

**WATER-BASED EXERCISE IN COPD WITH PHYSICAL CO-MORBIDITIES: A  
RANDOMISED CONTROLLED TRIAL**

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## **ABSTRACT**

Land-based exercise is often difficult for people with COPD who have co-existing obesity, musculoskeletal or neurological conditions. This randomised controlled trial aimed to determine the effectiveness of water-based exercise training in improving exercise capacity and quality of life compared to land-based exercise training and control (no exercise) in people with COPD and physical co-morbidities.

Participants referred to pulmonary rehabilitation were randomly allocated to a water-based exercise, land-based exercise or control group. The two exercise groups trained for eight weeks, three sessions per week.

Forty-five of 53 participants, (mean (SD) age 72 (9) years, FEV<sub>1</sub> 59 (15) % predicted), completed the study. Compared to control, water-based exercise training significantly increased 6-minute walk distance, incremental and endurance shuttle walk distances, and improved Chronic Respiratory Disease Questionnaire (CRDQ) dyspnoea and fatigue. Compared to land-based exercise training, water-based exercise training significantly increased incremental shuttle walk distance (mean difference 39m, 95% CI 5 to 72), endurance shuttle walk distance (mean difference 228m, 95% CI 19 to 438) and improved CRDQ fatigue.

Water-based exercise training was significantly more effective than land-based exercise training and control in increasing peak and endurance exercise capacity and improving aspects of quality of life in people with COPD and physical co-morbidities.

## INTRODUCTION

One of the most effective strategies for the management of chronic obstructive pulmonary disease (COPD) is land-based exercise training as part of integrated pulmonary rehabilitation. Land-based exercise training improves exercise capacity and quality of life.[1] However, the majority of people with COPD referred to pulmonary rehabilitation are in the older-age category[2] and a high proportion have physical co-morbidities such as skeletal muscle abnormalities, cerebrovascular disease, arthroses and obesity[3-5] which may limit their ability to participate in land-based exercise training. High drop-out rates from land-based exercise training ranging from 14% to 66% have been reported, as completion of land-based exercise training is often difficult or impossible for patients with co-morbid conditions.[2, 6] The limitations such physical co-morbidities place on a person's ability to perform land-based exercise training may considerably reduce the effectiveness of this form of training. People with COPD and physical co-morbidities are usually excluded from research studies of the effects of exercise training and therefore the findings of such studies cannot be extrapolated to them. Water-based exercise training is effective in the management of people with a primary diagnosis of musculoskeletal conditions including rheumatoid and osteo-arthritis and chronic low back pain, as well as some neurological conditions, peripheral vascular disease, and obesity.[7-9] For people with COPD and a secondary diagnosis of these conditions, water-based exercise training may provide an alternative mode of training.

Water-based exercise training had previously been thought to be unsafe for people with COPD due to the increased chest wall pressure and increased cardiac output that result from immersion in water.[10] Despite lung function restriction in water, no adverse events have been reported from a single exercise session in water and oxygen saturation was maintained even in those with severe COPD.[11] Only one prospective study has examined the effect of water-based exercise training in COPD.[12] In a semi-randomised trial (randomisation by geographical distance from training venue), Wadell *et al* (2004) reported significantly greater improvements in endurance walking capacity and self-reported quality of life following 12 weeks of water-based exercise training compared to land-based exercise training.[12] Importantly, people with any physical co-morbidity that could impact on exercise performance were excluded from participating in this study. In contrast, we postulated that people with COPD and a

physical co-morbidity would benefit more from water-based exercise training as these people were less likely to be able to complete or derive benefit from land-based exercise training.

The primary purpose of this study was to determine the effects of water-based exercise training on exercise capacity, and secondarily on health-related quality of life and respiratory muscle strength, compared with land-based exercise training or no exercise training in people with COPD and physical co-morbidities. We hypothesised that water-based exercise training in people with COPD and a physical co-morbidity would be more effective in improving exercise capacity, quality of life and respiratory muscle strength than land-based exercise training or no exercise training.

