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Research

Twelve weeks of water-based circuit training exercise improves fitness, body fat and leg strength in people with stable coronary heart disease: a randomised trial

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KEY WORDS

Hydrotherapy
Coronary artery disease
Circuit-based exercise
Muscle strength
Cardiorespiratory fitness

ABSTRACT

Question: In people with stable coronary heart disease, what are the effects of water-based circuit training exercise on aerobic capacity, strength and body composition? How do these effects compare with those of gym-based exercise? **Design**: Parallel group, randomised controlled trial with concealed allocation and intention-to-treat analysis. **Participants**: Fifty-two participants with stable coronary heart disease. **Interventions**: Twelve weeks of: three 1-hour sessions per week of moderate-intensity water-based circuit training exercise with alternating aerobic and resistance stations (WEX); three 1-hour sessions per week of moderate-intensity gym-based circuit training exercise (GEX); or continuing usual activities (control). **Outcome measures**: Aerobic capacity (VO_{2peak}), upper and lower limb one repetition maximum strength (biceps curl, latissimus dorsi pulldown, hamstring curl and leg press), anthropometry (weight, body mass index and girth) and dual energy x-ray absorptiometry. **Results**: Forty-five participants completed the study (WEX n = 15, GEX n = 18, control n = 12). Both training groups significantly improved VO_{2peak} compared with control: WEX by 2.5 ml/kg/min (95% CI 0.6 to 4.4) and GEX by 2.3 ml/kg/min (95% CI 0.6 to 4.0). WEX and GEX improved hamstring strength compared with control: WEX by 6.3 kg (95% CI 1.2 to 11.3) and GEX by 7.6 kg (95% CI 2.9 to 12.2). Compared with control, GEX increased leg press strength by 15.5 kg (95% CI 5.7 to 25.3), whereas the effect of WEX was less clear (MD 7.1 kg, 95% CI –3.5 to 17.7). Only GEX improved latissimus dorsi pulldown strength. Compared with control, total body fat was reduced with WEX (–1.1 kg, 95% CI –2.3 to 0.0) and GEX (–1.2 kg, 95% CI –2.3 to –0.1). There were negligible between-group differences in weight or waist circumference. **Conclusion**: WEX was well tolerated and improved aerobic capacity, leg strength and body fat to a similar degree as GEX in people with coronary heart disease. These findings suggest that WEX is an effective exercise training alternative to GEX for people with coronary heart disease. **Trial registration**: ANZCTR12616000102471. **[Scheer A, Shah A, Ito Ramos de Oliveira B, Moreno-Suarez I, Jacques A, Green D, Maiorana A (2021) Twelve weeks of water-based circuit training exercise improves fitness, body fat and leg strength in people with stable coronary heart disease: a randomised trial. *Journal of Physiotherapy* 67:284–290]**

Introduction

Exercise participation and higher levels of aerobic fitness have been associated with reduced mortality and morbidity in people with coronary heart disease (CHD).[1,2] As such, exercise training has become an important component of CHD management.[3,4] Guidelines recommend accumulating 150 to 300 minutes per week of moderate-intensity physical activity, 75 to 150 minutes of vigorous-intensity physical activity, or an equivalent combination, along with muscle strengthening exercises on $\geq$ 2 days per week.[5] Despite the established benefits of exercise in people with CHD, many do not undertake sufficient physical activity to meet guidelines.[6,7]

Physical activity is particularly low in people with CHD who have comorbid conditions such as arthritis or obesity.[8,9] This is concerning, given that arthritis is experienced by over half of the CHD population[9] and approximately two-thirds of people with CHD are overweight or obese.[10] The high prevalence of these comorbidities suggests that low-impact exercise strategies may be beneficial for many people with CHD.[11] Water-based exercise presents one such option due to the effects of buoyancy on reducing the weight bearing load on the lower limbs and spine.[12]

It was recently reported that an aquatic exercise training circuit with integrated aerobic and resistance exercises improved strength and aerobic fitness in people with type 2 diabetes.[13] However, there are currently very few randomised controlled studies with a duration of > 3 weeks comparing water-based exercise with gym-based exercise in people with CHD. The only study with a duration > 3 weeks comparing water-based and gym-based exercise found promising improvements in body weight, skinfolds, exercise test time and maximum strength in people with CHD following water-based

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exercise that were similar to those observed with gym exercise.[14] However, this study was limited by the lack of gold-standard outcome measures such as peak oxygen uptake and imaging-derived body composition measures.

This study aimed to investigate the effect of 12 weeks of water-based circuit training exercise (WEX) training compared with 12 weeks of gym-based circuit training exercise (GEX) training at a similar intensity, to determine if water-based exercise is an effective alternative to the widely prescribed approach of gym-based exercise for people with CHD.

Therefore, the research questions for this randomised controlled trial were:

1. In people with stable coronary heart disease, what are the effects of water-based circuit training exercise on aerobic capacity, strength and body composition?
2. How do the effects compare with those of gym-based exercise?

