Ground walk training improves functional exercise capacity more than cycle training in people with chronic obstructive pulmonary disease (COPD): a randomised trial

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Questions: Does an eight-week program of walk training improve endurance walking capacity in people with COPD compared to cycle training? Does walk training improve peak walking capacity, cycle capacity, and quality of life compared to cycle training? Is the endurance shuttle walk test (ESWT) responsive to change in walking capacity elicited by exercise training? **Design**: Randomised trial with concealed allocation, assessor blinding, and intention-to-treat analysis. **Participants**: 36 people with stable COPD recruited with four dropouts. **Intervention**: Participants were randomised into either a walk or cycle training group. Both groups trained indoors for 30 to 45 minutes per session, three times weekly over eight weeks at Concord Hospital. Training intensities were based on baseline peak exercise tests and progressed as able. **Outcome measures**: The primary outcome was endurance walking capacity measured by the ESWT. Secondary outcomes included peak walking capacity, peak and endurance cycle capacity, and health-related quality of life. Measures were taken at baseline (Week 0) and following training (Week 8). **Results**: The walk training group increased their endurance walking time by 279 seconds (95% CI 70 to 483) more than the cycle training group. No significant differences between the groups were found for any other outcome. **Conclusion**: Ground walk training increased endurance walking capacity more than cycle training and was similar to cycle training in improving peak walking capacity, peak and endurance cycle capacity and quality of life. This study provides evidence for ground walking as a mode of exercise training in pulmonary rehabilitation programs. **Trial registration:** ACTRN12608000126314. **[Leung RWM, Alison JA, McKeough ZJ, Peters MJ (2010) Ground walk training improves functional exercise capacity more than cycle training in people with chronic obstructive pulmonary disease (COPD): a randomised trial. *Journal of Physiotherapy* 56: 105–112]**

Key words: COPD, Walking, Cycle ergometer, Exercise therapy, Exercise test, Physiotherapy

Introduction

Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality worldwide (Lopez et al 2006) and results in an economic and social burden that is substantial and increasing (Access Economics Pty Limited 2008, Chapman et al 2006). The real prevalence of COPD is likely to be under-estimated due to under-diagnosis or misdiagnosis of the disease (Bednarek et al 2008).

Pulmonary rehabilitation is recognised as an essential component of the management of people with COPD and improves exercise capacity and health-related quality of life (Lacasse et al 2006, Ries et al 2007). Due to the increasing prevalence of COPD, modes of training that are widely available and easy to implement need to be evaluated in order to meet the growing demand (The Australian Lung Foundation 2007). Ground walk training is one such mode of training. While ground walking, which requires no equipment, has been incorporated into rehabilitation programs, it has not been evaluated extensively as a training modality in people with COPD. The few studies that have examined walk training in COPD have used treadmills (Puente-Maestu et al 2000); used unsupervised walking programs that either had a high drop-out rate (Hernandez et al 2000) or used the assistance of technology to monitor walking speed (Liu et al 2008); or used peak and endurance cycle capacity as the main outcome (Na et al 2005), which may not best reflect change in functional walking capacity. No studies have evaluated supervised, individually prescribed, high intensity ground walking as a training modality in people with COPD, and none have evaluated the effects of ground walk training on exercise capacity compared to the commonly used training modality of stationary cycling. Therefore, the research questions for this study were:

1. Does ground walk training improve endurance walking capacity in people with COPD compared to cycle training?
2. Does ground walk training improve peak walking capacity, peak and endurance cycle capacity and quality of life compared to cycle training in people with COPD?
3. Is the endurance shuttle walk test responsive to change in walking capacity elicited by exercise training?

If walk training is effective in improving exercise capacity and quality of life in people with COPD, compared to equipment-dependent training such as cycle training, it would provide an easily available training modality, particularly for those living in places with limited resources such as rural and remote areas.

Method

Design

A randomised trial was conducted with concealed allocation, blinded outcome assessment, and intention-to-treat analysis. Participants were recruited from referrals to the pulmonary rehabilitation program at Concord Repatriation General Hospital, Sydney. After confirmation of eligibility and collection of baseline measures, participants were randomly allocated to a walk training group or a cycle training group (Figure 1) via a computerised phone dial-up system. The randomisation was stratified for lung function (FEV_1 > or ≤ 40% predicted), 6-minute walk distance (> or ≤ 50% predicted) (Troosters et al 1999), and the main limiting symptom in the initial endurance cycle test (ie, dyspnoea, leg fatigue, or a combination of both symptoms). Participants undertook three sessions per week of supervised group training in their allocated exercise mode for eight weeks. Each participant maintained his/her medication regimen during the intervention period. An assessor, blinded to group allocation, performed the outcome measures at the end of the intervention period.

