7*,** 1-RM leg press (kg): 62.05±3.6 to 80.35±3.7*,** 1-RM chest press (kg): 25.45± 1.7 to 32.00±1.70*,** 1-RM lat pull down (kg): 28.77 ±1.4 to 28.28±1.0 Hand grip (kg): 24.05±1.2 to 27.14±1.3*,**	Sit and reach test (cm): 21.15±1.9 to 23.60±1.8*	FFM (kg): 38.0±1.1 to 39.3±1.2*
	C—control group (*N*=10)		Knee extension (N m) 82.5± 9.2 to 83.6±12.2 Knee flexion (N m) 55.1±9.2 to 57.8±11.3 1-RM knee extension (kg): 40.50±2.6 to 41.37±2.7 1-RM leg press (kg): 57.18±4.0 to 58.44±4.6 1-RM chest press (kg): 24.81± 1.8 to 25.56±1.80 1-RM lat pull down (kg): 25.94 ±0.8 to 24.19±1.4 Hand grip (kg): 23.4±2.7 to 23.6±2.3	Sit and reach test (cm): 22.56±2.4 to 22.87±2.4	FFM (kg): 41.0±0.8 to 40.7±0.7
Takeshima et al. (2002)	TR—training group (*N*=15)	VO_2 at lactate threshold (l min^{-1}): 0.777± 0.214 to 0.934±0.224 (20%)*	Knee extension (N m) 34.4± 8.0 to 37.3±7.4*,**	Trunk extension (cm): 32.6±11.1 to 36.1±8.0	Sum of skinfold (mm): 40.5±11.1 to 37.3 ±10.3*

Table 3 (continued)

Author	Group	Aerobic or endurance capacity	Strength and muscular endurance	Flexibility	Body composition
		Peak VO_2 (l min^{-1}): 1.178±0.39 to 1.314 ±0.341 (12%)*	Knee flexion (N m): 26.0±7.8 to 29.3±8.1*,**	Trunk flexion (cm): 15.4±5.9 to 16.6 ±4.7	Arm girth (cm): 27.7± 2.8 to 28.0±2.9
			Chest press (N m): 216.4±46.1 to 231.9±49.1*,**		Thigh girth (cm): 45.0 ±3.7 to 45.5±4.6
			Chest pull (N m): 224.1±45.2 to 248.2±53.2*,**		
			Low back extension (N m): 216.4±78.1 to 230.0±51.8*,**		
			Low back flexion (N m): 132.8 ±30.9 to 127.9±39.4		
			Shoulder press (N m): 88.2± 28.1 to 92.0±25.4*,**		
			Shoulder pull (N m): 193.8± 43.3 to 205.5±47.4*,**		
			Vertical jump (cm): 23.1±4.6 to 25.2±4.4*,**		
	Nonexercise control group (*N*=15)	VO_2 at lactate threshold (l min^{-1}): not reported	Knee extension (N m): 34.4± 5.3 to 33.7±5.3	Trunk extension (cm): 29.7±9.6 to 29.2±9.9	Sum of skinfold (mm): 47.5±12.5 to 49.4± 12.7
		Peak VO_2 (l min^{-1}): not reported	Knee flexion (N m): 34.4±5.3 to 33.7±5.3	Trunk flexion (cm): 8.3±8.0 to 8.5±8.3	Arm girth (cm): 28.4± 1.8 to 28.3±2.0
			Chest press (N m): 216.6±41.4 to 213.1±40.7		Thigh girth (cm): 46.8± 2.8 to 47.0±2.8
			Chest pull (N m): 234.2±45.1 to 229.3±46.1		
			Low back extension (N m): 231.1±57.4 to 197.9±74.6		
			Low back flexion (N m): 142.6 ±41.7 to 117.5±49.9		
			Shoulder press (N m): 106.6± 22.8 to 96.7±22.9		
			Shoulder pull (N m): 223.8± 36.2 to 208.0±42.9		
			Vertical jump (cm): 23.0±4.8 to 22.3±4.5		
Taunton et al. (1996)	Water-based exercise program (*N*=23)	VO_2 max (ml kg^{-1} kg^{-1}): 18.8 ±3.5 to 21.1±3.3 (11.7%)*	Grip strength (kg): 52.2±10.7 to 52.5±9.3	Sit and reach test (cm): 29.3±9.2 to 31.9±9.1	Sum of skinfold (mm): 80.8±30.4 to 82.3 ±33.3
			Curl-up (number min^{-1}): 34± 20 to 45±33		Waist to hip ratio (cm): 0.85±0.07 to 0.85 ±0.06
			Push-up (number to exhaustion): 19±19 to 22±12		
	Land-based exercise program (*N*=18)	VO_2 max (ml kg^{-1} kg^{-1}): 18.4 ±3.2 to 20.9±3.6 (10.9%)*	Grip strength (kg): 49.5±10.7 to 48.3±8.9	Sit and reach test (cm): 28.8±7.8 to 27.6±10.9	Sum of skinfold (mm): 82.6±35.8 to 83.3 ±37.1
			Curl-up (number min^{-1}): 32± 15 to 53±30*		Waist to hip ratio (cm): 0.81±0.06 to 0.76 ±0.17
			Push-up (number to exhaustion): 17±13 to 21±10		
Ruoti et al. (1994)	Exercise group (*N*=12)	VO_2 max (ml kg^{-1} kg^{-1}): 23.37 ±0.4 to 26.95±0.5*,**	Work capacity—shoulder abduction–adduction (repetitions/min): 6.29±0.3 to 8.48±0.3*,**		Fat mass (%): 38.48 ±0.5 to 36.90±0.5
		Endurance work (heart rate at the same	Work capacity—shoulder flexion–extension		

