A predominantly home-based progressive resistance exercise program increases knee extensor strength in the short-term in people with chronic obstructive pulmonary disease: a randomised controlled trial

Simone D O'Shea[1,2], Nicholas F Taylor[1] and Jennifer D Paratz[3]

[1]La Trobe University [2]Wodonga Regional Health Service [3]University of Queensland Australia

Questions: Does a 12-week, predominantly home-based program of progressive resistance exercises reduce impairments, activity limitations, and participation restrictions in people with chronic obstructive pulmonary disease? Are any gains maintained 12 weeks after the cessation of the program? **Design**: Randomised controlled trial with concealed allocation, assessor blinding, and intention-to-treat analysis. **Participants**: 54 people with moderately severe chronic obstructive pulmonary disease not undergoing pulmonary rehabilitation. **Intervention**: The experimental group performed six progressive resistance exercises three times per week (once a week hospital-based, twice a week home-based) for 12 weeks. Exercise intensity was three sets of 8 to 12 repetition maximum progressed against elasticised bands of increasing resistance. The control group received no intervention. **Outcome measures**: Primary outcomes were strength (knee extensor, hip abductor, shoulder horizontal flexor, shoulder flexor) measured using hand-held dynamometry, and walking capacity measured by the 6-minute Walk Test performed before and after intervention and again at 12 weeks after the cessation of intervention. **Results**: The experimental group increased their knee extensor strength by 4.9 kg (95% CI 1.1 to 8.7) more than the control group by Week 12. However, this gain was not maintained at Week 24. No difference between the groups was found for any of the other primary outcomes. **Conclusions**: A predominantly home-based progressive resistance exercise program led to modest improvements in knee extensor strength in people with chronic obstructive pulmonary disease. However, 44% of the experimental group were unable to complete the exercise program, highlighting the need to understand factors influencing adherence to exercise in this population. **[O'Shea SD, Taylor NF, Paratz JD (2007) A predominantly home-based progressive resistance exercise program increases knee extensor strength in people with chronic obstructive pulmonary disease: a randomised controlled trial. *Australian Journal of Physiotherapy* 53: 229–237]**

Key words: Chronic Obstructive Pulmonary Disease, Muscle Strength, Rehabilitation, Exercise Therapy, Muscle Strength

Introduction

Muscle weakness is associated with exercise intolerance and a poorer prognosis for people with chronic obstructive pulmonary disease (ATS and ERS 1999). Therefore, the inclusion of progressive resistance exercise during pulmonary rehabilitation has been recommended (Troosters et al 2005, ATS and ERS 2006, Ries et al 2007). A recent systematic review of progressive resistance exercise for people with chronic obstructive pulmonary disease demonstrated moderate to large effects for increases in upper and lower body strength after progressive resistance exercise (O'Shea et al 2004). However, there was limited information regarding the effect on broader outcomes such as task performance (activity) and social roles (participation). The specific effects of progressive resistance exercise for people with chronic obstructive pulmonary disease also remain unclear as trials have often compared resistance exercise with endurance training or included it as part of a mixed program (O'Shea et al 2004). Little is known about the effectiveness of home-based progressive resistance exercise programs as trials have predominantly been undertaken in supervised outpatient settings using machine weights (O'Shea et al 2004). Moreover, it is unclear how well changes after progressive resistance exercise are maintained, with conflicting findings from the only two located trials (Troosters et al 2000, Ortega et al 2002).

The aim of this investigation was to further understand the role and contribution of progressive resistance exercise in pulmonary rehabilitation. The research questions were:

1. Does a 12-week, predominantly home-based program of progressive resistance exercises reduce impairements, activity limitations and participation restrictions in people with chronic obstructive pulmonary disease?
2. Are any gains maintained 12 weeks after the cessation of the program?

Method

Design

A parallel-group single-blind randomised trial was conducted across four sites, including three regional health services and one large metropolitan hospital. People with chronic obstructive pulmonary disease were recruited

via pulmonary rehabilitation databases, medical clinics, and media promotions. Group allocation sequence was generated by a member of the research team not involved in participant recruitment, and concealed in envelopes until after completion of baseline measurement. Participants were stratified according to past pulmonary rehabilitation status (rehabilitation or no rehabilitation) and randomly allocated from each stratum, via block randomisation, to one of two groups: progressive resistance exercise or control (Altman and Bland 1999). Participants were advised of group allocation (after initial assessment) by a member of the research team responsible for recruitment. Participants were assessed prior to the intervention (0 weeks), immediately after intervention (12 weeks), and 12 weeks after intervention had ceased (24 weeks). All measurement sessions were conducted by an independent and trained assessor, blinded to group allocation. Ethics approval was obtained from all four study sites.

Participants

Inclusion criteria were: a diagnosis of chronic obstructive pulmonary disease (McKenzie et al 2003), written informed consent, and no pulmonary rehabilitation in the previous 12 months. Participants were excluded if they had respiratory conditions other than chronic obstructive pulmonary disease, or unstable medical conditions limiting the performance of progressive resistance exercise. Lung function was measured using spirometry, performed according to American Thoracic Society guidelines (ATS 1995), to monitor disease stability. The key measures were forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC, and the percentage predicted of FEV_1 (FEV_1 % predicted).

Intervention

The experimental group undertook a progressive resistance exercise program consisting of six exercises three times per week for 12 weeks. One session per week was conducted in an outpatient clinic under the supervision of an experienced physiotherapist; the remaining two sessions were performed independently at home. Exercises included hip abduction in standing, simulated lifting, sit-to-stand, seated row, lunges, and chest press. For each exercise, participants attempted to complete three sets of 8 to 12 repetitions maximum against elasticised resistance bands (Kraemer et al 2002). Resistance level (ie, band colour) was increased when participants could perform three sets of 12 repetitions maximum with correct technique through the full range of movement. An exercise logbook was provided to record intensity, frequency, and duration of exercise sessions. After 12 weeks, the resistance bands were left with participants but ongoing exercise was a personal choice.