Method

Design

This was a three-arm, parallel group, randomised controlled trial with concealed allocation and intention-to-treat analysis. Participants underwent baseline assessments prior to group allocation. The blocked random allocation list was weighted towards the two experimental groups and concealed in opaque and sealed envelopes. Participants were allocated to continue their allocated intervention (WEX or GEX three times per week, or continuing usual activities for the control group) for 12 weeks, before reassessment within 2 weeks of the final training session. The nature of the exercises prevented blinding of participants. Recruitment occurred from December 2016 to March 2019. Data collection was completed in July 2019.

Participants, therapists, centre

Participants were recruited through hospital databases and community advertising (Figure 1). The inclusion criteria were: a diagnosis of CHD (based on a previous myocardial infarction, percutaneous coronary intervention, diagnostic imaging showing $\geq$ 50% occlusion of $\geq$ 1 coronary artery, or coronary artery bypass graft surgery); stable medication for $\geq$ 1 month; and $\geq$ 6 months after any coronary event or surgery. Participants were excluded if they: had an ejection fraction < 45%: had severe musculoskeletal, respiratory or neurological impairment that would limit exercise training; had received current or recent (within 6 months) chemotherapy or radiotherapy for cancer treatment; had displayed an adverse response on baseline exercise testing (ie, ischaemic signs or symptoms at a workload of < 4 METs, new-onset left bundle branch block or ventricular tachyarrhythmia); had baseline blood test results suggesting significant other health issues; had participated in a supervised exercise program in the past 3 months; were current smokers; or were using insulin.

Assessments and exercise training sessions were conducted in a tertiary hospital outpatient setting in Perth, Australia, by a physiotherapist or an accredited exercise physiologist. Therapists were not blinded for the assessments. All water-based exercise sessions were supervised by at least two people (at least one physiotherapist or exercise physiologist).

Intervention

Regardless of which intervention group they were randomised to, participants were asked to maintain their usual diet throughout the study. Any medication changes during the study were documented.

Exercise training programs

The WEX and GEX participants trained 3 days per week for approximately 1 hour per session. All sessions commenced and concluded with 5 minutes of light aerobic activity and stretching. The conditioning phase involved a circuit of alternating aerobic and resistance exercise stations (45 seconds work, 15 seconds active recovery). Sessions progressed over the first 3 weeks from one to three circuits per session. Aerobic exercise intensity commenced at 50 to 65% of measured heart rate maximum in weeks 1 and 2, and increased to 60 to 65% in weeks 3 and 4, 60 to 70% in weeks 5 and 6, 70 to 80% in weeks 7 and 8, and 80% in weeks 9 to 12. Heart rate was monitored using wrist-worn monitors with chest straps[a]. Rating of perceived exertion (RPE) was also used to guide exercise prescription and was progressed from 11 to 14 over the course of training.[15] Resistance exercises were matched for muscle group between WEX and GEX, and the range of motion of the arm exercises for both groups was limited to the range allowed by the water level of the WEX group. Resistance exercise RPE targets were 12 to 15.

The WEX group trained in a graded-depth hydrotherapy pool (34.5 °C) and were submersed to the xiphoid process. Aerobic exercises included walking/jogging and high knee lifts. Strength exercises included unilateral knee flexion/extension, unilateral hip flexion/extension, unilateral hip abduction/adduction (with the side of this exercise alternated at each circuit), bilateral elbow flexion/extension, and bilateral shoulder abduction/adduction (limited by water depth). More details are presented in Appendix 1 on the eAddenda. The resistance was provided by custom-designed paddles, using acrylic sheets either side of the limb, fastened by hook and loop fasteners or buckles, ranging from 15 x 20 cm to 30 x 35 cm (see Appendix 1 on the eAddenda). Resistance was progressed by increasing the speed of movement guided by waterproof metronomes worn by participants on headbands[b] whilst maintaining the same range of movement. Exercises were progressed to include larger paddle sizes once participants were able to maintain the set pace per repetition with good technique and Borg RPE fell below 13.

The GEX group exercised in a cardiac rehabilitation outpatient gymnasium. Aerobic exercises involved stationary cycling and treadmill walking. Strength exercises involved bilateral knee extension, bilateral latissimus pulldown, bilateral knee flexion, unilateral hip flexion/extension, bilateral triceps[c], unilateral hip abduction/adduction with ankle weights[d], bilateral biceps and bilateral shoulder abduction with dumbbells (limited to the height of the xiphoid process). Resistance exercises were initially prescribed at approximately 50% one repetition maximum (1RM). Participants commenced with 10 repetitions and progressed to the next weight once they could achieve 12 to 15 repetitions in 45 seconds, with good technique and at an RPE < 13. Due to the concentric-only nature of the WEX training, biceps and triceps and shoulder abduction and latissimus pulldown were alternated each circuit in the GEX program, so that after two consecutive sessions the time training each muscle group was matched between the WEX and GEX groups.

Control group

Participants in the control group were instructed to maintain their usual activities throughout the study and were offered an optional gym-based exercise program or home exercise advice at the completion of the study.

Outcome measures

Primary outcome

The primary outcome was aerobic exercise capacity (VO_{2peak}).