Table 3 (continued)

Author	Group	Aerobic or endurance capacity	Strength and muscular endurance	Flexibility	Body composition
		workload): 123.94± 6.3 to 98.36±6.2*,**	(repetitions/min): 3.08±0.1 to 3.41±0.1*,**		
	Control group (N=8)	VO_2 max (ml kg^{-1} kg^{-1}): 23.17 ±0.4 to 21.84±0.6	Work capacity—shoulder abduction–adduction (repetitions/min): 6.07±0.2 to 5.82±0.3		Fat mass (%): 38.20± 0.6 to 38.21±0.6
		Endurance work (heart rate at the same workload): 120.84± 6.9 to 122.46±7.8	Work capacity—shoulder flexion–extension (repetitions/min): 3.13±0.1 to 2.87±0.1		

Change (%) has been reported when defined in the included studies

* $p<0.05$ in within group analysis; ** $p<0.05$ in between group analysis; *** $p<0.05$ among all group analysis

Katsura et al. [17] showed a statistically significant improvement (+12% and +19%, respectively). A positive effect was also highlighted by Cancela Carral et al. [18] in both intervention groups (+7% and +14%). On the contrary, Takeshima et al. [15] and Taunton et al. [19] did not find any statistical modification in flexibility after 12 weeks of water exercise intervention.

To summarize, the lack of effects reported in one high quality RCT and one RUT (vs. four positive reports, positive findings in less than 75% of studies [10]), suggest to classify as moderate the evidence of efficacy for water exercise to improve flexibility.

Body composition

Body composition was assessed in five studies [14–16, 19]. Only two studies found significant changes in the intervention group: Tsourlou et al. [14] in the fat-free mass (+3.4%) and Takeshima et al. [15] in the subcutaneous fat (−7.9% in the sum of skinfolds).

Considering the lack of effect in three studies and the use of different methods in the two positive studies, inconclusive evidences support the efficacy of water-based exercise as a method to improve body composition.

Discussion

There is a lack of meta-analysis and systematic reviews to describe the effects of water-based exercise on physical fitness parameters in elderly subjects. In fact, the existing high quality reviews are mainly focused on knee osteoarthritis [8], fibromyalgia [22] and the relief from back pain [23]. Additionally, the evidence of an effective improvement of physical fitness parameters with a water-based exercise program in healthy older adults is lacking.

When considering the studies analyzing the benefits of water exercises programs in terms of aerobic capacity, strength, flexibility and body composition improvements, several limitations were identified. Firstly, examining cohort characteristics of the included studies, seven of them involved a sample of female subjects, while only two manuscripts [16, 17] presented mixed groups. This means that in the available literature, the overall number of healthy older male subjects studied was 12. Although some evidences revealed no gender differences in the magnitude of improvement in aerobic capacity with endurance training [24, 25], few older studies suggested that women were less trainable than men [26, 27]. Conversely, Peterson et al. [28] reported that the regression analysis performed in their systematic review failed to identify an association between gender and strength main effects, suggesting a significant potential adaptive response for both men and women. Further, Hakkinen et al. [29] indicated women as hypertrophycally responsive to a twice-a-week strength training, while the same program showed limited effects on muscle hypertrophy in men. Thus, similar to water-based strength exercise, whether muscular adaptations to different land-based activities between genders are comparable, is still unclear. Moreover, the normal decline in physical function occurring with aging could alter the analysis of gender effect on training of flexibility and body composition.