## **METHODS**

### **Participants**

Patients referred to outpatient pulmonary rehabilitation at an Australian tertiary public hospital were included in the study if they had a confirmed diagnosis of COPD according to GOLD criteria ( $FEV_1/FVC < 70\%$ ) which was in a stable phase, and the presence of one or more physical co-morbidities (including musculoskeletal condition/s affecting lumbar spine or lower limbs, one or more lower limb joint replacements restricting mobility and/or range of motion, or peripheral vascular disease; neurological conditions such as a stroke; or obesity with body mass index  $\geq 32 \text{ kg/m}^2$ ). Diagnosis of the physical co-morbidity was based on medical referral, patient history and physical examination. Subjects were excluded if they had unstable cardiac disease, contraindications to water-based therapy[13] such as uncontrollable incontinence or open wounds, completed pulmonary rehabilitation in the past 12 months or were currently attending an exercise program, had cognitive decline or were unable to understand oral and written English. Subjects using supplemental oxygen were included.

### **Study design and randomisation**

This study was a prospective randomised controlled trial with assessor blinding. Participants satisfying the eligibility criteria were randomised by an investigator external to the study using a web-based computer-generated sequence ([www.randomisation.com](http://www.randomisation.com)). Concealed allocation was achieved using

opaque envelopes. Participants were randomised to one of three groups: water-based exercise training, land-based exercise training or control (no exercise). Randomisation was stratified according to the limiting factor in the six-minute walk test (that is, breathlessness or physical co-morbidity) and body mass index ( $\geq 32 \text{ kg/m}^2$ ). Due to the nature of the exercise interventions, it was not possible to blind the therapist or participants to their allocation. Ethics approval was obtained by the Northern Network Human Research Ethics Committee and written informed consent was obtained. The trial was registered with the Australian New Zealand Clinical Trials Registry (ACTR number: ACTRN012606000408583).

## **Measurements**

The primary outcome measure was endurance exercise capacity measured by the endurance shuttle walk test (ESWT).

Participants attended two visits within a seven day period at both baseline and immediately post-intervention to undergo the following measurements.

### *Pulmonary function tests*

Spirometry (forced expiratory volume in 1 second ( $\text{FEV}_1$ ) and forced vital capacity (FVC)), diffusing capacity for carbon monoxide ( $\text{DL}_{\text{CO}}$ ), static lung volumes by body plethysmography and maximum inspiratory mouth pressures (MIP) and maximum expiratory mouth pressures (MEP) were performed according to recommended guidelines[14-17] following administration of inhaled salbutamol via a spacer device.

### *Exercise tests*

Exercise capacity was assessed by the self-paced 6MWT, and the externally-paced ISWT and ESWT according to standardised guidelines.[18-20] Two tests were performed for each walk test over two visits within seven days of each other, separated by a period of at least 30 minutes. The order of the three tests at each visit was 6MWT, ISWT, followed by ESWT. The better result for each test was used in the analysis. Self-reported dyspnoea and exertion was measured on the modified BORG 0 to 10 category ratio scale for dyspnoea and perceived exertion.[21]

### *Health-related quality of life and anxiety and depression*

Participants completed the self-reported Chronic Respiratory Disease Questionnaire (CRDQ)[22] and the Hospital Anxiety and Depression (HAD)[23] questionnaire.

## **Intervention**

The water-based and land-based exercise training groups attended three sessions weekly for eight weeks of 60 minutes supervised exercise led by the same experienced physiotherapist, with a maximum of 12 participants per session. Exercise in water and on land was matched as closely as possible for intensity, duration and muscle groups trained considering the different exercise mediums (notably the increased resistance experienced during movement in water) (Table 1). Participants were encouraged to exercise at an intensity rating of three to five on the modified BORG scale for dyspnoea and perceived exertion.

Training intensity was measured three times during each exercise session with the mean value recorded. If the intensity was reported below three, participants were encouraged to increase their intensity as detailed in Table 1. The land-based exercise training group exercised in a temperature-controlled hospital gymnasium and participants walked at an intensity of 80% of the average six-minute walk test speed either over-ground or on a treadmill. The water-based exercise training group exercised in a hospital hydrotherapy pool (depth graduating from 1.1m to 1.6m; length 18m; width 6m) with water temperature of 34°C, air temperature 30°C and relative air humidity of 30%. Water-based exercise training participants were able to choose the most comfortable level of water immersion in the standing position to perform the majority of exercises, which was always between the xiphisternum and the clavicles for each participant. Exercises in water and on land were progressed as detailed in Table 1. Control group participants received usual medical care and no exercise training. They were asked not to alter their exercise level over the study period.