Participants

Participants were included if they had COPD stage I to IV (Global Initiative for COPD classification (GOLD) 2008). Participants were excluded if any of the following criteria applied: acute exacerbation of COPD within the last 4 weeks, significant co-morbidity including malignancy, symptomatic cardiovascular disease, or other systemic or musculoskeletal disease that could hinder the exercise training. As well, participants were excluded if they had a body mass index (weight in kg/height in m^2) ≥ 35 kg/m^2, required supplemental oxygen during exercise training, or used a walking aid.

The study participants underwent pulmonary function testing including spirometry, lung volumes, and carbon monoxide transfer factor, and the six-minute walk test. Pulmonary function tests were performed according to the recommended standards (ATS/ERS Task Force 2005a, 2005b, 2005c) and results were compared with predicted normal values (Quanjer et al 1993).

Intervention

In the walk group, participants trained on a 26-m circular indoor track with the initial training speed set at 75% of the participant's peak walking speed, achieved in the incremental shuttle walk test (Hernandez et al 2000). Each participant was given a goal of completing a set number of laps in each five-minute period. All participants used a lap counter to monitor the number of laps walked during the prescribed duration. In the cycle group, participants were trained on an upright cycle ergometer with the initial training intensity set at 60% of the peak work capacity achieved in the incremental cycle test (Maltais et al 1997). The initial training intensities were chosen based on previous studies that reported that these training intensities were tolerated by participants with COPD (Hernandez et al 2000, Maltais et al 1997). The training intensities for both groups were progressed as symptoms permitted so that the dose of training was maximised, with participants in the walk group walking at a faster pace and those in the cycle group cycling at a higher work rate. In the walk group, if walking speed became limited by stride length, further progress of training intensity was achieved by adding weights in 2 kg increments to a backpack. The duration of training for both groups was 30 minutes in the first week and increased by five minutes every two weeks to a maximum of 45 minutes by Week 6. Participants were permitted to take short rests if needed with the total exercise time (exclusive of rests) being the target training duration. Both the walk group and the cycle group trained three times a week for eight weeks. No other form of training or education was provided to either group during the study period.

Outcome measures

The primary outcome was endurance walking capacity and the secondary outcomes were peak walking capacity, peak cycling capacity, endurance cycling capacity, and health-related quality of life.

Peak and endurance walking capacity were measured by the distance walked during the incremental shuttle walk test and the total time walked in the endurance shuttle walk test, respectively. Both the incremental shuttle walk test (Singh et al 1992) and endurance shuttle walk test (Revill et al 1999) were performed according to published protocols with the endurance shuttle walk test intensity set at 85% of predicted peak oxygen consumption. Each test was performed twice at baseline and twice at follow-up testing and the better result was recorded for analysis. Peak and endurance cycling capacity were measured by the peak work rate in the incremental cycle test and the total time cycled in the endurance cycle test, respectively. For the incremental cycle test, the work increments were 5–15 watts every minute according to each participant's predicted peak work from the six-minute walk test (Luxton et al 2008) in order to ensure the test duration was between 8 and 10 minutes (Benzo et al 2007). For the endurance cycle test, the work rate was set at 75% of peak work capacity achieved on the incremental cycle test. The identical walking speed or cycling intensity used in the endurance shuttle walk test or endurance cycle test respectively at baseline was used in follow-up testing.

For both cycle tests, physiological responses were also collected. Each participant was seated on an electrically braked cycle ergometer and connected to a calibrated mass flow sensor with expired gas sampled on a breath-by-breath basis so that oxygen consumption, carbon dioxide production, tidal volume, breathing frequency, and minute ventilation could be determined. These data were analysed at the end of the cycle exercise tests as well as at isotime in the endurance cycle test. Isotime was defined as the end time of the shorter pre- or post-training test.