The control group received no intervention. They were instructed not to commence any form of progressive resistance exercise or to alter their baseline exercise routine significantly. Exercise levels of all participants were reviewed via telephone at 6, 12, 18, and 24 weeks of the trial.

Outcome measures

Outcomes were categorised under the headings impairments, activity limitations, and participation restrictions according to the International Classification of Functioning, Disability and Health (WHO 2002). The primary outcomes were strength (knee extensor, hip abductor, shoulder horizontal flexor, and shoulder flexor) and walking capacity.

Impairments: Strength was measured using hand-held dynamometry and reported in kg. Three trials each of knee extensor, hip abductor, shoulder horizontal flexor, and shoulder flexor strength were performed for both right and left limb, with the final two trials averaged across right and left limbs. Good test-retest reliability (ICC > 0.79) over a two-week interval has been demonstrated for muscle strength measures obtained via this method for people with chronic obstructive pulmonary disease (O'Shea et al 2007b).

Physical and psychological impairments were measured with the Chronic Respiratory Disease Questionnaire, for which good reliability and validity has been reported in chronic obstructive pulmonary disease populations (Guyatt et al 1987). The questionnaire was administered by an interviewer and each domain (dyspnoea, fatigue, emotion and mastery) was scored from 1 to 7 where 1 represents maximum impairment and 7 represents no impairment.

Activity limitations: Walking capacity was measured using the 6-minute Walk Test (Butland et al 1982), and reported as distance walked in metres. The test was administered according to American Thoracic Society guidelines (Crapo et al 2002).

Mobility was measured using the Timed Up and Go test and reported in seconds with a lower score representing good performance. Three trials were performed, with the times for the final two trials averaged. The test is highly repeatable (Podsiadlo and Richardson 1991).

Upper limb activity was measured using the Grocery Shelving Test and reported in seconds with a lower score representing good performance. The test required participants to place 10 items (410g each) from each of two grocery bags onto a shelf 15 cm above shoulder height as fast as possible. Three trials were performed, with times for the final two trials averaged. High test-retest reliability over a six week interval has been demonstrated for people with chronic obstructive pulmonary disease (Hill et al 2001).

Participants rated their own activity performance using the Patient-Specific Functional Scale (Stratford et al 1995). Participants nominated up to five tasks they had difficulty with because of their breathing problem and rated their performance on each of them (from 0 to 10). The score was determined by averaging the individual ratings (Stratford et al 1995). Moderate test-retest reliability has previously been demonstrated in people with chronic obstructive pulmonary disease (O'Shea et al 2005).

Participation restrictions: Participation restrictions were measured using the London Handicap Scale (Harwood and Ebrahim 1995) which has moderate test-retest reliability for people with chronic obstructive pulmonary disease (ICC = 0.71) (O'Shea et al 2005). The scale considers disadvantage in six dimensions: mobility, physical independence, occupation, social integration, orientation, and economic self-sufficiency. Participants answered questions about these dimensions and a handicap score (0 to 100) was determined, where a score of 100 implies no disadvantage and a score of 0 represents maximum disadvantage (Harwood and Ebrahim 1995).

Data analysis

In estimating sample size, a minimum clinical improvement in muscle strength of 15% was regarded as worth detecting. The standard deviation of a similar population was 18%

Table 1. Mean (SD) of characteristics of participants by group and by completion of the trial.

Characteristic	Participants by group		Participants by completion	
	Exp (n = 27)	Con (n = 27)	Completed (n = 41)	Withdrew (n = 13)
Age *(yr)*	66.9 (7.0)	68.4 (9.9)	67.1 (8.7)	69.7 (8.1)
Height *(m)*	1.63 (0.08)	1.64 (0.09)	1.64 (0.09)	1.62 (0.10)
Weight *(kg)*	67.9 (15.3)	74.7 (19.6)	68.4 (16.1)	80.5 (20.2)
Body Mass Index *(kg/m^2)*	25.5 (5.1)	27.8 (7.9)	25.3 (5.6)	30.8 (8.4)
Number co-morbidities	2.3 (1.4)	2.7 (1.6)	2.5 (1.2)	2.5 (1.8)
Number medications	6.5 (3.9)	5.5 (2.4)	5.4 (2.5)	8.0 (4.4)
History of smoking *(packs/day x years smoking)*	40.0 (29.4)	26.5 (21.5)	31.4 (27.5)	39.0 (22.3)
Time since quit smoking *(yr)*	10.1 (10.5)	9.4 (12.7)	10.3 (12.4)	8.1 (8.1)
FEV_1 *(% predicted)*	49 (25)	52 (22)	52 (24)	46 (20)
FEV_1/FVC *(%)*	50 (16)	49 (15)	49 (15)	52 (17)

(O'Shea et al 2004). Therefore, to have 80% power of detecting a 15% difference, 45 participants were required. The minimum clinical improvement in walking capacity worth detecting was regarded as 80 m (Wise and Brown 2004). The standard deviation of a similar population was 95.1 m (Sciurba et al 2003). Therefore, to have 80% power of detecting an 80 m difference, 44 participants were required. Taken together, and allowing for an attrition rate of 20%, 56 participants were required.

Two-way ANOVA for repeated measures was used to examine changes occurring between baseline (Week 0) and immediately after intervention (Week 12), and baseline (Week 0) and 12 weeks after cessation of intervention (Week 24). Intention-to-treat analysis via the carry forward method was used when withdrawing participants could not be reassessed at follow up (Hollis and Campbell 1999).