**Table 1 Land-based and water-based exercise training program**

	<b>DURATION</b>	<b>LAND-BASED EXERCISE TRAINING PROGRAM</b>	<b>WATER-BASED EXERCISE TRAINING PROGRAM</b>
Warm up	8 minutes	Upper and lower limb aerobics including punching and kicking Marching (stationary) Breathing control Lower limb stretches	Upper and lower limb aerobics including punching and kicking Jogging (stationary) Breathing control Lower limb stretches
Lower limb endurance	20 minutes	Walking (over-ground or treadmill)	Stationary and travelling (forwards, sideways, backwards): Jogging (narrow legs, wide legs, high knees) Straight leg kick with arm reach to opposite toe Straight leg shuffle Opposite elbow to opposite high knee Heel kicks to bottom
Rest period	3 minutes	Breathing control and hydration	Breathing control and hydration
Lower limb endurance	15 minutes	Cycling (stationary or dual-action bike)	Seated leg cycling on flotation device (stationary and travelling forwards, backwards, sideways); addition of multi-directional arm movements (scooping, paddling, breaststroke) Reclined suspended cycling Kicking (prone and supine) Standing single leg cycling Karate kicks (single and double leg, forwards, sideways, backwards, alternating side to side and front to back) Frog jumps Bunny hops Star jumps Cross-country ski
Rest period	2 minutes	Breathing control	Breathing control
Upper limb endurance	10 minutes	Hand-held dumbbells (commencing at 0.5 kg) Three unsupported arm exercises[26] 3 sets x 10 repetitions	Hand-held plastic bottles or foam dumbbells (commencing with 600 ml plastic bottle or single-width foam dumbbells) Slight variation of land-based unsupported arm exercises[26] (i.e. eccentric contraction against buoyancy) 3 sets x 10 repetitions
Cool down	2 minutes	Upper limb and thoracic cage stretches Breathing control	Upper limb and thoracic cage stretches Breathing control
Exercise progression		Aimed at maintaining intensity of dyspnoea and perceived exertion ratings of 3 to 5 on modified Borg category ratio 0 to 10 scale Included increasing treadmill speed and incline, stationary cycle resistance and weight of dumbbells	Aimed at maintaining intensity of dyspnoea and perceived exertion ratings of 3 to 5 on modified Borg category ratio 0 to 10 scale Included increasing water turbulence, resistance and buoyancy by increasing effort, speed, range of motion, length of lever arm and increasing foam dumbbell density and surface area

### **Sample size**

A total of 54 participants (18 per group) were required to ensure that 48 participants (16 per group) completed the study allowing for 10% loss to follow-up. Forty-eight participants were sufficient to detect as significant, at the 5% level (two-sided), a 203 metre difference in the mean ESWT distance between the water-based exercise training and land-based exercise training group. This assumed a standard deviation of 200 metres as previously reported.[24] A 203 metre difference in ESWT distance is considered the minimum important difference.[24] This sample size also provided sufficient power for the comparison of the water-based exercise training group to the control group and the land-based exercise training group to the control group.

### **Statistical analysis**

Statistical analysis was performed using SPSS Statistics 17.0. Within-group comparisons were examined using a paired *t* test. Statistical significance was determined from post-hoc comparisons using least significant differences. Analysis of covariance (ANCOVA) was used to conduct between-group comparisons of outcomes after adjusting for pre-intervention values,[25] however, there was no adjustment of p-values for multiple comparisons to avoid type II errors. The level of statistical significance was set at  $p < 0.05$  for all analyses. Uncertainty about the size of the mean differences between groups was quantified with 95% confidence intervals.

## **RESULTS**

Of 60 consecutive patients referred to pulmonary rehabilitation with COPD and physical co-morbidities, 53 were enrolled in the trial. Forty-five participants completed the study and were included in analyses (Figure 1). Baseline characteristics were similar between the three groups (Table 2).