Exercise tests were terminated when symptoms of dyspnoea or leg fatigue became intolerable or when the participant could not keep up with the set speed, exercise intensity, or required pedalling rate (50–60 revolutions per minute). Dyspnoea and rating of perceived exertion scores were recorded each minute during the cycle tests and at the beginning and end of all exercise tests using the modified Borg 0–10 Scale (Borg 1982). Heart rate and oxygen saturation were measured with a hand-held pulse oximeter during the cycle tests and at the beginning and end of the walk tests.

Health-related quality of life was measured with the interviewer-administered version of the Chronic Respiratory Disease Questionnaire (Guyatt et al 1987), which is a disease-specific measurement tool to assess health-related

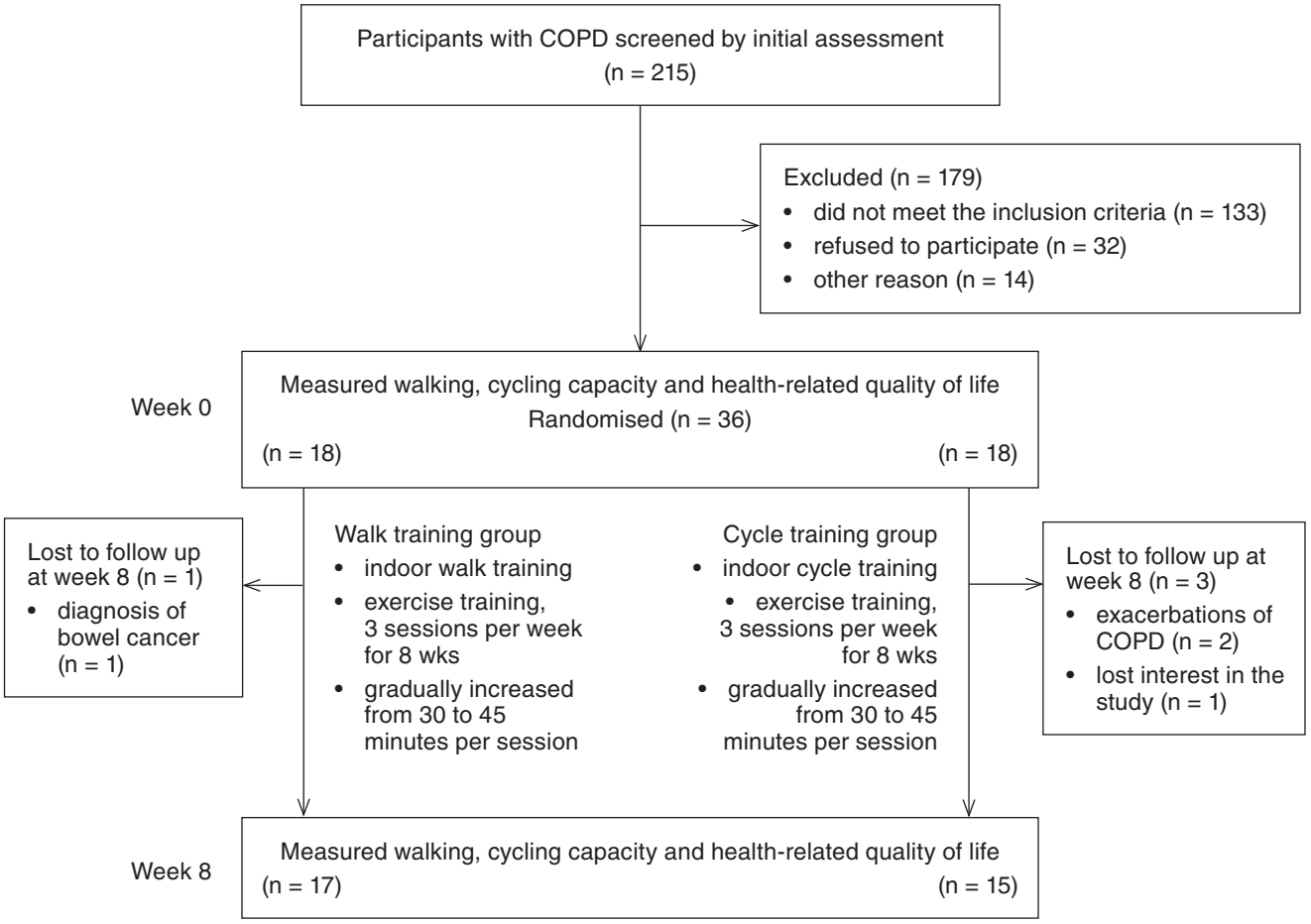

Figure 1. Design and flow of participants through the trial.