Secondary outcomes

Aerobic exercise capacity (VO_{2peak}) was assessed by indirect calorimetry[e] using a modified chronotropic protocol on a treadmill[f] with increases in speed and incline every 3 minutes. Participants were monitored with a 12-lead ECG[g]. The metabolic cart was calibrated according to standard procedures prior to each assessment. The test continued until volitional exhaustion, unless terminated by the supervising doctor.

Muscular strength was assessed with 1RM assessments for bicep curl using a dumbbell[h] and for latissimus pulldown, leg press and

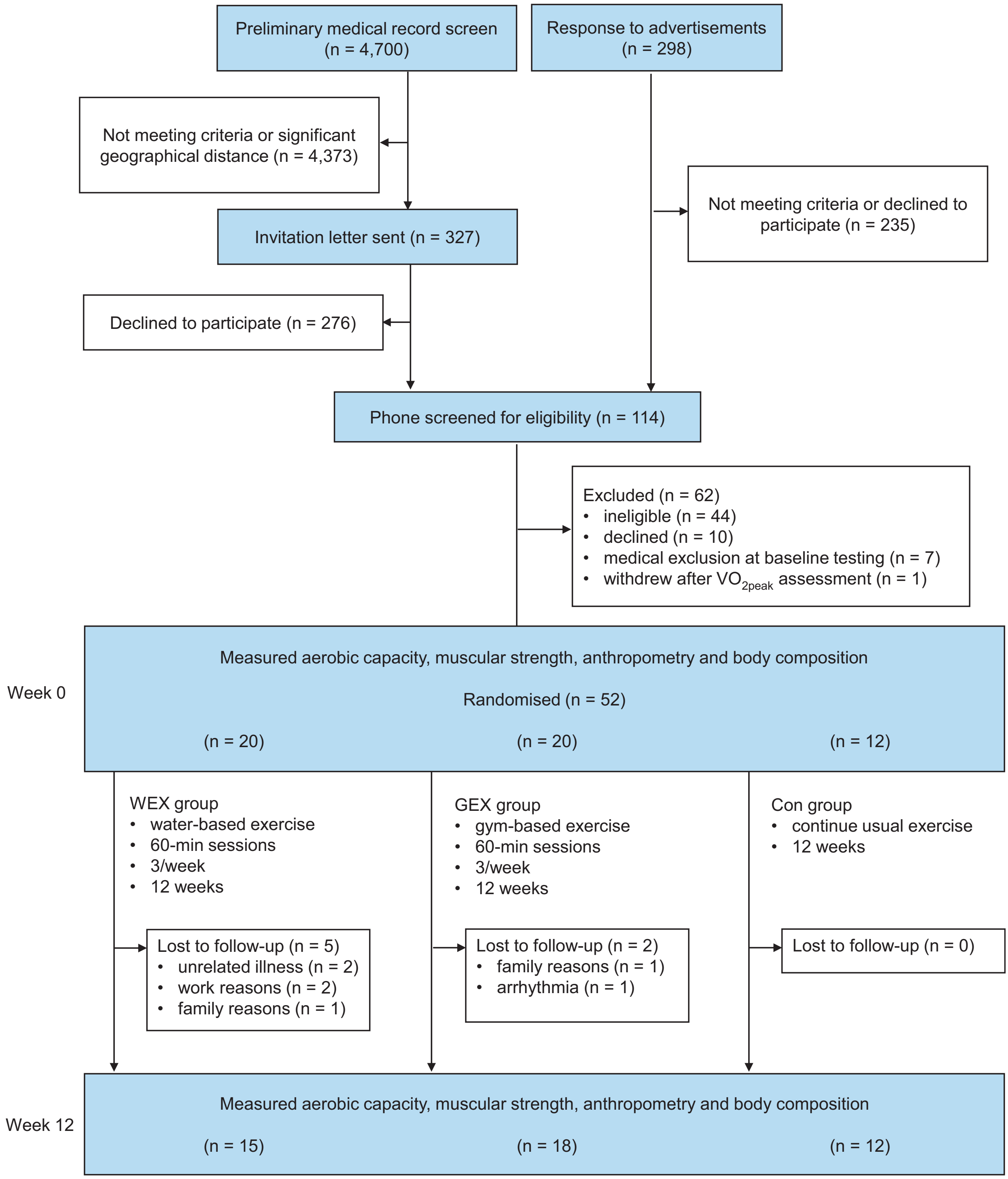

Figure 1. Design and flow of participants through the study.

hamstring curl using seated weight stack machines[i] and the machine settings at baseline were used for follow-up assessments for reproducibility. Participants were instructed to avoid a Valsalva manoeuvre throughout strength testing. Participants initially conducted six repetitions of a light weight for a muscle-specific warm-up, followed by 1-minute rest, then two repetitions of a moderate weight followed by a 1-minute rest. Subsequently, progressively heavier weights were lifted once with 2 minutes rest between repetitions, with the last successful repetition that could be lifted through a full range of motion recorded as the 1RM.