**Table 2 Baseline characteristics of study participants**

	<b>Water-based exercise training group (n = 18)</b>	<b>Land-based exercise training group (n = 20)</b>	<b>Control group (n = 15)</b>
Age (years)	72 (10)	73 (7)	70 (9)
Gender (male:female)	5:13	10:10	7:8
Current smokers (n)	3	1	2
Domiciliary O <sub>2</sub> (n)	0	0	2
BMI (kg/m <sup>2</sup> )	33 (6)	32 (5)	33 (6)
Pulmonary function			
FEV <sub>1</sub> (L)	1.26 (0.31)	1.43 (0.46)	1.26 (0.47)
FEV <sub>1</sub> (% predicted)	60 (10)	62 (15)	55 (20)
FVC (% predicted)	83 (13)	86 (21)	81 (20)
FEV <sub>1</sub> /FVC (%)	59 (9)	58 (9)	53 (13)
TLC (% predicted)	95 (14)	92 (20)	98 (16)
RV (% predicted)	110 (23)	99 (31)	130 (49)
DL <sub>CO</sub> (% predicted)	60 (16)	54 (18)	62 (19)
MIP (% predicted)	76 (27)	70 (22)	75 (30)
MEP (% predicted)	65 (29)	54 (16)	54 (15)
GOLD Stage (n)			
I	0	0	0
II	13	13	11
III	2	1	1
IV	0	1	3
Resting HR (bpm)	82 (16)	81 (11)	82 (11)
Resting SpO <sub>2</sub> (%)	94 (3)	95 (3)	93 (3)
Resting Borg dyspnoea score	1.4 (1.4)	1.5 (1.1)	1.2 (1.2)
Primary co-morbidity			
Musculoskeletal (n)	9	13	7
Neurological (n)	1	1	0
Obesity (n)	8	6	8
Mobility			
Independent (%)	72	70	87
Walking aid (%)	28	30	13

Data shown are mean (SD) unless otherwise indicated.

All values are post-bronchodilator.

O<sub>2</sub>, oxygen; BMI, body mass index; FEV<sub>1</sub>, forced expiratory volume in 1 second; FVC, forced vital capacity; TLC, total lung capacity; RV, residual volume; DL<sub>CO</sub>, lung diffusing capacity for carbon monoxide; MIP, maximal inspiratory mouth pressure; MEP, maximal expiratory mouth pressure; HR, heart rate; SpO<sub>2</sub>, pulse oximeter oxygen saturation; n, number of participants

Compliance with exercise group attendance was high with participants allocated to the water-based exercise training group attending a mean (SD) of 21 (2) sessions out of a total of 24 sessions and participants in the land-based exercise training group attending a mean of 19 (4) out of 24 sessions, with no statistical difference in attendance between groups ( $p=0.11$ ). Five participants randomised to the land-based exercise training group failed to complete the study. Four of these participants experienced an exacerbation of their primary co-morbid condition which caused them to drop-out of the study and one participant suffered acute-on-chronic knee pain during treadmill walking training and chose to drop-out of the study. Three participants randomised to the water-based exercise training group failed to complete the study, however, none of these withdrawals were related to

exacerbations of their co-morbid condition. One participant suffered an accidental skin tear to the lower leg from another participant and chose to drop-out of the study and the remaining two participants discontinued attending due to general fatigue. There were no statistically significant differences in baseline characteristics between participants completing the study and participants who dropped out of the study.

On the modified BORG 0-10 category ratio scale for dyspnoea, participants in the water-based exercise training group trained at an average self-reported intensity of 4.5 (0.5) over the eight week training period compared to 3.0 (0.5) in the land-based exercise training group ( $p<0.001$ ). On the modified BORG 0-10 category ratio scale for perceived exertion, participants in the water-based exercise training group trained at an average self-reported intensity of 4.5 (0.5) over the eight week training period compared to 3.5 (0.5) in the land-based exercise training group ( $p<0.001$ ). The mean (SD) training intensities achieved each week over the eight week training period in the two exercise training groups are illustrated in Figure 2. Aside from the dyspnoea ratings in the first two weeks of training in the land-based exercise training group, both training groups trained at the desired intensity for dyspnoea and perceived exertion.

### **Exercise capacity**

The mean changes in exercise test outcomes from baseline to immediately post-intervention are reported in Table 3. Significant within-group improvements in 6MWT distance occurred following training in the water-based and land-based exercise training groups (Table 3), and a significant between-group difference was found when each of the exercise groups were compared with the control group (Table 4). The water-based exercise training group was the only group to achieve a significant within-group change in the ISWT and ESWT following training (Table 3). Compared to land-based exercise training and control, water-based exercise training significantly increased incremental shuttle walk distance and endurance shuttle walk distance (Table 4). The predominant limiting factors in walking test performance for all participants were dyspnoea and musculoskeletal complaints. In the water-based exercise training group at baseline assessment, musculoskeletal pain

was the limiting factor in 53% and 60% of participants in the ISWT and ESWT respectively, whilst dyspnoea was the limiting factor in 40% and 33% of participants in the ISWT and ESWT, respectively. At final assessment, musculoskeletal pain was the limiting factor in 60% and 53% of participants in the ISWT and ESWT respectively, whilst dyspnoea was the limiting factor in 27% of participants in both the ISWT and ESWT. Following water-based exercise training, there was no significant change to the ISWT end-test dyspnoea score (both baseline mean (SD) and follow-up mean (SD) = 4 (1)) or the ESWT end-test dyspnoea score (baseline mean (SD) = 4.5 (2), follow-up mean (SD) = 4 (2)).

