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Supervised aquatic-based exercise for men with coronary artery disease: a meta-analysis of randomised controlled trials

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The beneficial effect of conventional forms of exercise for people with coronary artery disease (CAD) has been widely investigated.[1] Recent studies showed that less established fitness activities can also lead to health benefits.[2] Among these, aquatic-based exercise (AqEx) was shown to improve cardiovascular fitness, risk profile and muscle strength in healthy and special populations.[3–5] The intrinsic properties of water have been responsible for the observed physiological effects following acute and long-term exercise interventions. During immersion at the neck level, hydrostatic pressure redirects approximately 700 ml of peripheral blood centrally, increasing cardiac preload and stroke volume.[6] Recent reviews confirmed that the haemodynamic changes of AqEx are also well tolerated in stable patients with heart failure (HF), provided the water is comfortably warm.[7,8] AqEx is also a suitable activity for frail and overweight individuals who cannot exercise sufficiently and safely with land-based exercise (LEx) due to concomitant conditions impairing mobility (i.e. musculoskeletal, neurological),[9] which is often the case with cardiovascular patients.

Therefore, the main objective of this study was systematically to appraise the extant evidence on the effects of AqEx in people with CAD.

Methods

The PRISMA guidelines were followed for this study, which was registered in the PROSPERO register (CRD42019124169). Two authors independently searched PubMed/MEDLINE, PEDro, Scopus and Cochrane/CENTRAL to identify relevant randomised controlled trials (RCTs) published in English up to February 2019 combining keywords such as: ‘coronary artery disease’ AND ‘aquatic-based exercise’. Inclusion criteria were: individuals diagnosed with CAD; AqEx alone or combined with LEx; mid to long-term programmes ($\geq$2 weeks). Comparisons of interest were: AqEx versus controls (usual care without exercise); AqEx versus LEx; AqEx plus LEx versus LEx alone. Two authors independently extracted data from each RCT and assessed the study quality employing the TESTEX tool.[10] The GRADE system was employed to score the quality of evidence.[11] Meta-analyses were performed if at least two studies reported results for the same outcome, employing the Cochrane Review Manager 5.3.[12] Raw data (means and standard deviations (SDs)) were extracted or calculated from the available data. Study authors were contacted in case of missing data. The weighted mean difference (MD) was calculated employing a random effects model. Heterogeneity was assessed by chi-square and inconsistency I^2 tests.[12]

Results

Six studies were included in our qualitative synthesis[13–18] (see Supplementary file 1), involving 189 individuals with a documented diagnoses of CAD, i.e. myocardial infarction and acute coronary syndrome. Men were predominantly enrolled (91%), except in one study,[15] which also involved women (9%). Two studies involved both CAD and HF patients.[17,18] One study enrolled CAD patients and concomitant osteoarthritis.[15] All studies investigated the health effects of mid to long-term AqEx programmes performed alone or combined with

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Table 1. Characteristics and main findings of the included studies.