Anthropometric measures included weight, body mass index (BMI), waist circumference and hip circumference. Body weight was measured by digital scales[j]. Waist and hip girth measurements were taken in triplicate, with the median used for analysis. Dual energy x-ray absorptiometry (DXA) was used to measure body mass, body fat and bone mineral density. The DXA scan was performed on a body scanner[k] after $\geq$ 6-hour fast.[16] Standard procedure of omitting the right arm and duplicating the left arm was used if a participant was too large to fit on the DXA bed.

Data analysis

Sample size was based on data from Tokmakidis et al,[17] who found that water-based exercise training over 4 months increased VO_{2peak} in people with CHD from 26.2 (SD 4.0) to 28.4 (SD 4.9) ml/kg/min.[17] The calculated Cohen's d was 0.48,[18] with an effect size of 0.24.[19] Assuming 90% power and a 5% level of significance, and a conservative estimated correlation among repeated measures of 0.75 (based

Table 1
Baseline characteristics of participants.

Characteristic	Completed (n = 45)			Lost to follow-up (n = 7)	
	WEX (n = 15)	GEX (n = 18)	Con (n = 12)	WEX (n = 5)	GEX (n = 2)
Age (*yr*), mean (SD)	66 (8)	67 (8)	71 (5)	66 (5)	66 (7)
Gender, n males (%)	12 (80)	16 (89)	9 (75)	3 (60)	2 (100)
Time since diagnosis *(yr)*					
median	3.3	2.3	5.5	4.0	11.2
range	0.8 to 15	0.5 to 29	0.5 to 18	1.3 to 9	2.4 to 20
Medical history, n (%)					
cancer (other than skin)	1 (7)	5 (28)	2 (17)	1 (20)	0 (0)
type 2 diabetes	1 (7)	1 (6)	3 (25)	0 (0)	0 (0)
pre-diabetes	1 (7)	3 (17)	0 (0)	0 (0)	1 (50)
stroke	1 (7)	0 (0)	2 (17)	0 (0)	0 (0)
transient ischaemic attack	0 (0)	1 (6)	1 (8)	0 (0)	0 (0)
peripheral vascular disease	1 (7)	0 (0)	0 (0)	0 (0)	0 (0)
arthritis	5 (33)	4 (22)	3 (25)	2 (40)	0 (0)
non-specified joint pain	6 (40)	4 (22)	6 (50)	3 (60)	2 (100)
respiratory condition	2 (13)	4 (22)	3 (25)	2 (40)	0 (0)
Cardiac history, n (%)					
silent	3 (20)	2 (11)	2 (17)	0 (0)	0 (0)
angina only	4 (27)	7 (39)	5 (42)	1 (20)	0 (0)
myocardial infarction	8 (53)	9 (50)	5 (42)	4 (80)	2 (100)
Treatment, n (%)					
CABG	2 (13)	7 (39)	6 (50)	0 (0)	1 (50)
PCI	11 (73)	14 (78)	7 (58)	5 (100)	1 (50)
CABG and PCI	0 (0)	3 (17)	2 (17)	0 (0)	0 (0)
medication only	2 (13)	0 (0)	2 (17)	0 (0)	0 (0)
Medication, n (%)					
beta blockers	5 (33)	7(39)	9 (75)	1 (20)	1 (50)
lipid lowering	14 (93)	17 (94)	11 (92)	4 (80)	2 (100)
glucose lowering	0 (0)	1 (6)	3 (25)	0 (0)	0 (0)
antiplatelet/anticoagulant	15 (100)	17 (94)	12 (100)	5 (100)	2 (100)
ACE inhibitors	5 (33)	10 (56)	4 (33)	1 (20)	2 (100)
angiotensin II receptor blockers	4 (27)	4 (22)	5 (42)	2 (40)	0 (0)
calcium channel blockers	1 (7)	3 (17)	3 (25)	3 (60)	0 (0)
diuretic	0 (0)	1 (6)	1 (8)	1 (20)	0 (0)
proton pump inhibitors	5 (33)	4 (22)	5 (42)	2 (40)	1 (50)

ACE = angiotensin converting enzyme, CABG = coronary artery bypass graft surgery, Con = control, GEX = gym-based exercise, PCI = percutaneous coronary intervention, Silent = picked up on investigation without prior cardiac symptoms, WEX = water-based exercise.

on our previous study of water-based exercise for people with type 2 diabetes),[13] the estimated total sample size was 33 (ie, 11 per group for a repeated measures ANOVA (mixed model) with three groups over two timepoints)[l]. To allow for training program withdrawals, recruitment targets were set at 20 per group for the training groups.

Results were analysed with commercial software[m]. Generalised linear mixed models with appropriate links were used for within-group pre-post assessments and group-time interactions. Mixed effects Tobit models were used for leg press and hamstring data due to ceiling effects in those outcomes.

Results

Flow of participants and therapists through the study

Participant flow through the study is presented in Figure 1. Participant characteristics are described in Table 1. There was one adverse event during the study: a GEX participant with a history of supraventricular tachycardia experienced an episode of it during training in week 8 of his program. He received immediate medical attention and recovered fully that day, although he withdrew from the study to undergo an elective ablation procedure.