quality of life in patients with COPD. There are 20 questions which are grouped into one of four domains: dyspnoea (5 individualised dyspnoea questions), fatigue (4 questions), emotional function (7 questions), and mastery (4 questions), as well as total score. Each question was scored from one to seven, with higher scores indicating less impairment in health status. A change of 0.5 in the mean score per domain (calculated by dividing the overall score by the number of questions) has been shown to be associated with a minimal important difference in health status (Jaeschke et al 1989). This means that a minimal important difference would be 2.5 for dyspnoea, 2 for fatigue, 3.5 for emotional function, 2 for mastery, and 10 for the total Chronic Respiratory Disease Questionnaire score.

Data analysis

The minimal important difference of the endurance shuttle walk test has not yet been published. However, based on previous studies using other endurance tests, an improvement of 105 seconds has been suggested as meaningful (Casaburi 2004). We sought to detect a minimum difference of 120 seconds in the endurance shuttle walk test between groups. Assuming a SD of 108 seconds (Sewell et al 2006), 36 participants (18 per group) would provide 85% power to detect as significant, at the two-sided 5% level, a 120-second difference in endurance shuttle walk test time between the walk and cycle groups, allowing for a 15% loss to follow-up.

Repeated-measures analysis of variance was used to compare the changes between groups from pre- to post-training. The standardised response mean (SRM) was used to assess responsiveness of the endurance shuttle walk test using data from all participants. The SRM is the ratio of change in average scores over time to the SD of change (mean endurance shuttle walk test score at the end of training minus mean endurance shuttle walk test score at baseline/SD of the change). An SRM of approximately 0.2 is small, 0.5 is moderate, and greater than 0.8 is highly responsive (Garratt et al 1994).

Results

Flow of participants and therapists through the trial

The flow of participants is presented in Figure 1. Thirty-six participants were recruited and 32 (89%) completed the study with 17 in the walk group and 15 in the cycle group. Baseline characteristics of participants are presented in Table 1.

Participants were trained by the same physiotherapist in a rehabilitation gymnasium at Concord Repatriation General Hospital, Sydney. The training therapist was a qualified physiotherapist with extensive experience in exercise training in people with COPD.

Compliance with trial method

The mean attendance of participants for both groups was 23 sessions (SD 1) and no adverse events were reported. All participants were able to achieve the prescribed increments in duration at the appropriate time points before training

Table 1. Baseline characteristics of study participants.

Characteristic	Randomised (n = 36)		Lost to follow-up (n = 4)	
	Walk (n = 18)	Cycle (n = 18)	Walk (n = 1)	Cycle (n = 3)
Age (yr)	71 (7)	72 (8)	66 (0)	79 (6)
Gender, n females (%)	4 (22)	7 (39)	0 (0)	2 (67)
Body Mass Index (kg/m^2)	27 (3)	26 (5)	29 (0)	25 (1)
FEV_1 (% pred)	56 (17)	53 (18)	29 (0)	79 (19)
FVC (% pred)	86 (20)	84 (16)	95 (0)	95 (34)
FEV_1/FVC (%)	50 (10)	49 (14)	31 (0)	63 (10)
TLC (% pred)	99 (14)	102 (15)	98 (0)	88 (14)
FRC (% pred)	111 (29)	121 (30)	124 (0)	82 (13)
RV (% pred)	128 (37)	135 (40)	154 (0)	77 (14)
RV/TLC	0.51 (0.08)	0.56 (0.12)	0.62 (0)	0.47 (0.15)
DLCO (% pred)	55 (14)	54 (14)	55 (0)	41 (5)
6 minute walk distance (% pred)	72 (11)	65 (12)	49 (0)	66 (8)

Data presented as mean (SD), unless otherwise stated. FEV_1 = forced expiratory volume in one second, FVC = forced vital capacity, TLC = total lung capacity, FRC = functional residual volume, RV = residual volume, DLCO = diffusion capacity of the lung for carbon monoxide, % pred = % of predicted value

Table 2. Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups for walking capacity, cycling capacity and health-related quality of life.