First author, year and country	Disease	Sample size, mean age, gender	Intervention groups and protocols	Main outcomes	Time of assessment	Dropouts	Adherence (%)	Aquatic setting	Main results
Fiogbé et al. Brazil (2018)[13]	**Individuals with CAD:** Myocardial infarction, 11; myocardial revascularisation, 6; reperfusion surgery, 5; Obstruction <50% (coronary angiography), 15; LVEF%: NR; NYHA class: NR	26 men (≈59.18 years)	**AqEx group:** 14 men, **Protocol:** 3 times/week, 16 weeks, 60 min/session; supervised **Exercise intensity:** HR_{target} between the HR_{VT1} and 10% below the HR_{VT2} **Control group:** 12 men (usual care)	HRV analysis, body composition (BW, BMI, %BF), CPET variables	T0: pre-treatment T1: post-treatment (16 weeks)	Control group: lost to follow-up ($n = 2$ personal reasons) AqEx group: lost to follow-up ($n = 3$ personal reasons)	NR	Pool depth: 1.20–1.30 m; water temperature: 30–33°C	The AqEx group showed a significant improvement at the HRV indices. All body composition variables remained unchanged
Tokmakidis et al. Greece (2008)[14]	**Individuals with CAD:** Myocardial infarction, 10; Coronary artery bypass grafting, 5; percutaneous transluminal coronary angioplasty, 6; LVEF%: NR; NYHA class: NR	21 men (≈51.6 years)	**AqEx group:** 11 men, **Protocol:** 4 times/week, 18 weeks, 75 min/session; supervised **Exercise intensity:** aerobic exercise at 50–85% of maximal HR at CPET, and circuit weight training at 60–80% of RPE **Control group:** 10 men (usual care)	Body composition (BW, BMI, WHR, sum of skinfolds), total body strength, CPET variables, 6MWWT	T0: pre-treatment T1: post-treatment (18 weeks)	AqEx group: lost to follow-up ($n = 1$ orthopaedic injury)	89%	Pool depth: 1.20 m; water temperature: 28–30°C	The AqEx group improved exercise tolerance, VO_2 peak and total body strength. The control group did not show any significant change
Lee *et al.* Republic of Korea (2017)[15]	**All individuals with CAD** after percutaneous coronary intervention; LVEF%: AqEx group (60.9 ± 5.1); LEx group (61.4 ± 6.3); control group (61.3 ± 6.9); NYHA class: NR	60 Gait-impaired subjects due to OA (72.9 ± 4.7 years) (43 men, 17 women)	**AqEx group:** 20 subjects (14 men, 6 women), **Protocol:** 3 times/week, 24 weeks, 50 min/session; supervised **Exercise intensity:** at 50 to 65% of HRR at CPET **LEx group:** 21 subjects (15 men, 6 women), **Protocol:** 3 times/week, 24 weeks, 50 min/session; supervised **Exercise intensity:** at 50 (-15/17bpm) to 65% (-15/17bpm) of HRR at CPET **Control group:** 19 subjects (14 men, 5 women) (usual care)	Body composition (BMI, %BF), haematic variables (TG, TC, HDL, LDL, BFG), CPET and hemodynamic variables, psychosocial variables	T0: pre-treatment T1: post-treatment (24 weeks)	NR	NR	Pool depth: at the xiphoid process level; water temperature: 30–32°C	Significant differences were observed in the changes of %BF, TC level, resting HR and VO_2 peak among the groups. However, no significant differences in the change in these measures were found between the AqEx and LEx groups
Volaklis et al. Greece (2007)[16]	**Individuals with CAD:** Myocardial infarction, 13; coronary artery bypass grafting, 10; percutaneous transluminal coronary angioplasty, 11; LVEF ≥ 50%; NYHA class: NR	34 men (≈54 years)	**AqEx group:** 12 men, **Protocol:** 4 times/week, 18 weeks, 60 min/session; supervised **Exercise intensity:** aerobic programme at 50–70% of maximal HR at CPET, and resistance training at 60–80% of the maximal number of repetitions performed in each exercise at baseline **LEx group:** 12 men,	Body composition (BW, sum of skinfolds), total body strength, CPET variables and haematic variables (TG, TC, HDL, LDL)	T0: pre-treatment T1: post-treatment (18 weeks)	AqEx group: lost to follow-up ($n = 1$ orthopaedic injury) LEx group: Lost to follow-up ($n = 1$ orthopaedic injury)	AqEx (89%) LEx (86%)	Pool depth: 1.20 m; water temperature: 28–30°C	BW and sum of skinfolds decreased in the AqEx and LEx groups but not in the control group. The AqEx group improved exercise tolerance and total body strength in a similar manner compared to the LEx group. TC and TG decreased

(continued)