From a methodological point of view, a further limitation was the paucity of studies evaluating or reporting participants' level of physical activity at the start of the exercise protocol [13, 16, 18, 19]. From this perspective, elderly with higher or lower than normal functional capacity could have shown different outcomes at the end of the exercise interventions, especially in studies using higher volumes and intensities.

Six studies measured aerobic capacity (Table 3). All exercise protocols were similar for duration (8–12 weeks) and frequency (three times a week) but differed for modality of the aerobic exercise. Protocols included aerobic exercise [13], combined aerobic and resistance exercise [12, 13, 18, 19] and a sequence of specific water-based exercise [16]. On average, the intensity was set between 60 and 85% of age-predicted maximal HR. Despite these small differences, the mean improvement in aerobic capacity (VO_2 max) ranged between 10 and 15%. Only one study, a RUT [18], paradoxically the one with the longest duration of training (9 months), was unable to detect any significant change. However, this study was mainly focused on strength enhancement, while aerobic exercise was poorly developed, and its intensity was not quantified. On the other hand, the greater increase in VO_2 max (+42%), observed by Bocalini et al. [12], can probably be explained by their use of an indirect approach for maximal aerobic power estimation (ACSM's equation) [30].

On the whole, it would seem that these protocols, although slightly different for intensity, produced similar improvements in terms of VO_2 max. This suggests that water-based exercise, performed from moderate to high intensities, should also be considered a useful tool for the improvement of cardiovascular capacity in healthy elderly.

Most part of the studies evaluated strength using different testing modalities and different methods of strength training intensity monitoring; this variability yield a further limitation for data comparison and interpretation. Katsura et al. [17] described the intensity of strength exercises using Borg's rating of perceived exertion (RPE); Takeshima et al. [15] did not describe the intensity of the aquatic exercise although the authors imposed the full range of motion at the maximal velocity attainable in each set and repetition. Bocalini et al. [12] followed the exercise intervention methods of Takeshima et al. [15] with subtle adaptations, specific for older women. Finally, Taunton et al. [19] included strength and endurance (muscle endurance) exercises in their protocol without a suitable quantification of exercise intensity. A standardized method to evaluate intensity when considering water-based resistance exercises was proposed by Colado et al. [31]: the authors proposed the use of the exercise rhythm and the RPE as a valid method for reproducing the intensity of effort among different sets of the same aquatic resistance exercise. Future researches should use a common system to evaluate and monitor resistance training intensity, possibly adopting the method recommended by Colado [31], which also appears more suitable for fitness leaders of water-based exercise programs.

Although our analysis of literature shows that water-based exercise is a valid tool for the development of strength and muscle endurance, the intensity and the progression of the stimulus required are not well defined. In fact, the wide variability in strength tests and muscular groups evaluated precludes an objective analysis of the magnitude of the adequate stimulus. Future studies should focus on exercise intensity and its progression in resistance training protocols, not disregarding the practical applicability for exercise professionals.

A lack of evidences about the effect of flexibility training on a range of motion (D category of evidence) is highlighted by the ACSM/AHA physical activity guidelines for older adults. In this systematic review, out of nine papers, six specifically investigated flexibility, reporting contradicting results. If we separately analyze each paper, we observe that Taunton et al. [19] and Takeshima at al. [15] did not observe any change in flexibility after their water-based exercise protocols. Conversely, Bocalini et al. [12], Cancela Carral et al. [18], Tsorlou et al. [14] and Katsura et al. [17] described remarkable improvements on lower body flexibility (up to +50%). Despite none of these manuscripts specifically described the type and the intensity of flexibility exercise performed, five studies [12, 15, 17–19] reported a time of 7 to 20 min (time per exercise session) as being dedicated to the flexibility/stretching activities. Only one study provided data about the upper body flexibility [12], showing a 40% improvement, while papers reporting positive results on lower body flexibility described a mean improvement ranging between 7 and 19%. In light of this analysis, we emphasize the need for future research through well-defined training and assessment protocols in water exercise activities.

Currently, applying the ACSM/AHA recommendations, in water-based activity programs, we should include at least a twice-a-week flexibility exercise at moderate intensity (5–6 on the Borg's Scale from 0 to 10). Further, as pointed by Barbosa et al. [32], these exercises should be adapted to the aquatic condition. In fact, during flexibility exercises, body temperature does not reach the same levels in respect to aerobic activities. Then, these exercises should be carried out in higher water temperature or alternated with other exercises in order to reduce the loss of body heat.

Only four studies investigated body composition. Tsourlou et al. [14], using bioimpedance analysis, found a 3.4% significant increase of fat free mass. This improvement was concomitant with an enhancement on both upper and lower limb strength. In addition, Takeshima [15] found a statistically significant reduction of 7.9% in the sum of skinfold. Although the method of skinfold is not exempt from errors of measure, this decrease in subcutaneous fat indicates a clinically relevant improvement in body composition. The other two papers [16, 19] did not find any significant change.