	Groups				Difference within groups		Difference between groups
	Week 0		Week 8		Week 8 minus Week 0		Week 8 minus Week 0
	Walk (n = 17)	Cycle (n = 15)	Walk (n = 17)	Cycle (n = 15)	Walk	Cycle	Walk minus Cycle
ISWT *(m)*	402 (120)	372 (134)	456 (116)	417 (141)	54 (37)	45 (29)	9 (–15 to 34)
ESWT *(s)*	397 (196)	375 (304)	836 (379)	535 (359)	439 (346)	160 (204)	279 (70 to 483)
ICT *(W)*	59 (24)	50 (28)	64 (28)	63 (31)	6 (13)	13 (14)	–7 (–17 to 2)
ECT *(s)*	324 (115)	332 (131)	463 (176)	625 (404)	140 (154)	293 (361)	–154 (–350 to 42)
CRQD	17 (5)	16 (4)	21 (5)	20 (4)	4 (4)	4 (2)	0.5 (–2 to 3)
CRQF	18 (4)	15 (4)	21 (4)	17 (5)	3 (2)	2 (2)	1 (–0.4 to 3)
CRQEF	36 (6)	33 (8)	41 (6)	35 (8)	4 (3)	2 (4)	2 (–1 to 4)
CRQM	22 (4)	18 (6)	24 (3)	20 (6)	2 (2)	2 (2)	0 (–2 to 2)
CRQT	93 (13)	82 (15)	107 (13)	92 (18)	14 (9)	10 (8)	4 (–2 to 10)

ISWT = incremental shuttle walk test, ESWT = endurance shuttle walk test, ICT = incremental cycle test, ECT = endurance cycle test, CRQD = chronic respiratory disease questionnaire dyspnoea domain, CRQF = chronic respiratory disease questionnaire fatigue domain, CRQEF = chronic respiratory disease questionnaire emotional function domain, CRQM = chronic respiratory disease questionnaire mastery domain, CRQT = chronic respiratory disease questionnaire total score, shaded row = primary outcome

intensity was progressed. The progression of training intensity is presented in Figure 2. The mean (SD) training intensity of participants in the walk group increased to 80% (SD 4) peak walking speed by week eight. Two participants reported being unable to increase walking speed despite minimal symptoms, suggesting stride length was a limiting factor. Consequently, a 2 kg weight in a backpack was added during training. The mean training intensity of participants in the cycle group increased to 95% (SD 38) of the initial peak work rate by Week 8.

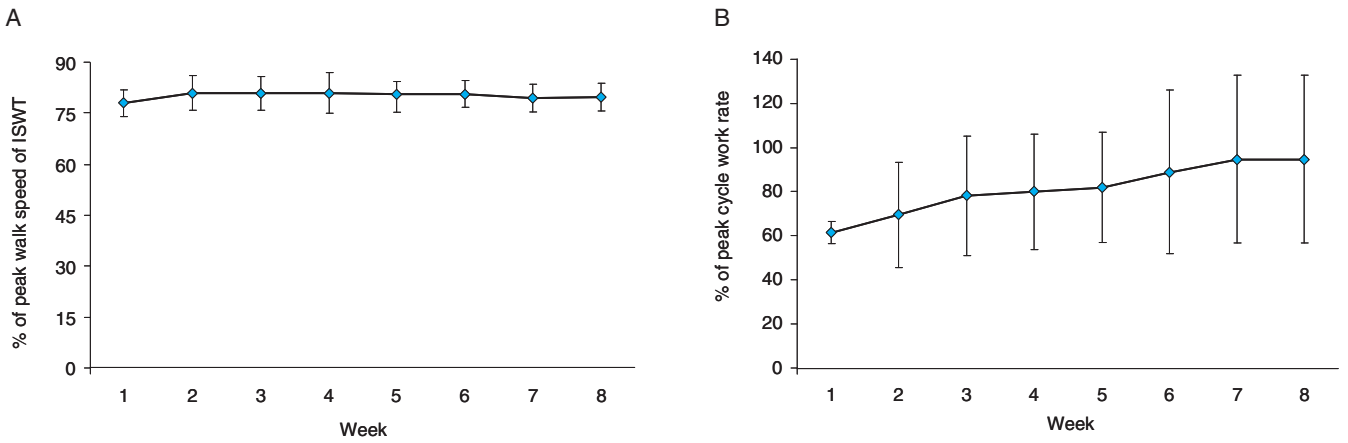

Figure 2. Mean (SD) of the progression of training intensity in a) walk training and b) cycle training group. The % peak walk speed of ISWT and the % peak cycle work rate were % of the peak measure in each test at baseline. Two participants reported being unable to increase walking speed despite minimal symptoms suggesting stride length was a limiting factor. Consequently, a two-kilogram weight in a backpack was added during training which is not reflected in the graph. ISWT = incremental shuttle walk test.