Aerobic capacity assessments were incomplete for three WEX participants (one due to illness, one injured outside the study and one unable to tolerate a mask or mouthpiece). Muscular strength assessments were incomplete for one WEX and one control participant due to illness. Due to musculoskeletal limitations, paired data were unavailable for leg press in three WEX, two GEX and two control participants; hamstring curl in two WEX and one control participant; biceps curl in one WEX, two GEX and one control participant; and latissimus pulldown in four WEX, three GEX and three control participants. DXA scans were not available for one WEX, one GEX and one control participant due to machine servicing/unavailability, and one control participant due to illness. DXA data were incomplete in one WEX participant due to artefact.

Research question 1

Water-based exercise improved the primary outcome – aerobic capacity – by a mean of 2.5 ml/kg/min (95% CI 0.6 to 4.4) (Table 2). Water-based exercise also improved a measure of leg strength (mean difference in 1RM hamstring curl of 6.3 kg, 95% CI 1.2 to 11.3) (Table 2). Water-based exercise also reduced total body fat by a mean of 1.1 kg (95% CI 0.0 to 2.3) (Table 3). Water-based exercise induced no clear changes in upper body strength or anthropometric measures (Tables 2 and 3).

Research question 2

Both modes of exercise training improved exercise capacity (VO_{2peak}) to a similar extent and GEX increased exercise time (Table 2). Both WEX and GEX increased leg strength, but only GEX significantly improved latissimus pulldown strength (Table 2). Body fat decreased with both types of exercise training over time, with a negligible difference between the effects of the two types of training (Table 3).

The results from all participants who completed baseline testing are available in Appendix 2 (aerobic capacity and strength testing) and Appendix 3 (body composition) on the eAddenda. Individual participant data are presented in Table 4 on the eAddenda.

Discussion

The estimates of treatment effects generated by this study show that water-based circuit training resulted in similar benefits in aerobic capacity, leg strength and total body fat as traditionally prescribed gym-based circuit training. These findings highlight water-

Table 2
Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups for paired aerobic capacity and muscular strength data.

Outcome	Groups						Difference within groups			Difference between groups[a]		
	Week 0			Week 12			Week 12 minus Week 0			Week 12 minus Week 0		
	WEX	GEX	Con	WEX	GEX	Con	WEX	GEX	Con	WEX minus Con	GEX minus Con	WEX minus GEX
VO_{2peak} *(ml/kg/min)*	29.1 (8.9)	26.3 (5.5)	24.6 (6.7)	30.9 (9.1)	27.9 (5.8)	23.9 (5.9)	1.8 (2.6)	1.6 (1.9)	–0.7 (2.6)	2.5 (0.6 to 4.4)	2.3 (0.6 to 4.0)	0.2 (–1.5 to 1.9)
VO_{2peak} *(ml/min)*	2,398 (616)	2,188 (383)	1,970 (594)	2,502 (571)	2,302 (384)	1,915 (576)	104 (242)	114 (128)	–55 (239)	166 (16 to 317)	167 (30 to 305)	–1 (–138 to 136)
Percent of predicted VO_2 maximum	104.2 (23.5)	97.4 (21.5)	97.8 (20.4)	110.6 (24.9)	103.3 (21.7)	95.0 (15.4)	6.4 (9.9)	5.9 (7.2)	–2.8 (7.4)	9.5 (2.5 to 16.5)	8.7 (2.3 to 15.1)	0.8 (–5.5 to 7.2)
Exercise duration *(s)*	942 (184)	843 (116)	831 (233)	998 (220)	946 (120)	867 (174)	56 (83)	103 (39)	36 (84)	22 (–35 to 79)	68 (16 to 121)	–47 (–98 to 5)
VCO_{2peak} *(ml/min)*	2,679 (703)	2,392 (526)	2,117 (683)	2,836 (654)	2,620 (581)	2,090 (624)	157 (277)	228 (185)	–27 (267)	195 (9 to 381)	253 (83 to 424)	–58 (–228 to 112)
V_E/VCO_2 slope	28.9 (3.9)	27.6 (4.1)	29.6 (3.5)	29.0 (3.4)	27.8 (4.0)	28.7 (3.4)	0.1 (1.6)	0.2 (1.4)	–0.9 (1.5)	1.1 (–0.8 to 3.0)	1.1 (–0.7 to 2.8)	–0.0 (–1.7 to 1.7)
RER	1.12 (0.07)	1.09 (0.08)	1.07 (0.08)	1.14 (0.08)	1.13 (0.10)	1.10 (0.06)	0.02 (0.03)	0.04 (0.03)	0.03 (0.03)	–0.01 (–0.05 to 0.04)	0.01 (–0.03 to 0.05)	–0.02 (–0.06 to 0.02)
RPE	17 (2)	18 (2)	17 (1)	17 (2)	18 (2)	17 (2)	0 (1)	0 (1)	0 (1)	–1 (–2 to 0)	0 (–1 to 1)	–1 (–2 to 0)
Bicep curl 1RM *(kg)*	11.4 (4.4)	10.1 (3.5)	9.0 (2.7)	11.2 (4.2)	11.1 (3.6)	9.2 (3.0)	–0.2 (1.7)	1 (1.3)	0.2 (1.3)	–0.4 (–1.4 to 0.7)	0.7 (–0.3 to 1.7)	–1.0 (–2.0 to –0.1)
Latissimus pulldown 1RM *(kg)*	45.0 (12.7)	41.3 (10.9)	38.8 (9.5)	47.0 (10.9)	47.0 (12.1)	40.0 (8.5)	2 (5.3)	5.7 (4.2)	1.2 (4.5)	0.6 (–3.7 to 4.8)	4.2 (0.3 to 8.1)	–3.6 (–7.3 to 0.0)
Hamstring curl 1RM *(kg)*	49.9 (12.5)	50.6 (12.4)	44.6 (9.8)	55.1 (16.0)	57.3 (12.1)	43.4 (11.1)	5.2 (5.9)	6.7 (4.1)	–1.2 (11.1)	6.3[b] (1.2 to 11.3)	7.6 [b] (2.9 to 12.2)	–1.3 [b] (–5.8 to 3.2)
Leg press 1RM *(kg)*	124.0 (37.0)	121.5 (33.6)	122.5 (44.8)	132.1 (39.9)	138.2 (31.4)	123.5 (49.2)	8.1 (16.4)	16.7 (11.5)	1 (22.2)	7.1 [b] (–3.5 to 17.7)	15.5 [b] (5.7 to 25.3)	–8.4 [b] (–17.6 to 0.8)