Results

Flow of participants through the trial

Fifty-seven volunteers (22 male, 35 female) were recruited between April and September 2004. Fifty-four participants were randomly allocated to either the experimental (Exp = 27) or control (Con = 27) group, after two female participants withdrew (surgery, personal choice), and one male volunteer was excluded at baseline assessment due to an incorrect diagnosis (chronic heart failure). The characteristics of each group were similar at baseline (Table 1). Of the 27 participants in each group, 16 people (59%) had completed pulmonary rehabilitation, six (22%) were on long-term oxygen therapy, approximately 70% reported exercising nil to less than twice weekly. Cardiovascular (Exp = 21, Con = 25) and musculoskeletal (Exp = 27, Con = 24) co-morbidities were similar across groups. There was very little deterioration in the participants' condition over the 24 weeks of the trial. At baseline, their % predicted FEV_1 was 51% (SD 23), at 12 weeks it was 50% (SD 22), and at 24 weeks it was unchanged at 50% (SD 24). At baseline, their FEV_1/FVC was 50% (SD 16), at 12 weeks it was 48% (SD 14), and at 24 weeks it was 47% (SD 15).

Ten participants (Exp = 7, Con = 3) withdrew during the first 12 weeks of the study, and a further three people (Exp = 1, Con = 2) withdrew prior to the Week 24 measurement (Figure 1). Reasons for withdrawal included respiratory exacerbation (Exp = 3, Con = 1), illness unrelated to chronic obstructive pulmonary disease (Exp = 1, Con = 1), injury unrelated to the trial (Exp = 2), family issues (Exp = 1, Con = 1), personal choice (Con = 2), or change in treatment (Exp = 1). Participants who withdrew from the trial were heavier ($t_{(52)} = -2.24$, $p = 0.03$), had a higher body mass index ($t_{(52)} = -2.71$, $p = 0.01$), had reduced baseline 6-minute walk distance ($t_{(52)} = 2.17$, $p = 0.03$) and were more likely to have never completed pulmonary rehabilitation when compared to participants who completed the trial ($\chi^2 = 4.31$, $p = 0.04$) (Table 1).

Compliance with trial method

Twenty out of 27 participants (74%) in the experimental group completed a mean 30.5 (SD 5.7) out of 36 exercise sessions (85%, range 44–100%). Five of these 20 participants had to cease exercising prior to the end of the 12 week intervention because of respiratory exacerbation (n = 2),

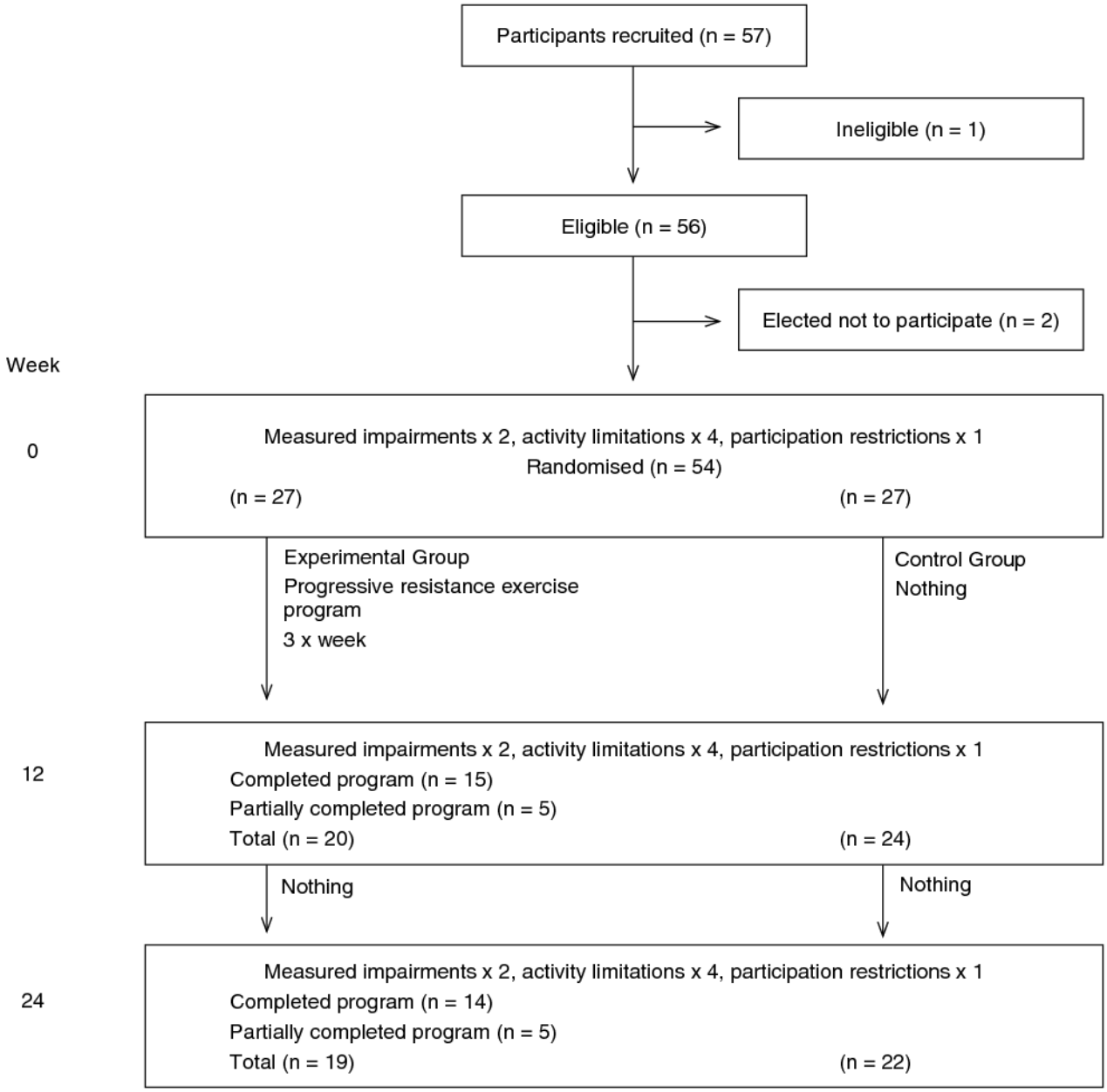

Figure 1. Design and flow of participants through the trial.