Table 3. Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups for physiological response at end and at isotime of the endurance cycle test.

	Groups				Difference within groups		Difference between groups
	Week 0		Week 8		Week 8 minus Week 0		Week 8 minus Week 0
	Walk (n = 17)	Cycle (n = 15)	Walk (n = 17)	Cycle (n = 15)	Walk	Cycle	Walk minus Cycle
At end ECT							
VO_2 (L/min)	0.94 (0.28)	0.84 (0.24)	0.91 (0.24)	0.85 (0.24)	−0.03 (0.24)	0.01 (0.14)	−0.05 (−0.19 to 0.09)
VCO_2 (L/min)	1.07 (0.41)	0.90 (0.34)	0.92 (0.21)	0.89 (0.34)	−0.15 (0.35)	−0.01 (0.17)	−0.14 (−0.35 to 0.06)
RER	1.11 (0.19)	1.06 (0.17)	1.03 (0.18)	1.04 (0.14)	−0.08 (0.20)	−0.02 (0.18)	−0.05 (−0.19 to 0.08)
VT *(L)*	1.35 (0.26)	1.19 (0.32)	1.31 (0.22)	1.18 (0.38)	−0.05 (0.21)	−0.01 (0.17)	−0.04 (−0.18 to 0.10)
F_b (br/min)	29 (6)	29 (6)	27 (5)	28 (7)	−2 (4)	0 (3)	−2 (−4 to 0.4)
V_E (L/min)	40 (10)	34 (11)	35 (9)	33 (12)	−5 (8)	−1 (6)	−4 (−9 to 1)
At isotime ECT							
VO_2 (L/min)	0.94 (0.28)	0.84 (0.24)	0.86 (0.26)	0.83 (0.23)	−0.08 (0.17)	−0.005 (0.13)	−0.08 (−0.18 to 0.03)
VCO_2 (L/min)	1.07 (0.41)	0.90 (0.34)	0.91 (0.32)	0.86 (0.30)	−0.16 (0.31)	−0.04 (0.16)	−0.12 (−0.31 to 0.08)
RER	1.11 (0.19)	1.06 (0.17)	1.04 (0.17)	1.03 (0.11)	−0.06 (0.15)	−0.03 (0.15)	−0.03 (−0.14 to 0.08)
V_T *(L)*	1.35 (0.26)	1.19 (0.32)	1.28 (0.22)	1.18 (0.36)	−0.07 (0.21)	−0.004 (0.15)	−0.07 (−0.20 to 0.07)
F_b (br/min)	29 (6)	29 (6)	26 (7)	26 (5)	−3 (3)	−3 (3)	−0.3 (−3 to 2)
V_E (L/min)	40 (10)	34 (11)	33 (10)	31 (11)	−6 (7)	−3 (5)	−4 (−8 to 1)

ECT = endurance cycle test, VO_2 = oxygen consumption, VCO^2 = carbon dioxide production, RER = respiratory exchange ratio, VT = tidal volume, Fb = breathing frequency, V_E = minute ventilation, br = breaths

Effect of intervention

Group data for exercise capacity and health-related quality of life at baseline (Week 0) and following training (Week 8) for the walk group and cycle group are presented in Table 2. Following training, the mean difference in endurance walk time between the walk group and cycle group was 279 seconds (95% CI 79 to 483). Six participants in the walk group and three participants in the cycle group reached the 20-minute completion time of the endurance shuttle walk test following training. There were no significant differences

Table 4. Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups for dyspnoea and rate of perceived exertion score (RPE) at the end of and at isotime of the exercise tests.

