

Effects of a Pulmonary Rehabilitation Programme on Physiologic and Psychosocial Outcomes in Patients with Chronic Respiratory Disorders

K C Ong,*^{FAMS, MBBS, MRCP (UK)}, W P Wong,**^{BPT (Hons)}, A R Jailani,**^{B AppSc (PT)}, S Sew,**^{BPT},
Y Y Ong,***^{FAMS, M Med (Int Med), FRACP}

Abstract

Introduction: The purpose of this prospective study is to determine the effects of a pulmonary rehabilitation programme (PRP) conducted at our centre for patients with chronic lung disease. **Materials and Methods:** Thirty-four patients (27 men and 7 women, mean age 67.6 years) with predominantly moderate-to-severe chronic obstructive pulmonary disease (31 patients), bronchiectasis (2 patients) and interstitial lung disease (1 patient) completed a 6-week outpatient PRP that included education, physical and respiratory care instruction and supervised exercise training. Outcome assessment was performed at baseline, on completion of PRP and 3 months after PRP. Physiologic measures included pulmonary function, incremental exercise and 6-minute walk tests (6MWTs). Disease-specific quality of life was assessed using the Chronic Respiratory Disease Questionnaire (CRDQ). **Results:** There was no significant change in resting spirometry or lung volumes after PRP. Maximal oxygen uptake and work-rate improved significantly after PRP by $132.4 \text{ mL kg}^{-1} \text{ min}^{-1}$ and 10.7 W , respectively. 6MWT distance improved significantly by a mean of 67.3 m ($P < 0.0001$). Maximum Borg dyspnoea scores decreased significantly by 1.2 ± 0.5 ($P < 0.038$). All domains of the CRDQ completed by a sub-group of patients improved significantly and the total scores increased by a mean of 21.7 points at the end of the PRP. The improvements gained in maximal exercise capacity immediately following PRP were maintained in 17 patients who returned for repeat assessment 3 months after PRP. **Conclusion:** Patients who completed a comprehensive PRP at our centre showed significant increase in functional capacity, reduction of exertional dyspnoea and improvement in health status.

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Key words: Chronic Obstructive Pulmonary Disease, Disability, Exercise capacity, Exercise training, Functional status

Introduction

Pulmonary rehabilitation is a multi-disciplinary programme of care for patients with chronic respiratory impairment that is individually designed to optimise physical and social performance and autonomy.¹ In recent years, the efficacy and scientific foundation of pulmonary rehabilitation have been firmly established.² The belief that there is little hope for improvement in patients with advanced chronic respiratory disease has been refuted, and pulmonary rehabilitation is no longer viewed as a last-ditch attempt to improve the condition of patients with severe respiratory impairment. Strategies employed by pulmonary rehabilitation programmes are now an integral part of the clinical management of patients with chronic respiratory disease who remain symptomatic or continue to have decreased function despite standard medical management.

Although the benefits of pulmonary rehabilitation are

widely accepted, there is great variation in clinical outcomes of patients reported by different centres around the world.³ Undoubtedly, many factors such as the components, duration and site of a programme, patient selection criteria, and assessment of outcomes can influence results. In addition, most previous studies on pulmonary rehabilitation have been conducted on patients from western populations. As the health beliefs and value on functional independence and exercise habits of these patients may be different from those of Asian origins,⁴ evaluation of the overall effectiveness of a pulmonary rehabilitation programme (PRP) conducted locally is necessary.

The aim of this prospective study was to evaluate the effects of a PRP conducted at our centre on the physiologic and psychosocial outcomes of a series of patients with chronic respiratory disorders.

* Consultant

Department of Respiratory Medicine, Tan Tock Seng Hospital

*** Senior Consultant

Department of Respiratory and Critical Care Medicine, Singapore General Hospital

** Physiotherapist

Physiotherapy Department, Singapore General Hospital

Address for Reprints: Dr Ong Kian Chung, Department of Respiratory Medicine, Tan Tock Seng Hospital, 11 Jalan Tan Tock Seng, Singapore 308433.

Patients and Methods

Patients

From July 1998 till March 2000, 51 patients with chronic pulmonary disorders were enrolled in the Singapore General Hospital Pulmonary Rehabilitation Programme. Eligibility criteria were as follows:

1. Clinical diagnosis of chronic obstructive or restrictive pulmonary disease that was confirmed by history, physical examination, pulmonary function tests and chest roentgenograms. Among patients with chronic obstructive pulmonary disease (COPD), diagnoses of emphysema, chronic bronchitis or asthmatic bronchitis (cases of bronchial asthma with persistent cough, sputum production and dyspnoea resulting from chronic exposure to cigarette smoke) were accepted whereas patients with primarily acute, reversible airway disease (asthma) and no chronic airflow obstruction were excluded.
2. Presence of dyspnoea on exertion that interfered with activities of daily living
3. Stable condition while the patient was receiving treatment and under the care of a respiratory physician. Patients presenting for evaluation who were not under specialist care were referred for appropriate evaluation and treatment before they enrolled in the PRP.
4. Ability to ambulate with minimal assistance.
5. Absence of contraindications to exercise testing or prescription.
6. Non-smoking status for at least 3 months.