hospitalisation unrelated to chronic obstructive pulmonary disease (n = 1), injury secondary to motor vehicle accident (n = 1), and surgery (n = 1). Therefore, 15 participants completed the full 12-week program, and performed an average 32.7 (SD 3.9) out of 36 exercise sessions (91%, range 64–100%), exercised at an intensity greater than or equal to 'somewhat hard' (Borg 1982), and demonstrated good progression of their exercise by increasing the colour and number of resistance bands. The seven participants who withdrew from the experimental group completed a mean 5.3 (SD 4.3) out of 36 exercise sessions (15%, range 0–33%). At Week 24, 15 out of the 19 participants (79%) in the experimental group reported continuing or resuming some level of resistance exercise during the follow-up period. However, only eight participants (42%) exercised for the full 12 weeks, and exercise frequency and intensity were also reduced.

No participants in the control group reported any changes in their exercise habits or level of activities across the course of the trial.

Effect of intervention

Group data for all outcomes are presented in Table 2 according to intention-to-treat analysis, while individual data for the three measurement occasions are presented in Table 3 (see eAddenda for Table 3). In terms of the primary outcomes, the experimental group had increased their knee extensor strength by 4.9 kg (95% CI 1.1 to 8.7, $p = 0.01$) more than the control group immediately after the intervention at Week 12. This is equivalent to a 17% greater increase in strength than the control group. However, this gain was not maintained at Week 24. No difference was found between the groups for any of the other primary or secondary outcomes ($p > 0.05$).

Table 2. Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups for all outcomes using an intention-to-treat analysis.

Outcome	Groups						Difference within groups				Difference between groups	
	Week 0		Week 12		Week 24		Week 12 minus Week 0		Week 24 minus Week 0		Week 12 minus Week 0	Week 24 minus Week 0
	Exp n = 27	Con n = 27	Exp n = 27	Con n = 27	Exp n = 27	Con n = 27	Exp	Con	Exp	Con	Exp minus Con	Exp minus Con
Impairments												
Strength (kg)												
Knee ext	28.8 (10.9)	27.9 (13.9)	34.1 (14.4)	28.3 (12.9)	31.7 (12.8)	27.3 (13.7)	5.3 (7.4)	0.4 (6.3)	2.9 (5.3)	–0.6 (8.8)	4.9 (1.1 to 8.7)	3.5 (–0.5 to 7.5)
Hip abd	26.5 (12.3)	22.0 (12.0)	32.1 (15.0)	25.8 (13.2)	30.5 (14.0)	25.3 (13.8)	5.6 (8.9)	3.8 (6.7)	4.0 (7.1)	3.3 (7.4)	1.8 (–2.5 to 6.1)	0.6 (–3.3 to 4.6)
Sh horiz flex	14.2 (9.0)	13.6 (9.6)	16.1 (9.5)	15.2 (7.8)	13.8 (6.9)	14.2 (8.1)	1.9 (3.9)	1.7 (5.7)	–0.4 (5.9)	0.6 (6.8)	0.2 (–2.5 to 2.9)	–1.1 (–4.5 to 2.4)
Sh flex	13.6 (8.8)	13.3 (7.9)	16.9 (12.0)	15.6 (7.4)	15.2 (9.6)	13.9 (7.4)	3.3 (5.8)	2.4 (3.9)	1.6 (4.7)	0.6 (5.5)	1.0 (–1.7 to 3.7)	1.0 (–1.8 to 3.8)
CRDQ (1 to 7)												
Dyspnoea	3.5 (1.0)	3.6 (0.9)	4.1 (1.0)	3.6 (1.0)	4.0 (0.9)	3.9 (1.0)	0.6 (1.5)	0 (1.0)	0.5 (1.0)	0.3 (0.9)	0.6 (–0.1 to 1.2)	0.3 (–0.2 to 0.8)
Fatigue	3.8 (1.1)	3.9 (1.2)	4.2 (1.0)	3.8 (1.1)	4.1 (1.2)	4.0 (1.0)	0.4 (1.2)	–0.1 (1.0)	0.3 (1.2)	0.1 (1.0)	0.4 (–0.1 to 1.0)	0.2 (–0.4 to 0.8)
Emotion	4.9 (1.1)	4.8 (1.1)	5.3 (1.0)	4.9 (1.0)	5.2 (1.1)	5.1 (1.1)	0.4 (0.8)	0.2 (0.7)	0.3 (1.0)	0.3 (0.6)	0.2 (–0.2 to 0.6)	0 (–0.5 to 0.4)
Mastery	5.0 (1.2)	4.9 (1.3)	5.3 (1.2)	5.1 (1.2)	5.1 (1.3)	5.1 (1.1)	0.3 (0.8)	0.2 (0.8)	0.1 (0.8)	0.2 (1.0)	0.1 (–0.3 to 0.5)	–0.1 (–0.6 to 0.4)
Activity limitations												
6-min Walk Test (m)	376 (114)	337 (83)	380 (115)	346 (94)	380 (114)	344 (91)	4 (22)	9 (48)	4 (24)	8 (38)	–5 (–26 to 15)	–4 (–21 to 14)
TUG (s)	9.7 (3.1)	9.6 (1.6)	9.3 (2.7)	9.3 (1.8)	9.3 (2.9)	9.2 (1.7)	–0.4 (1.5)	–0.3 (1.0)	–0.4 (1.6)	–0.4 (1.0)	–0.2 (–0.9 to 0.5)	–0.1 (–0.8 to 0.7)
GST (s)	53.0 (16.9)	52.8 (13.3)	49.7 (16.9)	51.2 (14.1)	48.9 (17.0)	50.3 (13.1)	–3.3 (7.3)	–1.6 (5.7)	–4.1 (7.6)	–2.5 (5.2)	–1.7 (–5.1 to 2.0)	–1.6 (–5.0 to 2.1)
PSFS (0 to 10)	3.3 (1.5)	3.3 (1.5)	3.6 (1.8)	3.4 (1.8)	3.8 (1.7)	3.8 (1.8)	0.3 (1.2)	0.1 (1.2)	0.5 (1.0)	0.5 (1.5)	0.2 (–0.4 to 0.9)	0 (–0.7 to 0.8)
Participation restrictions												
LHS (0 to 100)	79.3 (11.5)	75.9 (10.5)	79.4 (11.6)	77.1 (9.4)	78.0 (10.6)	75.6 (8.5)	0.1 (6.2)	1.1 (9.4)	–1.3 (4.8)	–0.4 (7.9)	–1.0 (–5.4 to 3.4)	–0.9 (–4.5 to 2.6)