We believe that these different outcomes could have been affected by the rather short duration of the exercise protocols, the lack of control of diet and the different methods used to evaluate body composition. Further, differently from the other studies, in the two "effective" protocols [14, 15], none of subjects had ever participated in a weight training program.

Among all variables of physical fitness, the modification of body composition was the least studied. Future high qualities studies should consider the inclusion of more advanced body composition analysis techniques (e.g., dual energy x-ray absorptiometry), which are able to evaluate whole and segmental body composition as well as a standardization of other important variables such as dietary intake and previous weight training activities. Considering the relevance of sarcopenia in the aging process, these methods could add clinically important information.

Conclusion

Overall, it appears that water-based exercise can produce many beneficial effects on physical fitness when properly prescribed in healthy older individuals. The use of water-based exercise for the improvement of both aerobic capacity and strength is supported by strong evidence, while moderate evidence supports its use for flexibility improvements, and inconclusive evidences are currently available regarding its effects on body composition.

More high quality RCTs involving healthy elderly males are needed, and future investigations should pay closer attention to the exact quantification of exercise intensity, especially for strength exercise.

The evidences provided from this review suggest that a minimum frequency of twice per week water-based exercise sessions performed at moderate–high intensities can lead to improvements in aerobic capacity. However, it seems that three sessions per week of combined aerobic and resistance training should be required in order to obtain significant improvements in both aerobic capacity and muscular strength.

Reference

1. United Nations, Department of Economic and Social Affairs, Population Division (2004) World population prospects to 2300. Working Paper No. 2003ST/ESA/SER.A/
2. American College of Sports Medicine (2009) Exercise and physical activity for older adults. Med Sci Sports Exerc 4:1510–1530. doi:10.1249/MSS.0b013e3181a0c95c
3. Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, Macera CA, Castaneda C (2007) Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Circulation 116:1094–1105. doi:10.1249/mss.0b013e3180616aa2
4. Hauer K, Specht N, Schuler M, Bärtsch P, Oster P (2002) Intensive physical training in geriatric patients after severe falls and hip surgery. Age Ageing 31:49–57. doi:10.1093/ageing/31.1.49
5. Ortega E, García JJ, Bote ME, Martín-Cordero L, Escalante Y, Saavedra JM, Northoff H, Giraldo E (2009) Exercise in fibromyalgia and related inflammatory disorders: known effects and unknown chances. Exerc Immunol Rev 15:42–65
6. Bartels EM, Lund H, Hagen KB, Dagfinrud H, Christensen R, Danneskiold-Samsøe B (2003) Aquatic exercise for the treatment of knee and hip osteoarthritis. Cochrane Database Syst Rev 4. doi:10.1002/14651858.CD005523.pub2
7. Bosomworth NJ (2009) Exercise and knee osteoarthritis: benefit or hazard? Can Fam Physician 55:871–878
8. Kamioka H, Tsutani K, Okuizumi H, Mutoh Y, Ohta M, Handa S, Okada S, Kitayuguchi J, Kamada M, Shiozawa N, Honda T (2010) Effectiveness of aquatic exercise and balneotherapy: a summary of systematic reviews based on randomized controlled trials of water immersion therapies. J Epidemiol 20:2–12. doi:10.2188/jea.JE20090030
9. Van Tulder MW, Assendelft WJ, Koes BW, Bouter LM (1997) Method guidelines for systematic reviews in the Cochrane Collaboration Back Review Group for Spinal Disorders. Spine 22:2323–2330
10. Proper KI, Staal BJ, Hildebrandt VH, van der Beek AJ, van Mechelen W (2002) Effectiveness of physical activity programs at worksites with respect to work-related outcomes. Scand J Work Environ Health 28:75–84
11. Ide MR, Belini MA, Caromano FA (2005) Effects of an aquatic versus non-aquatic respiratory exercise program on the respiratory muscle strength in healthy aged persons. Clinics 60:151–158. doi:10.1590/S1807-59322005000200012
12. Bocalini DS, Serra AJ, Murad N, Levy RF (2008) Water-based versus land-based exercise effects on physical fitness in older women. Geriatr Gerontol Int 8:265–271. doi:10.1111/j.1447-0594.2008.00485.x
13. Broman G, Quintana M, Lindberg T, Jansson E, Kaijser L (2006) High intensity deep water training can improve aerobic power in elderly women. Eur J Appl Physiol 98:117–123. doi:10.1007/s00421-006-0237-2
14. Tsourlou T, Benik A, Dipla K, Zafeiridis A, Kellis S (2006) The effects of a twenty-four-week aquatic training program on muscular strength performance in healthy elderly women. J Strength Cond Res 20:811–818
15. Takeshima N, Rogers ME, Watanabe E, Brechue WF, Okada A, Yamada T, Islam MM, Hayano J (2002) Water-based exercise improves health-related aspects of fitness in older women. Med Sci Sports Exerc 34:544–551. doi:10.1007/s00421-004-1193-3
16. Ruoti RG, Troup JT, Berger RA (1994) The effects of non-swimming water exercises on older adults. Orthop Sports Phys Ther 19:140–145
17. Katsura Y, Yoshikawa T, Ueda SY, Usui T, Sotobayashi D, Nakao H, Sakamoto H, Okumoto T, Fujimoto S (2010) Effects of aquatic exercise training using water-resistance equipment in elderly. Eur J Appl Physiol 108:957–964. doi:10.1007/s00421-009-1306-0
18. Cancela Carral JM, Ayán Pérez C (2007) Effects of high-intensity combined training on women over 65. Gerontology 53:340–346. doi:10.1159/000104098
19. Taunton JE, Rhodes EC, Wolski LA, Donelly M, Warren J, Elliot J, McFarlane L, Leslie J, Mitchell J, Lauridsen B (1996) Effect of land-based and water-based fitness programs on the cardiovascular fitness, strength and flexibility of women aged 65–75 years. Gerontology 42:204–210. doi:10.1159/000213794
20. Vale RG, de Oliveira RD, Pernambuco CS, de Meneses YP, Novaes Jda S, de Andrade AF (2009) Effects of muscle strength and aerobic training on basal serum levels of IGF-1 and cortisol in