	Groups				Difference within groups		Difference between groups
	Week 0		Week 8		Week 8 minus Week 0		Week 8 minus Week 0
	Walk (n = 17)	Cycle (n = 15)	Walk (n = 17)	Cycle (n = 15)	Walk	Cycle	Walk minus Cycle
Dyspnoea *(0–10)*							
ISWT end	4 (3)	5 (2)	4 (3)	5 (3)	–0.3 (2)	0.1 (2)	–0.5 (–2 to 1)
ESWT end	5 (3)	5 (2)	4 (3)	5 (2)	–1 (2)	–0.2 (2)	–0.4 (–2 to 1)
ICT end	6 (3)	4 (2)	5 (3)	5 (3)	–1 (3)	1 (2)	–2 (–4 to 0.2)
ECT end	6 (3)	4 (2)	5 (3)	5 (3)	–1 (2)	0.1 (2)	–1 (–3 to 0.5)
ECT isotime	6 (3)	4 (2)	4 (3)	3 (3)	–2 (3)	–1 (2)	–1 (–2 to 1)
RPE *(0–10)*							
ISWT end	3 (3)	3 (2)	2 (2)	2 (2)	–0.4 (2)	–1 (2)	0.4 (–1 to 2)
ESWT end	5 (3)	4 (2)	2 (1)	3 (2)	–2 (2)	–1 (2)	–1 (–3 to 0.02)
ICT end	6 (3)	4 (2)	4 (2)	4 (2)	–1 (3)	0 (2)	–1 (–3 to 1)
ECT end	5 (3)	5 (2)	5 (3)	4 (2)	0 (2)	–1 (2)	0.3 (–1 to 2)
ECT isotime	5 (3)	5 (2)	4 (2)	2 (2)	–1 (2)	–2 (2)	1 (–1 to 2)

ISWT = incremental shuttle walk test, ESWT = endurance shuttle walk test, ICT = incremental cycle test, ECT = endurance cycle test

in peak walking capacity, peak cycle, and endurance cycle capacity between the two groups following training. Furthermore, there was no significant difference between the two groups in health-related quality of life assessed by the individual domains and the total score of the Chronic Respiratory Disease Questionnaire following training.

Group data for physiological responses at end exercise and at isotime of the endurance cycle test at baseline and following training are presented in Table 3. Following training, there were no significant differences between groups in any of the physiological measures at end exercise or at isotime. Furthermore, following training there was no significant difference between groups in dyspnoea or rating of perceived exertion at the end of any of the exercise tests.

In terms of the responsiveness of the endurance shuttle walk test, the SRM of the endurance walk time was 0.97.

Discussion

The main finding of this study was that supervised, progressed walk training resulted in a significantly greater increase in endurance walking capacity compared to supervised, progressed stationary cycle training in people with COPD. In addition, walk training had very similar effects to cycle training on peak walking capacity, peak cycle capacity, endurance cycle capacity, and health-related quality of life. To our knowledge, this is the first study to demonstrate that supervised, ground walk training was more effective than cycle training in improving endurance walking capacity in people with COPD. As cycle training is the most commonly used mode of training that has demonstrated physiological training effects to improve exercise capacity and health-related quality of life in people with COPD (Casaburi et al 1991, Maltais et al 1996, Maltais et al 2008), the superiority of walk training in improving endurance walking capacity compared to cycle training is impressive.

Although the improvement in endurance walking time was 279 seconds (68%) greater with walk training than with cycle training, the true effect of walk training was probably underestimated as six participants in the walk group following training reached the completion time of 20 minutes for the endurance shuttle walk test with a potential to continue whereas only three participants in the cycle group following training reached the completion time. The greater improvement in the walk group compared to the cycle group in endurance walk time might be considered an important clinical difference since it exceeds the 105 second threshold suggested by Casaburi (2004) as the minimal important difference for endurance tests. It also exceeds the 120 second minimal important difference we nominated *a priori* for the study.

There have been no previous studies comparing ground walk training to stationary cycle training. Furthermore, evidence of the effectiveness of ground walk training alone in improving exercise capacity is limited as walk training is often part of a comprehensive training program in COPD (Goldstein et al 1994, Ries et al 1995, Ringbaek et al 2008). A previous randomised controlled trial has investigated the benefit of a home-based walk training program compared to usual care (no exercise training) (Hernandez et al 2000). In the study, participants in the walk training group trained six days per week for twelve weeks, unsupervised, and improved endurance walk time by 960 seconds (99%) more than the usual care group. Even though our study did not have a comparison group of no training, we showed a 68% greater improvement in the endurance walking time in the walk group compared to cycle training. This further demonstrates the ability of walk training to improve endurance walking capacity in people with COPD.