Knee ext = knee extensors, Hip Abd = hip abductors, Sh horiz flex = shoulder horizontal flexors, Sh flex = shoulder flexors, CRDQ = Chronic Respiratory Disease Questionnaire, TUG = Timed Up and Go test, GST = Grocery Shelving Test, PSFS = Patient-specific Functional Scale, LHS = London Handicap Scale. Shaded rows are primary outcomes.

Table 4. Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups for all outcomes using a per protocol analysis.

Outcome	Groups						Difference within groups				Difference between groups	
	Week 0		Week 12		Week 24		Week 12 minus Week 0		Week 24 minus Week 0		Week 12 minus Week 0	Week 24 minus Week 0
	Exp n = 15	Con n = 24	Exp n = 15	Con n = 24	Exp n = 14	Con n = 22	Exp	Con	Exp	Con	Exp–Con	Exp–Con
Impairments												
Strength (kg)												
Knee ext	29.1 (12.0)	27.3 (14.1)	38.7 (14.6)	27.8 (13.1)	33.5 (14.5)	27.7 (14.1)	9.6 (6.4)	0.4 (6.7)	4.0 (6.5)	–1.3 (9.5)	9.2 (4.8 to 13.5)	5.2 (–0.7 to 11.2)
Hip abd	27.2 (12.2)	21.4 (12.0)	37.8 (15.7)	25.7 (13.4)	34.5 (14.2)	26.1 (14.3)	10.6 (8.9)	4.3 (6.9)	7.4 (8.2)	3.5 (8.0)	6.3 (1.2 to 11.5)	3.8 (–1.8 to 9.5)
Sh horiz flex	15.5 (10.3)	13.3 (9.3)	19.7 (10.3)	15.2 (7.2)	15.4 (6.6)	14.3 (7.8)	4.2 (3.5)	1.9 (6.1)	–0.6 (7.8)	0.5 (7.5)	2.3 (–1.2 to 5.8)	–1.1 (–6.4 to 4.2)
Sh flex	14.2 (8.7)	12.9 (7.5)	20.8 (13.1)	15.6 (7.0)	17.0 (9.9)	14.1 (7.1)	6.5 (5.9)	2.6 (4.1)	2.3 (5.8)	0.5 (6.1)	3.9 (0.7 to 7.1)	1.8 (–2.4 to 6.0)
CRDQ (1 to 7)												
Dyspnoea	3.2 (0.8)	3.7 (0.9)	4.5 (1.0)	3.7 (1.0)	3.9 (0.8)	4.0 (1.0)	1.3 (1.3)	0 (1.0)	0.7 (1.1)	0.3 (0.9)	1.3 (0.5 to 2.0)	0.4 (–0.4 to 1.0)
Fatigue	3.5 (0.9)	4.0 (1.2)	4.4 (1.0)	3.9 (1.1)	3.9 (1.1)	4.1 (0.9)	0.9 (1.1)	–0.1 (1.1)	0.4 (1.5)	0.1 (1.0)	1.0 (0.3 to 1.8)	0.3 (–0.5 to 1.2)
Emotion	4.6 (0.9)	4.9 (1.1)	5.3 (0.9)	5.0 (0.9)	4.9 (1.0)	5.1 (1.1)	0.7 (0.8)	0.2 (0.8)	0.3 (1.1)	0.4 (0.6)	0.5 (0 to 1.0)	–0.1 (–0.6 to 0.5)
Mastery	4.9 (0.8)	4.9 (1.3)	5.5 (1.0)	5.1 (1.2)	5.0 (1.2)	5.2 (1.0)	0.6 (0.8)	0.2 (0.8)	0 (0.9)	0.3 (1.1)	0.4 (–0.1 to 0.9)	–0.3 (–1.0 to 0.4)
Activity limitations												
6-min Walk Test (m)	392 (129)	338 (87)	406 (129)	348 (98)	413 (127)	358 (91)	14 (22)	10 (50)	10 (28)	12 (40)	4 (–24 to 32)	–1 (–26 to 24)
TUG (s)	9.7 (3.2)	9.7 (1.6)	8.9 (2.4)	9.4 (1.9)	9.2 (2.7)	9.2 (1.8)	–0.8 (1.8)	–0.3 (1.1)	–0.5 (2.0)	–0.5 (1.1)	–0.5 (–1.5 to 0.4)	0 (–1.1 to 1.0)
GST (s)	50.7 (11.2)	53.2 (13.6)	45.8 (9.6)	51.3 (14.5)	44.7 (8.8)	49.6 (13.7)	–4.9 (9.3)	–1.9 (6.0)	–6.0 (9.8)	–3.6 (5.5)	–3.0 (–8.0 to 2.0)	–2.4 (–8.1 to 2.2)
PSFS (0 to 10)	3.3 (0.8)	3.4 (1.5)	4.1 (1.3)	3.5 (1.8)	4.4 (1.2)	4.1 (1.8)	0.8 (1.5)	0.1 (1.2)	1.1 (1.2)	0.7 (1.6)	0.7 (–0.2 to 1.6)	0.4 (–0.8 to 1.2)
Participation restrictions												
LHS (0 to 100)	79.8 (9.8)	75.6 (10.8)	80.7 (9.8)	76.9 (9.7)	78.7 (7.5)	76.0 (8.6)	0.9 (8.2)	1.3 (10)	–0.6 (5.6)	–0.4 (8.7)	–0.4 (–6.6 to 5.8)	–0.2 (–5.5 to 5.2)