Table 1. Continued

First author, year and country	Disease	Sample size, mean age, gender	Intervention groups and protocols	Main outcomes	Time of assessment	Dropouts	Adherence (%)	Aquatic setting	Main results
			Protocol: 4 times/week, 18 weeks, 60 min/session; supervised **Exercise intensity:** aerobic programme at 60 to 80% of maximal HR at CPET, and resistance training at 60% of 1-RM for each exercise **Control group:** 10 men (usual care)						significantly for both the exercise groups but not for the control group
Teffaha et al. France (2011)[17]	**Individuals with CAD** due to acute coronary syndrome with or without ST-segment elevation and with normal left systolic function; LVEF $\geq$ 50%; NYHA class: II **Individuals with HF** due to ischaemic or idiopathic dilated cardiomyopathy, with left ventricular systolic dysfunction; LVEF $\leq$ 40%; NYHA class: II/III	24 men with CAD ($\approx$ 53.7 years)	**AqEx + LEx group:** 12 men, **Protocol:** 5 times/week, 3 weeks, 80 min/session (30 min cycle ergometer or walking + 50 min callisthenic AqEx); supervised **Exercise intensity:** at an individualised target HR recorded at the ventilatory threshold during the CPET **LEx group:** 12 men, **Protocol:** 5 times/week, 3 weeks, 80 min/session (30 min cycle ergometer + 50 min callisthenic LEx); supervised **Exercise intensity:** at an individualised target HR recorded at the ventilatory threshold during the CPET	CPET variables, haemodynamic variables and autonomic nervous activities	T0: pre-treatment T1: post-treatment (3 weeks)	No dropouts	NR	Pool depth: 1.30 m; water temperature: 30–32°C	Significant increases in VO_2 peak, resting HR and exercise tolerance were observed in all patients after both types of exercise rehabilitation
Mourot et al. France (2009)[18]	**Individuals with CAD** due to acute coronary syndrome with or without ST-segment elevation and with preserved left systolic function; LVEF $\geq$ 45%; NYHA class: NR **Individuals with HF** due to ischaemic or idiopathic dilated cardiomyopathy, with left ventricular systolic dysfunction; LVEF $\leq$ 45%; NYHA class: NR	24 men with CAD ($\approx$ 53.7 years)	**AqEx + LEx group:** 12 men, **Protocol:** 5 times/week, 3 weeks, 80 min/session (30 min cycle ergometer + 50 min callisthenic AqEx); supervised **Exercise intensity:** at 60 to 70% of HRR **LEx group:** 12 men, **Protocol:** 5 times/week, 3 weeks, 80 min/session (30 min cycle ergometer + 50 min callisthenic LEx); supervised **Exercise intensity:** at 60 to 70% of HRR	Specific haematic variables (plasma concentration of N-terminal prohormone brain natriuretic peptide, catecholamine, nitric oxide metabolites), CPET variables	T0: pre-treatment T1: post-treatment (3 weeks)	No dropouts	NR	Pool depth: 1.30 m; water temperature: 30–32°C	In the AqEx + LEx group the plasma concentration of nitrates significantly increased, whereas any change was detected in LEx group. No changes in plasma catecholamine concentration occurred

CAD: coronary artery disease; LVEF: left ventricular ejection fraction; HF: heart failure; NYAH: New York Heart Association functional class; OA: osteoarthritis; AqEx: aquatic-based exercise; LEx: land-based exercise; HR: heart rate; HR_{VT}: heart rate at ventilatory threshold; HRV: heart rate variability; HRR: heart rate reserve; RPE: rate of perceived exertion; BW: body weight; BMI: body mass index; %BF: body fat percentage; CPET: cardiopulmonary exercise test; WHR: waist to hip ratio; 6MWWT: six-minute water walking test; TG: triglycerides; TC: total cholesterol; HDL: high-density lipoprotein; LDL: low-density lipoprotein; BFG: blood fasting glucose; VO_2 peak: peak oxygen uptake; RM: repetition maximal; NR: data not reported in the final paper.