### **Health-related quality of life and anxiety and depression**

A significant between-group difference was found between the water-based and land-based exercise training groups in the CRDQ fatigue domain and between the water-based exercise training and control group in dyspnoea and fatigue domains (Table 4). There was no between-group differences found in anxiety or depression scores following exercise training.

### **Respiratory muscle tests**

Compared to control, water-based exercise training significantly increased MIP (Table 4). There were no significant between-group differences in MEP.

**Table 3 Exercise capacity outcomes within-group changes**

	Water-based exercise training group (n=15)				Land-based exercise training group (n=15)				Control group (n=15)			
	Baseline Mean (SD)	Follow-up Mean (SD)	Mean Change (95% CI)	p value*	Baseline Mean (SD)	Follow-up Mean (SD)	Mean Change (95% CI)	p value*	Baseline Mean (SD)	Follow-up Mean (SD)	Mean Change (95% CI)	p value*
Endurance shuttle walk test (metres)	271 (153)	591 (367)	321 (123, 518)	0.004	222 (149)	339 (299)	117 (-3, 236)	0.055	396 (423)	345 (261)	-50 (-240, 140)	0.580
6 minute walk test (metres)	349 (91)	397 (68)	48 (27, 70)	<0.001	300 (142)	343 (131)	43 (22, 63)	0.001	364 (88)	347 (94)	-16 (-34, 1)	0.060
Incremental shuttle walk test (metres)	186 (93)	235 (96)	49 (26, 73)	0.001	165 (119)	178 (102)	13 (-16, 43)	0.350	195 (96)	195 (104)	-1 (-24, 22)	0.951

\*from paired t-test

**Table 4 Exercise capacity, health-related quality of life and maximum mouth pressure outcomes between-group comparisons**

	Water-based exercise training vs control group		Water-based exercise training vs land-based exercise training		Land-based exercise training vs control group		Three group comparison
	Mean difference (95% CI)	p value*	Mean difference (95% CI)	p value*	Mean difference (95% CI)	p value*	p value#
Endurance shuttle walk test (metres)	309 (96, 522)	0.006	228 (19, 438)	0.034	81 (-136, 297)	0.456	0.014
6 minute walk test (metres)	63 (38, 87)	<0.0001	12 (-13, 37)	0.342	51 (26, 76)	<0.001	<0.001
Incremental shuttle walk test (metres)	49 (16, 82)	0.005	39 (5, 72)	0.024	10 (-23, 44)	0.542	0.012
Chronic Respiratory Disease Questionnaire							
Dyspnoea	3.3 (0.9, 5.6)	0.007	1.7 (-0.6, 4.1)	0.145	1.6 (-0.8, 4.0)	0.193	0.026
Fatigue	4.7 (2.4, 7.0)	<0.001	3.1 (0.8, 5.4)	0.009	1.6 (-0.7, 3.9)	0.163	0.001
Emotion	3.1 (0.1, 6.1)	0.046	2.9 (-0.1, 5.9)	0.054	0.1 (-2.8, 3.1)	0.921	0.078
Mastery	1.9 (-0.2, 4.0)	0.070	1.1 (-0.9, 3.1)	0.282	0.8 (-1.2, 2.8)	0.414	0.187
Hospital Anxiety and Depression Scale							
Anxiety	-1 (-4, 1)	0.222	-1 (-4, 1)	0.222	0 (-2, 2)	0.990	0.369
Depression	-1 (-3, 0)	0.068	-1 (-2, 1)	0.208	0 (-2, 1)	0.544	0.176
MIP (cmH <sub>2</sub> O)	9 (0, 18)	0.045	1 (-9, 10)	0.906	9 (0, 18)	0.062	0.081
MIP (% predicted)	14 (2, 25)	0.018	4 (-7, 15)	0.464	9 (-2, 21)	0.100	0.052
MEP (cmH <sub>2</sub> O)	5 (-7, 18)	0.379	-5 (-18, 7)	0.391	11 (-2, 24)	0.088	0.230
MEP (% predicted)	-3 (-19, 13)	0.737	-2 (-19, 14)	0.801	-1 (-17, 16)	0.939	0.940