Knee extensors = knee extensors, Hip Abd = hip abductors, Sh horiz flex = shoulder horizontal flexors, Sh flex = shoulder flexors, CRDQ = Chronic Respiratory Disease Questionnaire, TUG = Timed Up and Go test, GST = Grocery Shelving Test, PSFS = Patient-specific Functional Scale, LHS = London Handicap Scale. Shaded rows are primary outcomes

The only adverse events were mild muscle soreness in the initial stages of progressive resistance exercise, one episode of acute low back pain, and one mild adductor strain which resolved after a week's rest. There were no reports of aggravation or exacerbation of pre-existing conditions as a result of the exercise program.

Feasibility of intervention

Due to the large number of participants unable to complete the intervention, *post-hoc* per protocol analyses were conducted to examine the efficacy of progressive resistance exercise for those participants who were able to complete the intervention (Exp = 15, Con = 24). Group data for all outcomes are presented in Table 4 according to a per protocol analysis. In terms of the primary outcomes, the experimental group had increased their knee extensor strength by 9.2 kg (95% CI 4.8 to 13.5, $p = < 0.001$), their hip abductor strength by 6.3 kg (95% CI 1.2 to 11.5, $p = 0.03$), and their shoulder flexor strength by 3.9 kg (95% CI 0.7 to 7.1, $p = 0.04$) more than the control group immediately after the intervention at Week 12. This is equivalent to a 20% greater increase in strength than the control group. However, these gains were not maintained at Week 24. No difference was found between the groups for the other primary outcomes of shoulder horizontal flexor strength or walking capacity ($p = 0.17$ and 0.78).

In terms of secondary outcomes, the experimental group had decreased their dyspnoea by 1.3 points (95% CI 0.5 to 2.0, $p = 0.001$) and their fatigue by 1.0 point (95% CI 0.3 to 1.8, $p = 0.02$) more than the control group immediately after the intervention at Week 12. This exceeds the minimum clinically-worthwhile difference of 0.5 units (Jaeschke et al 1989, Lacasse et al 1997). However, these gains were not maintained at 24 weeks ($p = 0.40$ and 0.44).

Discussion

Compared with no intervention, a predominantly home-based progressive resistance exercise program resulted in modest increases in knee extensor strength in people with chronic obstructive pulmonary disease, but no reduction in physical and psychological impairment, activity limitations, or participation restrictions. These findings suggest that progressive resistance exercise is not effective for people with chronic obstructive pulmonary disease, and seemingly contrast with previous investigations (O'Shea et al 2004). However, this trial used an intention-to-treat analysis to examine trial outcomes which may have underestimated effects compared with previous studies.

A number of factors may have influenced the lack of effectiveness of progressive resistance exercise. A relatively low completion rate was seen, and is likely to have influenced outcomes. The ability and willingness of participants to complete exercise is just as important for clinicians to consider as efficacy, but has received little attention in the literature. Health issues were the main reason that participants withdrew or were unable to continue the intervention in this trial. Fluctuating health is a feature of chronic obstructive pulmonary disease and may limit the ability to perform a progressive resistance exercise program consistently or at the required intensity to achieve meaningful changes. Therefore, the implementation of strategies to maximise adherence and the resumption of exercises after periods of illness needs to be considered by clinicians when prescribing progressive resistance exercise in this population.

Particular features of the program may also have limited overall effectiveness. The current program was largely home-based, whereas most previous investigations have been conducted in closely-supervised centre-based settings (O'Shea et al 2004). The only other home-based progressive resistance exercise program tested also demonstrated no difference in outcomes compared with no intervention (O'Hara et al 1984). Similarly, home-based progressive resistance exercise programs for healthy older adults have generally reported smaller effects than centre-based programs (Dodd et al 2003), which may be a consequence of less supervision and lower exercise intensities (Dodd et al 2003). Logbook recordings in the current trial provided evidence of suitable exercise intensities and progression; therefore, minimal supervision in combination with fluctuating health may have influenced participant completion rate. Greater supervision in the early stages of progressive resistance exercise or after periods of ill-health may be imperative so that participants gain confidence and maintain exercises over a long period.