Con = control group, GEX = gym-based exercise training group, RER = respiratory exchange ratio, RPE = rating of perceived exertion, VCO_{2peak} = peak carbon dioxide output, VO_{2peak} = peak oxygen uptake, WEX = water-based exercise training group, 1RM = one repetition maximum strength.
[a] Difference between estimated margins of means using general linear mixed model analysis.
[b] Metobit analysis used.

Table 3
Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups for paired anthropometry and body composition data.

Outcome	Groups						Difference within groups			Difference between groups[a]		
	Week 0			Week 12			Week 12 minus Week 0			Week 12 minus Week 0		
	WEX	GEX	Con	WEX	GEX	Con	WEX	GEX	Con	WEX minus Con	GEX minus Con	WEX minus GEX
Anthropometry												
Weight *(kg)*	85.2 (13.9)	84.7 (12.9)	80.3 (10.4)	84.4 (14.1)	83.8 (12.1)	80.1 (10.7)	–0.8 (5.1)	–0.9 (4.2)	–0.2 (4.3)	–0.6 (–2.0 to 0.8)	–0.7 (–2.1 to 0.6)	0.1 (–1.1 to 1.4)
BMI *(kg/cm²)*	29.1 (4.2)	28.4 (3.9)	28.0 (3.7)	28.8 (4.3)	28.1 (3.7)	27.9 (3.5)	–0.3 (1.6)	–0.3 (1.3)	–0.1 (1.5)	–0.2 (–0.6 to 0.3)	–0.2 (–0.7 to 0.3)	0.0 (–0.4 to 0.5)
Waist girth *(cm)*	100.6 (12.5)	102.8 (10.7)	101.5 (8.6)	100.2 (11.8)	101.2 (9.9)	101.6 (9.9)	–0.4 (4.4)	–1.6 (3.4)	0.1 (3.9)	–0.4 (–2.8 to 1.9)	–1.7 (–3.9 to 0.6)	1.2 (–0.8 to 3.3)
Hip girth *(cm)*	107.9 (7.4)	105.6 (6.2)	104.5 (6.9)	107.1 (8.7)	104.4 (5.8)	103.9 (7.5)	–0.8 (2.9)	–1.2 (2)	–0.6 (3.1)	–0.1 (–2.1 to 1.9)	–0.6 (–2.5 to 1.4)	0.4 (–1.3 to 2.2)
Waist:hip ratio	0.93 (0.09)	0.97 (0.07)	0.97 (0.06)	0.94 (0.07)	0.97 (0.06)	0.98 (0.08)	0.01 (0.03)	0.00 (0.02)	0.01 (0.03)	–0.00 (–0.03 to 0.02)	–0.01 (–0.04 to 0.01)	0.01 (–0.02 to 0.03)
DXA data												
Total mass *(kg)*	85.3 (14.7)	83.8 (13)	79.7 (11.4)	83.9 (14.9)	83.2 (12.4)	80.1 (11.9)	–1.4 (5.8)	–0.6 (4.4)	0.4 (5.2)	–1.8 (–3.3 to –0.4)	–1.2 (–2.5 to 0.2)	–0.7 (–1.9 to 0.6)
Total fat *(kg)*	29.5 (12.0)	28.6 (7.0)	27.1 (8.0)	28.5 (12.1)	27.6 (6.7)	27.3 (8.2)	–0.9 (4.7)	–1.0 (2.4)	0.2 (3.6)	–1.1 (–2.3 to 0.0)	–1.2 (–2.3 to –0.1)	0.1 (–0.9 to 1.1)
Tissue fat *(%)*	35.0 (11.4)	35.2 (6.1)	35.0 (7.7)	34.4 (12.1)	34.3 (6.5)	35.0 (7.5)	–0.6 (4.6)	–0.9 (2.2)	0.0 (3.4)	–0.6 (–1.6 to 0.5)	–0.8 (–1.8 to 0.2)	0.2 (–0.7 to 1.2)
Total lean *(kg)*	52.9 (9.7)	52.3 (8.6)	49.7 (8.4)	52.4 (9.9)	52.6 (9.0)	50.0 (8.2)	–0.4 (3.8)	0.3 (3.0)	0.3 (3.7)	–0.7 (–1.5 to 0.0)	0.0 (–0.7 to 0.7)	–0.7 (–1.4 to –0.1)
BMD *(g/cm²)*	1.28 (0.15)	1.28 (0.13)	1.27 (0.19)	1.27 (0.15)	1.28 (0.12)	1.26 (0.18)	–0.01 (0.06)	0.00 (0.05)	–0.01 (0.09)	0.01 (–0.01 to 0.02)	0.01 (–0.01 to 0.02)	0.00 (–0.01 to 0.02)