The other important finding of our study was that walk training and cycle training had very similar effects on peak walk capacity, peak and endurance cycle capacity and health-related quality of life (Table 2 and Table 3). For example, the difference in treatment effect between the walk group and cycle group was only 1% in peak walking

capacity (assessed by the incremental shuttle walk test). Similarly, there was only a 6% difference in treatment effect in health-related quality of life (assessed by the total score of Chronic Respiratory Disease Questionnaire) between the walk and cycle groups. Furthermore, the lower limits of the 95% CIs around the mean difference between walk and cycle training in the total score and the individual domain scores of the Chronic Respiratory Disease Questionnaire were all above the minimal important difference of 2.5 for dyspnoea, 2 for fatigue, 3.5 for emotional function, 2 for mastery, and 10 for the total CRQ score. This shows that the effect of ground walk training on health-related quality of life was as clinically worthwhile as cycle training.

We were unable to measure detailed physiological responses during the walk tests, thus limiting the ability to provide conclusive physiological explanations for the improvement in endurance walking capacity shown in the walk group. However, some explanations can be made by extrapolating from the physiological responses during the cycle tests. The results from the endurance cycle tests showed that there was no significant difference in the improvement in the physiological responses following training between the walk and cycle groups (Table 3). However, both groups had significantly reduced dyspnoea, rating of perceived exertion and breathing frequency at isotime on the endurance cycle test compared to baseline, and the walk group also had significantly reduced carbon dioxide production and minute ventilation at isotime compared to baseline. The reduction in carbon dioxide production and minute ventilation could be due to the improvement in oxidative capacity of the exercising muscles after walk training leading to a lower ventilation and dyspnoea at the same workload (Casaburi et al 1991, Casaburi et al 1997, Maltais et al 1997). The postulated improvement in oxidative capacity would help to explain why participants could sustain longer walk durations at an equivalent submaximal constant speed after walk training.

Appropriate outcome measures need to be chosen in order to evaluate the true effect of an intervention. Our study has demonstrated that the endurance shuttle walk test is highly responsive to change in walking capacity elicited by exercise training and thus was an appropriate outcome measure. Although incremental and endurance cycle tests have been used to measure physiological outcomes of programs in which the major aerobic component was walk training (Na et al 2005), our study has shown that such tests may not elucidate the improvement seen in endurance walking capacity that was demonstrated by the endurance shuttle walk test in the walk group. The current study is the first to use the endurance shuttle walk test to examine the benefit of ground walk training.

One limitation of this study was the lack of a control group of no exercise training. Therefore, we cannot determine the absolute effect of ground walk training or cycle training. However, the study design was based on the cycle group acting as an active control because of the substantial evidence indicating the effectiveness of cycle training compared with no training. Thus, the lack of a difference between cycle training and walk training for the majority of outcomes supports the beneficial effects of walking training for people with COPD. A further limitation was that we were not able to measure equivalence of training intensity in terms of VO_2 between walk and cycle groups. However, since the initial training intensity was set at the tolerable level in both groups and training was progressed as able, the results represent the responses to attainable levels of walk and cycle training.

In conclusion, this study provides evidence for the inclusion of ground walk training as an effective training modality in pulmonary rehabilitation for people with COPD. This is a significant finding as ground walk training is simple, readily available, and requires no equipment. Walk training, as prescribed in this study, could be replicated in different indoor settings, especially in rural and remote areas where resources may be limited or in programs with limited funding. Thus, the availability of effective pulmonary rehabilitation programs could be increased to meet the growing demands of COPD. ■

Ethics: Concord Repatriation General Hospital Human Ethics Committee, and The University of Sydney Human Ethics Committee approved this study. Participants gave written informed consent before data collection began.

Competing interests: None declared.

Acknowledgements: The authors would like to thank Professor Christine Jenkins, Mr Peter Rogers, and Miss Leigh Seccombe for reviewing the manuscript; Dr Roger Adams for statistical advice; and Miss Courtney Rugg, Mrs Caroline Reynolds, Mr Alan Chung, and the Department of Thoracic Medicine at Concord Repatriation General Hospital for their assistance with the study.

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