Whilst the overall effectiveness of the program was shown to be limited, *post hoc* per protocol analysis suggested that progressive resistance exercise was effective in increasing muscle strength if participants undertook the whole program. The use of elasticised resistance bands led to increases in strength of 27–46% which is similar to increases previously reported using other forms of equipment in people with chronic obstructive pulmonary disease (weighted mean differences 23–36%, O'Shea et al 2004), and healthy older adults (weighted mean differences 27–43%, Dodd et al 2003). The program also led to reduced dyspnoea and fatigue, two of the most commonly-reported symptoms limiting activity for people with chronic obstructive pulmonary disease (Killian et al 1992). However, reductions in these impairments did not lead to improvements in activity or participation.

The initial degree of activity limitation may affect the degree of change possible after progressive resistance exercise (Chandler et al 1998, Dodd et al 2003); therefore, where no activity limitation exists for a task prior to progressive resistance exercise, increases in strength may not result in improvements in task performance (Chandler et al 1998). Additionally, interventions aimed at reducing impairments (such as progressive resistance exercise) that are delivered short-term, may have limited value in reducing activity limitations and participation restrictions (Harwood and Ebrahim 1995). Moreover, due to the broad and varied nature of activity and participation between individuals, finding suitable measures to detect changes in activity and participation may also be challenging (O'Shea et al 2007c).

Twelve weeks after cessation of the intervention, no differences were found between participants in the experimental versus the control group. Even those participants completing the full exercise program demonstrated dissipation of gains made in increasing muscle strength and decreasing dyspnoea and fatigue. These findings are consistent with an investigation examining long-term outcomes of progressive resistance exercise in people with chronic obstructive pulmonary disease (Ortega et al 2002), and general investigations of detraining (Mujika and Padilla 2001), suggesting that ongoing exercise performance is required to maintain gains. Therefore, future research in this population should explore the optimal doses of progressive resistance exercise for maintenance.

A key factor in the success of maintenance progressive resistance exercise programs is likely to be long-term adherence to exercise. Marked reductions in adherence have been reported in the general population within six-months of commencing an exercise program (Dishman 1982), and adherence may be further reduced when chronic health conditions are present (Sabate 2003). Reduced long-term adherence to exercise after pulmonary rehabilitation has been demonstrated in people with chronic obstructive pulmonary disease despite ongoing supervision and support (Brooks et al 2002). Strategies, such as education, contracts, logbooks, and ongoing supervision or review, have been suggested to maximise adherence to interventions aimed at improving health (Ferri et al 1998, O'Shea et al 2007a). However, greater understanding of the factors influencing long-term adherence to exercise by people with chronic obstructive pulmonary disease is required in order to develop effective strategies to maximise long-term outcomes.

This study represents one of the first attempts to examine the effects of progressive resistance exercise on activity and participation in people with chronic obstructive pulmonary disease. The exercise program was clinically feasible, requiring minimal supervision and simple and inexpensive equipment. The trial investigated a heterogeneous sample reflecting the diversity of people with chronic obstructive pulmonary disease referred to pulmonary rehabilitation. This trial is also the only investigation of progressive resistance exercise in this population to examine effectiveness using intention-to-treat analysis. A limitation of the trial was the number of participants unable to complete the intervention and/or lost to follow up, which may have increased the likelihood of Type II statistical error for some outcomes. However, participant withdrawal is the real challenge that clinicians face in prescribing exercise in this population.

In conclusion, a 12-week, predominantly home-based, progressive resistance exercise program led to modest, short-term improvements in knee extensor strength in people with chronic obstructive pulmonary disease, but this did not carry over to improvements in activity and participation. This minimally-supervised progressive resistance exercise program was shown to be relatively safe for people with chronic obstructive pulmonary disease, with only two minor musculoskeletal adverse events reported. However, many participants were unable to complete the full program, highlighting the need for greater understanding of factors that can influence adherence to exercise in this population. Future research should determine optimal prescription of exercise for long-term programs.

eAddendum: Table 3 at www.physiotherapy.asn.au

Acknowledgement: Equipment grant: Theraband® Academy, Hygenic Corporation, USA.

Correspondence: Dr Simone O'Shea, Wodonga Regional Health Service, PO Box 156, Wodonga VIC 3689, Australia. Email: simoshe@optusnet.com.au

References

Altman DG, Bland JM (1999) Statistics notes: how to randomise. *BMJ* 319: 703–704.

ATS (1995) Standardization of spirometry: 1994 update. *American Journal of Respiratory and Critical Care Medicine* 152: 1107–1136.

ATS, ERS (1999) Skeletal muscle dysfunction in chronic obstructive pulmonary disease: a joint statement of the American Thoracic Society and European Respiratory Society. *American Journal of Respiratory and Critical Care Medicine* 159: S1–40.

ATS, ERS (2006) American Thoracic Society/European Respiratory Society Statement on Pulmonary Rehabilitation. *American Journal of Respiratory and Critical Care Medicine* 173: 1390–1413.

Borg GAV (1982) Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise* 14: 377–381.

Brooks D, Krip B, Mangovski-Alzamora S, Goldstein RS (2002) The effect of postrehabilitation programmes among individuals with chronic obstructive pulmonary disease. *European Respiratory Journal* 20: 20–29.

Butland RJA, Pang J, Gross ER, Woodcock AA, Geddes DM (1982) Two, six and 12 minute walking tests in respiratory disease. *BMJ* 284: 1607–1608.

Chandler JM, Duncan PW, Kochersberger G, Studenski S (1998) Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders? *Archives of Physical Medicine and Rehabilitation* 79: 24–30.

Crapo RO, Enright PL, Zeballos RJ (2002) ATS Statement: Guidelines for the six-minute walk test. *American Journal of Respiratory and Critical Care Medicine* 166: 111–117.

Dishman RK (1982) Compliance/adherence in health related exercise. *Health Psychology* 1: 237–267.