BMD = bone mineral density, BMI = body mass index, Con = control group, DXA = dual energy x-ray absorptiometry, GEX = gym-based exercise training group, WEX = water-based exercise training group.
[a] Difference between estimated margins of means using general linear mixed model analysis.

based exercise as an effective alternative to gym-based training for people with CHD.

It is believed that this study is the first parallel-group controlled trial to investigate the effect of water-based versus gym-based circuit training on VO_{2peak} in people with stable CHD. It found that WEX resulted in a similar magnitude improvement in VO_{2peak} to GEX, increasing by 1.8 ml/kg/min and 1.6 ml/kg/min, respectively. This is similar to DeSchutter et al's finding of a 1.9 ml/kg/min mean improvement in a large cohort trial in centre-based exercise rehabilitation.[2] Whilst not a randomised controlled trial, Tokmakidis et al examined two 4-month blocks of water-based exercise training, separated by 4 months of detraining in people with CHD.[17] They reported comparable increases in VO_{2peak} of 2.2 ml/kg/min and 1.8 ml/kg/min.[17] There is increasing recognition that aerobic capacity is an important prognostic indicator across a range of chronic conditions.[2,20] In people with CHD, a 1 ml/kg/min higher VO_{2peak} at baseline or improvement over time has been associated with a 10 to 16% improvement in cardiac and all-cause mortality,[2,20,21] highlighting the importance of even modest improvements in VO_{2peak} in this population. The mean change in VO_{2peak} for both WEX and GEX exceeded 1 ml/kg/min more than the mean change in the control group, and there was no important difference in the change in VO_{2peak} for the two training types, suggesting that these forms of exercise training are equally effective.

Despite similar changes in VO_{2peak} with both types of exercise training, only GEX significantly increased exercise test time compared with the control group. A similar effect was observed in a study of 24 weeks of water-based and land-based walking in older adults,[22] which found a significant increase in exercise test time with land-based walking only, despite similar VO_{2peak} changes. This may have been due to the specificity of treadmill training and land-based walking to the outcome of treadmill test duration,[23] in contrast to a more generalisable effect on aerobic capacity, as measured by change in VO_{2peak}.

Both training groups experienced a similar mean reduction in fat mass. These reductions in fat mass occurred in the absence of dietary modifications. Previous studies have examined other markers of body fat, such as sum of skinfolds, and found favourable effects of aquatic exercise on reducing body fat,[14,17] which appear similar to gym exercise,[14] whilst the effect on body fat measured with bioelectric impedance did not reach significance in another study.[24] However, it is believed that this is the first study comparing DXA data in response to water-based exercise training compared with gym-based training in people with CHD. There were no significant pre-post differences for lean tissue data in any group; however, there was a difference in the change in lean mass observed between GEX and WEX. The individual group differences were < 450 g, which fall within the margin of accuracy of 0.61 to 0.86 kg for lean tissue changes for the scanner[k] proposed by several studies,[25–27] suggesting that clarification with a larger sample is required to determine the effects on lean tissue mass. Additionally, research in older adults found that 24 weeks of water-walking significantly increased lower limb lean tissue mass compared to a control group,[28] suggesting a longer duration program may be required to induce substantial lean tissue changes.

The mean improvements in leg strength with GEX equated to a 13% improvement in hamstring curl and a 14% improvement in leg press. The mean improvements with WEX equated to 10% for hamstring curl and 7% for leg press, with some uncertainty in the latter estimate (Table 2). For upper limb strength (latissimus pulldown), there were greater changes with GEX than WEX. This may reflect the limited range of motion for upper limb exercises during WEX due to the water depth during training.[29] Buoyancy-resisted exercises may have a greater impact on upper limb strengthening in the pool and would be an interesting concept for future research. Alternatively, it may be necessary to supplement aquatic exercises with some gym-based or free weight exercises to address upper-body strength.