\*from post-hoc comparison using least significant differences

#from ANCOVA adjusting follow-up measurement for baseline measurements

MIP, maximal inspiratory mouth pressure; MEP, maximal expiratory mouth pressure

## DISCUSSION

This is the first prospective randomised controlled study of the effects of water-based exercise training in people with a primary diagnosis of COPD and secondary physical co-morbidities. This study showed that water-based exercise training in people with COPD and physical co-morbidities improved peak and endurance exercise capacity and the fatigue domain of the CRDQ significantly more than an equivalent land-based exercise training program or a control group of no exercise training. Furthermore, water-based exercise training resulted in significant improvements in inspiratory muscle strength and the dyspnoea domain of the CRDQ compared to no exercise training.

Water-based exercise training was shown to be more effective in improving exercise capacity than land-based exercise training and no exercise training. The between-group differences for the ISWT and ESWT surpassed the minimum clinically important differences for both these tests in all group comparisons.[27, 24] However, there was no significant difference in 6MWT distance between the water- and land-based exercise training groups. Only one previous prospective study has compared water-based exercise training with land-based exercise training in people with COPD, showing a between-group difference of 20 m in ISWT distance and 164 m in ESWT distance in favour of water-based exercise training.[12] However, in this study subjects with physical co-morbidities were excluded and the study was only semi-randomised with groups determined by geographical distance from training venue rather than by true randomisation.[12] A key difference is that our study examined people with physical co-morbidities and had stronger methodological features of randomisation and assessor blinding. Interestingly, our results demonstrated a greater between-group difference in exercise capacity of 39 m in ISWT distance and 228 m in ESWT distance in favour of water-based exercise training suggesting that people with COPD and physical co-morbidities may be better responders to water-based exercise training than those with COPD alone. An interesting finding was that although the water- and land-based groups increased 6MWT distance, there was no significant difference between the groups, despite a significant between-group difference in ESWT in favour of the water-based training. This finding is most likely related to the constructs of the tests. For an improvement in 6MWT the participant needs to walk faster, whereas for improvement in the

ESWT the participant needs to walk at the same constant speed for longer. In people with physical co-morbid conditions, training in water may not improve walking speed as much as endurance walking capacity, thus the ESWT may be more sensitive to change than the 6MWT following water-based exercise training in people with physical co-morbidities.

Whilst the water-based exercise training was shown to be very effective compared to land-based exercise training, it is interesting to note that in this cohort of people with COPD and physical co-morbidities, land-based exercise training was still effective compared to the control of no exercise. Although there is high level evidence from randomised controlled trials that there are benefits of land-based exercise training in improving exercise capacity in people with COPD, no previous studies have specifically examined people with COPD and physical co-morbidities. This work extends the previous findings and demonstrates that land-based exercise training can be effective for those with COPD and physical co-morbidities. However, our findings of superiority of water-based exercise training compared to land-based exercise training suggest that the water medium has added benefits. The unique water properties of buoyancy to support body weight,[28] combined with resistance and turbulence to increase exercise intensity,[28] as well as the proposed effects of warm water on blood flow to muscle[28] may have enabled our population of people with COPD and physical co-morbidities to exercise at a higher intensity by reducing the impact of their physical co-morbidity on exercise. Some indirect support for higher exercise intensity in water compared to land was provided by the subjective symptom responses to training shown in Figure 2.

Our data shows that water-based exercise training achieved important outcomes for daily life in people with COPD, with a reduction in CRDQ dyspnoea and fatigue domain scores compared to no training, as well as a significant reduction in CRDQ fatigue domain score compared to land-based exercise training. As the CRDQ is a disease-specific health-related quality of life questionnaire, these improvements demonstrate that water-based exercise training in people with COPD and physical co-morbidities has a greater effect than just improving the physical co-morbid condition and actually improves health-related quality of life and management of COPD.