Dodd K, Taylor N, Bradley S (2003) Strength training for older people. In Schoo A, Morris M (Eds): Promoting physical activity and exercise in older people. Oxford: Butterworth Heinemann.

Ferri M, Brooks D, Goldstein RS (1998) Compliance with treatment – an ongoing concern. *Physiotherapy Canada* 50: 286–290.

Guyatt GH, Berman LB, Townsend M, Pugsley SO, Chambers LW (1987) A measure of quality of life for clinical trials in chronic lung disease. *Thorax* 42: 773–778.

Harwood RH, Ebrahim S (1995) Manual of the London Handicap Scale. Nottingham: Department of Health Care of the Elderly, University of Nottingham.

Hill C, Denehy L, Nosworthy J, McDonald C (2001) Development of an outcome measure for upper limb function in patients with chronic obstructive pulmonary disease. *Australian Journal of Physiotherapy* 47: 278.

Hollis S, Campbell F (1999) What is meant by intention to treat analysis? Survey of published randomised controlled trials. *BMJ* 319: 670–674.

Jaeschke R, Singer J, Guyatt GH (1989) Measurement of health status: ascertaining the minimal clinically important difference. *Controlled Clinical Trials* 10: 407–415.

Killian KJ, LeBlanc P, Martin DH, Summers E, Jones NL, Campbell EJ (1992) Exercise capacity and ventilatory, circulatory and symptom limitation in patients with chronic airflow obstruction. *American Review Respiratory Disease* 146: 935–940.

Kraemer WJ, Adams K, Cafarelli E, Dudley GA, Dooley C, Feigenbaum MS, Fleck SJ, Franklin B, Fry AC, Hoffman JR, Stone MH, Ratamess NA, Triplett-McBride T (2002) American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise* 34: 364–380.

Lacasse Y, Wong E, Guyatt GH (1997) A systematic overview of the measurement properties of the chronic respiratory questionnaire. *Canadian Respiratory Journal* 4: 131–139.

McKenzie DK, Frith PA, Burdon JGW, Town GI (2003) The COPDX Plan: Australian and New Zealand guidelines for the management of chronic obstructive pulmonary disease 2003. *Medical Journal of Australia* 178: S3–39.

Mujika I, Padilla S (2001) Muscular characteristics of detraining

in humans. *Medicine and Science in Sports and Exercise* 33: 1297–1303.

O'Hara W, Lasachuk K, Matheson P, Renahan M, Schlotter D, Lilker E (1984) Weight training and backpacking in chronic obstructive pulmonary disease. *Respiratory Care* 29: 1202–1210.

Ortega F, Toral J, Cejudo P, Villagomez R, Sanchez H, Castillo J, Montemayor T (2002) Comparison of effects of strength and endurance training in patients with chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine* 166: 669–674.

O'Shea SD, Taylor NF, Paratz J (2004) Peripheral muscle strength training in chronic obstructive pulmonary disease: a systematic review. *Chest* 126: 903–914.

O'Shea SD, Taylor NF, Paratz JD (2005) Measuring activity limitations and participation restrictions for people with COPD. *International Journal of Therapy and Rehabilitation* 12: 264–268.

O'Shea SD, Taylor NF, Paratz JD (2007a) …But watch out for the weather: factors affecting adherence to progressive resistance exercise for persons with COPD. *Journal of Cardiopulmonary Rehabilitation and Prevention* 27: 166–174.

O'Shea SD, Taylor NF, Paratz JD (2007b) Measuring muscle strength for people with chronic obstructive pulmonary disease: Retest reliability of hand-held dynamometry. *Archives of Physical Medicine and Rehabilitation* 88: 32–36.

O'Shea SD, Taylor NF, Paratz JD (2007c) Qualitative outcomes of progressive resistance exercise for people with COPD. *Chronic Respiratory Disease* 4: 135–142.

Podsiadlo D, Richardson S (1991) The timed 'up & go' test: A test of basic functional mobility for frail elderly persons. *Journal American Geriatric Society* 39: 142–148.

Ries AL, Bauldoff GS, Carlin BW, Casaburi R, Emery CF, Mahler DA, Make B, Rochester CL, ZuWallack RL, Herrerias C (2007) Pulmonary Rehabilitation: Joint ACCP/AACVPR Evidence-based Clinical Practice Guidelines. *Chest* 131: S4–42.

Sabate E. (2003). Adherence to long-term therapies: Evidence for action. Geneva: World Health Organization. Accessed 15 January 2006 from www.who.int/chp/knowledge/publications/adherence_introduction.pdf

Sciurba F, Criner GJ, Lee SM, Mohsenifar Z, Shade D, Slivka W, Wise RA (2003) Six-minute walk distance in chronic obstructive pulmonary disease: reproducibility and effect of walking course layout and length. *American Journal of Respiratory and Critical Care Medicine* 167: 1522–1527.

Stratford P, Gill C, Westaway M, Binkley J (1995) Assessing disability and change of individual patients: a report of a patient specific measure. *Physiotherapy Canada* 47: 258–263.

Troosters T, Casaburi R, Gosselink R, Decramer M (2005) Pulmonary rehabilitation in chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine* 172: 19–38.

Troosters T, Gosselink R, Decramer M (2000) Short- and long-term effects of outpatient rehabilitation in patients with chronic obstructive pulmonary disease: a randomized trial. *American Journal of Medicine* 109: 207–212.

WHO (2002) International Classification of Functioning, Disability and Health. World Health Organization. www.who.int/classifications/icf/site/icftemplate.cfm [Accessed 24 April 2003].

Wise RA, Brown CD (2004) Minimal clinically important differences in the six-minute walk test and the incremental shuttle walk test. *COPD: Journal of Chronic Obstructive Pulmonary Disease* 2: 125–129.