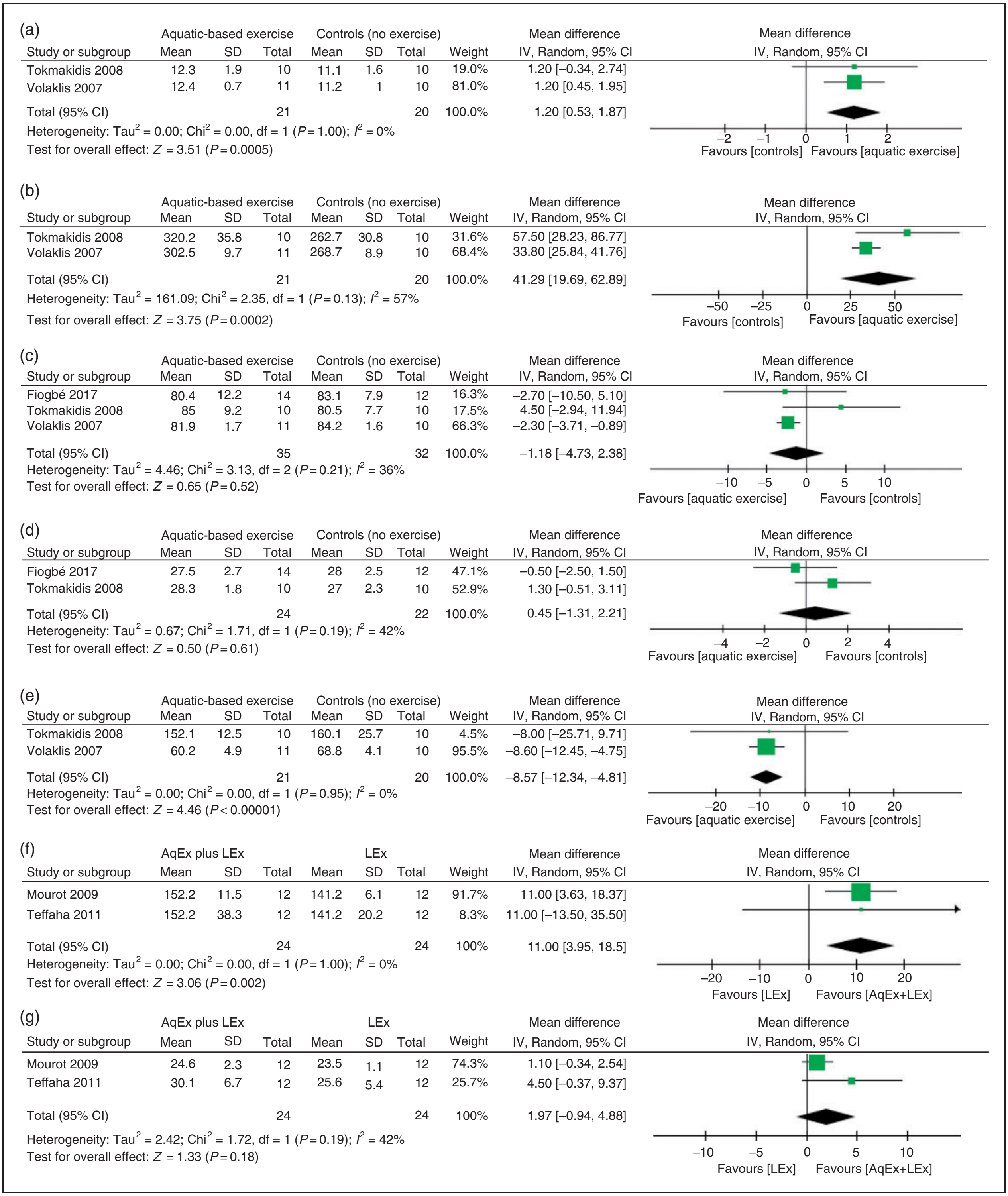

Figure 1. Forest plots showing the effects of aquatic-based exercise (AqEx) compared to controls (no exercise) and AqEx plus land-based exercise (LEx) compared to LEx alone in individuals with coronary artery disease (CAD). (a) Exercise tolerance (two studies, 41 participants); (b) Total body strength (two studies, 41 participants); (c) Body weight (two studies, 67 participants); (d) Body mass index (two studies, 46 participants); (e) Sum of skinfolds (two studies, 41 participants); (f) Peak power output (two studies, 48 participants); (g) Peak oxygen uptake (two studies, 48 participants). IV: inverse variance; CI: confidence Interval; df: degrees of freedom; I^2: inconsistency statistic. Significance set at $P < 0.05$.