elderly women. Arch Gerontol Geriatr 49:343–347. doi:10.1016/j.archger.2008.11.011
21. Rikli RE, Jones JC (1999) Senior fitness test. Human Kinetics, Champaign
22. Tomas-Carus P, Gusi N, Hakkinen A, Hakkinen K, Raimundo A, Ortega-Alonso A (2009) Improvements of muscle strength predicted benefits in HRQOL and postural balance in women with fibromyalgia: an 8-month randomized controlled trial. Rheumatology 48:1147–1151. doi:10.1093/rheumatology/kep208
23. Waller B, Lambeck J, Daly D (2009) Therapeutic aquatic exercise in the treatment of low back pain: a systematic review. Clin Rehabil 23:3–14. doi:10.1177/0269215508097856
24. American College of Sports Medicine (1998) The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness and flexibility in healthy adults. Med Sci Sports Exerc 30:975–991
25. Skinner JS, Jaskolski A, Jaskolska A, Krasnoff J, Gagnon J, Leon AS, Rao DC, Wilmore JH, Bouchard C (2001) Age, sex, race, initial fitness, and response to training: the HERITAGE Family Study. J Appl Physiol 90:1770–1776
26. Blumenthal JA, Emery CF, Madden DJ, George LK, Coleman RE, Riddle MW, Mekee DC, Reasoner J, Williams RS (1989) Cardiovascular and behavioral effects of aerobic exercise training in healthy older men and women. J Gerontol 44:M147–M157
27. Seals DR, Hagberg JM, Hurley BF, Ehsani AA, Holloszy JO (1984) Endurance training in older men and women. Cardiovascular responses to exercise. J Appl Physiol 57:1024–1029
28. Peterson MD, Rhea MR, Sen A, Gordon PM (2010) Resistance exercise for muscular strength in older adults: a meta-analysis. Ageing Res Rev 9:226–237
29. Hakkinen K, Newton RU, Gordon SE, McCormick M, Volek JS, Nindl BC, Gotshalk LA, Campbell WW, Evans WJ, Hakkinen A, Humphries BJ, Kraemer WJ (1998) Changes in muscle morphology, electromyographic activity, and force production characteristics during progressive strength training in young and older men. J Gerontol A Biol Sci Med Sci 53:B415–B423
30. American College of Sports Medicine (2005) Health-related physical fitness assessment manual. Lippincott Williams & Wilkins, Philadelphia
31. Colado JC, Tella V, Triplett NT (2008) A method for monitoring intensity during aquatic resistance exercises. J Strength Cond Res 22:2045–2049. doi:10.1519/JSC.0b013e31817ae71f
32. Barbosa TM, Marinho DA, Reis VM, Silva AJ, Bragada JA (2009) Physiological assessment of head-out exercises in healthy subjects: a qualitative review. J Sports Sci Med 8:179–189