Other studies of WEX in CHD have reported overall strength gains of between 12 and 13%[14,17] and found similar changes between WEX and GEX.[14] However, individual breakdown of muscle groups was not reported in these studies, so it is unknown if the lack of upper limb response is universal in response to WEX. Encouragingly, improvements in leg strength alone have been associated with reduced all-cause and cardiovascular mortality in people with CHD,[30] suggesting that the strength changes seen in the current study are of clinical value, despite the lack of upper limb improvement.

With improved treatment for acute coronary events, increasing numbers of people are living with chronic CHD. To reduce recurrent coronary events in this group, it is important that the exercise prescription paradigm shifts from merely a focus on time-limited rehabilitation to long-term secondary prevention. The findings from this study suggest that water-based exercise should be encouraged as one of the suite of exercise options to help people with chronic CHD be sufficiently active to achieve health and fitness benefits. Importantly, WEX was well tolerated in the cohort of participants with stable CHD, with no adverse events occurring in this group. The three sessions of WEX per week prescribed in the study is consistent with exercise training guidelines.[5] In the context of community exercise participation, people may wish to undertake multiple WEX sessions or combine WEX with other modes of exercise, depending on their preference and capabilities. For example, WEX could be used as an initial entry into exercise programs for deconditioned patients or those with musculoskeletal comorbidities. Alternatively, WEX could be used as an adjunct with GEX and/or walking programs to increase exercise variety. Clinicians wishing to prescribe similar aquatic exercise programs to the WEX program investigated in this study could easily and cheaply replicate the equipment used in this study (acrylic plastic sheets, with hook and loop or buckle fastenings, as pictured in Appendix 1) or use commercially available aquatic resistance equipment. Importantly, once individual tolerance to the program is established and correct techniques have been taught, many patients would be able to continue the program independently.

This study excluded people with CHD if they also had left ventricular dysfunction, type 1 diabetes, treatment with insulin, or serious respiratory, neurological or musculoskeletal pathology, so the generalisation of the safety and efficacy for these sub-populations remains unknown. Additionally, participants were recruited $\geq$ 6 months after any myocardial infarction, coronary artery bypass graft surgery or percutaneous coronary intervention, so the results may not be applicable to the initial stages of cardiac rehabilitation. It is recommended that future research should examine the effects of water-based exercise in sub-acute outpatient cardiac rehabilitation. It should be noted that the resistance machines used for strength assessment of latissimus pulldowns, biceps curl and hamstring curl were the same as those employed during training. This specificity may have influenced the findings for the GEX group.

This is the first outpatient-based, parallel-group, randomised controlled trial of combined aerobic and resistance exercise comparing water-based and gym-based exercise to examine the effect on VO_{2peak} and DXA-derived body composition. The study found that water-based circuit training was well tolerated and effective for improving aerobic capacity, leg strength and fat mass, similar to gym-based exercise in people with stable CHD. This supports the expansion of exercise prescription options for people with stable CHD to include water-based exercise, which may be useful for adding a low joint-impact exercise option to facilitate exercise engagement.

What was already known on this topic: With improved treatment for acute coronary events, increasing numbers of people are living with coronary heart disease. To reduce recurrent coronary events in this group, it is important that the exercise prescription includes a focus on long-term secondary prevention.
What this study adds: Water-based circuit training that included both aerobic and resistance stations was well tolerated and effective for improving aerobic capacity, leg strength and fat mass in people with stable coronary heart disease. The benefits were similar in magnitude to the benefits of gym-based exercise in this population.

Footnotes: [a]A300, FT4 and FT7 watches, Polar Electronics, Guangzhou, China. [b]Tempo Trainer Pro, FINIS, Tracy, USA. [c]Bravo Pulley Machine, Cybex International, Medway, USA. [d]Ankle cuff weight, Fortress Fitness, Sydney, Australia. [e]Vmax Encore Metabolic Cart, Vyntus, Vyaire Medical, Illinois, USA. [f]TMX428220, Trackmaster, Newton, USA. [g]PC ECG 1200, Norav Medical, Wiesbaden, Germany. [h]Australian Barbell Company, Australia. [i]Cybex, Cybex International, Medway, USA. [j]Seca 676 wireless scales, Seca gmbh & co, Hamburg, Germany. [k]GE Lunar iDXA, GE Healthcare, Wisconsin, USA. [l]G*Power 3, Universität Düsseldorf, Düsseldorf, Germany. [m]STATA V16 for Windows, Microsoft, Redmond, USA.

eAddenda: Table 4 and Appendices 1 to 3 can be found online at DOI: https://doi.org/10.1016/j.jphys.2021.08.012.

Ethics approval: The Royal Perth Hospital Human Research Ethics Committee approved this study (ref: RGS0000002071), with reciprocal approval from Curtin University (ref: HR227/2015) and The University of Western Australia's (Ref: RA/4/1/8382) Human Research Ethics Committees. All participants gave written informed consent before data collection began.

Competing interests: Nil.

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