LEx (mean length 13.7 ± 8.7 weeks; range 3–24). Training frequency was 4.0 ± 0.9 sessions/week (range 3–5) lasting 61.3 ± 10.3 minutes (range 50–75) when AqEx was performed alone and 80 minutes when combined with LEx (see Table 1). Data from two studies comparing AqEx versus no exercise revealed significant between-groups differences in exercise tolerance (minutes at the cardiopulmonary exercise test; CPET) favouring AqEx (MD 1.2; 95% confidence interval (CI) 0.5–1.9)[14,16] and in total body strength favouring AqEx (MD 41.3; 95% CI 19.7–62.9). Data pooling from the studies that assessed body composition (body weight, body mass index (BMI) and sum of skinfolds) revealed no differences in body weight (MD −1.2; 95% CI −4.7–2.4)[13,14,16] and BMI (MD 0.45; 95% CI −1.3–2.2).[13,14] Conversely, a significant difference was found for the sum of skinfolds, favouring AqEx (MD −8.6; 95% CI −12.3 to −4.8).[14,16] In the meta-analyses of the two studies[17,18] comparing AqEx plus LEx versus LEx alone, data showed a significant difference in peak power output (watts at CPET) favouring AqEx plus LEx (MD 11.0; 95% CI 4.0–18.1), while no significant difference was detected for peak oxygen uptake (MD 2.0; 95% CI −0.9–4.9) (see Figure 1). The median TESTEX score for study quality was 8/15 (range 6–9), while the overall level of evidence assessed by GRADE was very low to low (see Supplementary files 2 and 3).

Conclusions

Limited exercise capacity and fitness are well-known risk factors for cardiovascular events in the CAD population.[19] Based on the available evidence, AqEx improves exercise tolerance in men with CAD. The beneficial effects of AqEx include peripheral venous compression due to hydrostatic water pressure, with an increase in venous return balanced by a reduction in heart rate and afterload. Taken together, these events promote increased left ventricular output and, overall, cardiac performance.[6] The significant reduction in skinfolds with unchanged body weight and increased total muscle strength confirms AqEx as safe, feasible and effective in reducing body fat mass and enhance muscle performance. The latter is achieved due to the property of water to offer resistance against limb movements, resulting in greater strength and mobility. When combined with LEx, AqEx led to a greater benefit in peak power than LEx alone, which may be of importance because exercise capacity is acknowledged as a key predictor of self-perceived energy loss and sickness in the CAD population.[20] Given its safety and feasibility, supervised AqEx can be viewed as a complementary exercise modality in the rehabilitation of selected cardiovascular patients. In particular, these findings seem to depict AqEx as a potential co-adjuvant form of rehabilitation, especially for people with CAD presenting with musculoskeletal comorbidities.

The findings of this review, however, warrant careful interpretation as some limitations should be acknowledged: the paucity of studies aggregated; the limited number of participants per study; the heterogeneity of the comparison groups and interventions; and the lack of agreement among researchers on a core set of outcomes. Furthermore, the external validity of the pooled estimate calculated is threatened by the imbalanced gender composition (only 9% of women), confirming the gender bias issue in cardiovascular rehabilitation literature.[21] Adequately powered and gender-balanced RCTs with homogeneous comparison groups are needed.

In conclusion, patients who prefer the aquatic setting, and have the chance to perform cardiovascular rehabilitation programmes in a supervised and comfortable hydrotherapy context, must know that water is a feasible and safe way to exercise, which represents a suitable alternative or a complementary approach to LEx, particularly when musculoskeletal conditions are associated.

Author contribution

LC contributed to the conception and design of the work. LC, AM and GM contributed to the acquisition, analysis and interpretation of data for the work. LC drafted the manuscript. All authors critically revised the paper and gave final approval. All authors agree to be accountable for all aspects of the work ensuring integrity and accuracy.

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Declaration of conflicting interests

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