It has been previously proposed that immersion in water may not be tolerated by people with COPD as the hydrostatic pressure placed on the chest wall may increase the work of breathing.[11] However, people with COPD in our study tolerated the water environment well with a high attendance rate, fewer drop-outs than the land-based exercise training group and the ability to train at the desired intensity. It is likely the hydrostatic pressure placed on the chest wall provided an added load to the inspiratory muscles of respiration which resulted in a training stimulus as indicated by an increase in MIP compared to control. This is the first study to show a positive effect of water-based exercise training on inspiratory muscle strength.

A limitation of this study was that no physiological data were available to verify that the improvements in exercise capacity were specifically related to adaptation of peripheral muscles. However, dyspnoea scores were similar to pre-training values at the end of the ISWT and ESWT after water-based exercise training in spite of greater work capacity being achieved. This result provides some evidence to suggest that changes in peripheral muscle may have occurred, such as less lactate production for the same work providing less stimulus to ventilation and hence less dyspnoea. The fact that exercise was terminated at the same level of dyspnoea in the two walk tests is consistent with a large body of evidence concerning physiological limits to exercise.[29] Further studies need to be conducted to confirm that these changes in exercise capacity following water-based exercise training are the result of physiological training effects. Furthermore, as the majority of participants in this study were classified as GOLD stage 2, these results may not apply to people with severe COPD and thus further investigation is required.

## **CONCLUSION**

This randomised controlled trial found that water-based exercise training was effective in improving exercise capacity and some aspects of health-related quality of life in people with COPD and physical co-morbidities compared to land-based exercise training and no exercise training. This study

provides compelling evidence for water-based exercise training as an alternative to land-based exercise training to improve function on land in people with COPD and physical co-morbidities.

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Figure 1

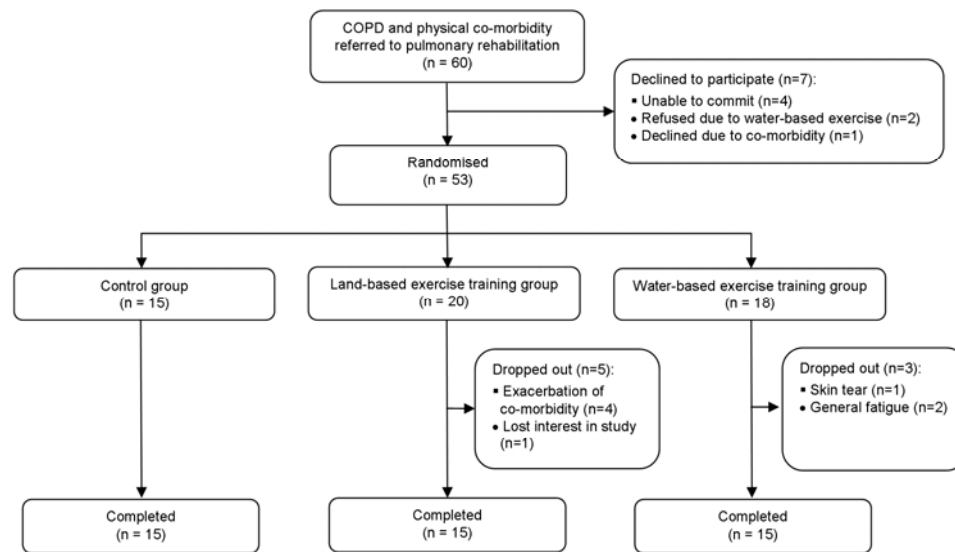


Figure 2a

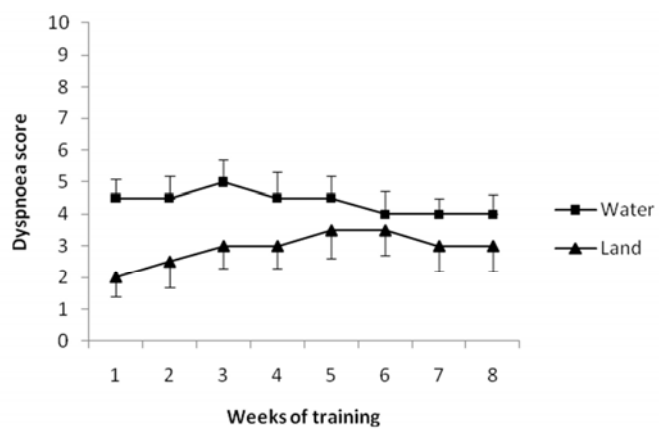


Figure 2b