Pulmonary Rehabilitation Programme

The comprehensive PRP consisted of 18 2-hour sessions over 6 weeks in an outpatient (hospital-based) setting. The PRP included 3 main components:

1. Education. Pulmonary rehabilitation staff taught groups of 3 to 6 patients in informal, group-discussion sessions. Topics included anatomy and physiology of the lung, pathophysiology of lung disease, medications, nutrition, oxygen therapy, stress management, energy-saving techniques, self-care tips and breathing techniques. Patients who were underweight (body mass index <18 kg/m²) or overweight (body mass index >27 kg/m²) were referred for dietary advice and intervention by a dietician.
2. Physical and respiratory care instruction. Patients received individual instruction in respiratory care and chest physiotherapy techniques such as postural drainage, pursed lip and diaphragmatic breathing, flexibility exercises, oxygen therapy and proper use of respiratory therapy equipment.
3. Supervised exercise training. After baseline incremental cardiopulmonary exercise testing (CPET), each patient

received an individualised exercise prescription with the target level of exercise training intensity determined by the results of the baseline CPET. For patients in whom the anaerobic threshold could be determined non-invasively during CPET, exercise training was conducted at a minimum workload that can achieve anaerobic metabolism. All other patients trained at a target exercise intensity of 80% of the peak work-rate as determined during baseline CPET. Heart rate, dyspnoea ratings (using the modified Borg dyspnoea scale) or absolute power output were used as targets to guide the intensity of exercise during training sessions. The primary exercise-training modalities were walking and cycling. Training emphasised steady-state lower limb aerobic exercises consisting of continuous walking or cycling at the targeted work-rate for a minimum of 20 to 30 minutes. For patients who cannot tolerate training at this intensity, interval training, consisting of 2 to 3 minutes of high-intensity (60% to 80% maximal work-rate) training alternating with equal periods of rest, was conducted. Patients with severe hypoxaemia (PaO₂ <55 mmHg at rest) and those with significant oxygen desaturation during initial CPET were trained using supplemental oxygen. Patients were also trained in upper-extremity exercise using an isokinetic upper-body ergometer or weight lifting. Flexibility and stretching exercises (warm-up and cool-down) were taught and performed during each exercise training session. Written exercise prescriptions were provided for patients when they had completed the rehabilitation programme and maintenance exercises were encouraged.

Assessment

Patients had physiologic and psychosocial function evaluated before the PRP (baseline), immediately after the programme ended (6 weeks) and 3 months after the PRP (4.5 months). Physiologic measures included tests of pulmonary function, maximal exercise tolerance, endurance exercise, and rest and exercise gas exchange. Pulmonary function tests included spirometric measurements of vital capacity and expiratory flow rates, lung volumes by body plethysmography, maximal inspiratory pressure (at residual volume) and expiratory pressure (at total lung capacity) to assess respiratory muscle strength, and maximal voluntary ventilation (MVV). Maximum exercise tolerance was measured with incremental, symptom-limited CPET performed using an electro-magnetically braked cycle ergometer (JAEGER® ER 900; ERICH JAEGER GmbH, Germany) after informed consent was obtained on all patients prior to exercise testing. CPET was performed under the supervision of a physician with defined criteria for stopping, such as serious cardiac arrhythmias,

hypotension and electrocardiographic changes and severe oxygen desaturation. An incremental exercise protocol was used in which the work rate was increased by 5 W per minute after an initial 3 minutes of unloaded pedalling. Standard 12-lead electrocardiograms were obtained at rest, every 3 minutes during exercise and for 5 minutes into the recovery phase while blood pressures were measured using a standard cuff sphygmomanometer at similar intervals. Measurements of mixed expired oxygen, mixed expired carbon dioxide and expired volume were determined at rest and every 10 seconds throughout exercise using a metabolic cart (JAEGER® Oxycon Alpha; ERICH JAEGER GmbH, Germany). Oxygen saturation (SaO₂) via pulse oximetry and heart rate by electrocardiography were recorded continuously throughout exercise and during recovery. At the end of exercise, the reason/s for termination and perceived breathlessness were rated using the modified Borg scale, a 0 to 10 category ratio scale of perceived exertion.⁵ Exercise endurance was measured on a separate day. This test was done at a work level based on 80% of the initial maximal exercise tolerance. Patients were instructed to cycle on an ergometer for as long as possible and the total exercise time at the target levels was recorded (maximum, 30 minutes). The 6-minute walk test (6MWT) was also used to assess the patient's functional capacity. The patients were instructed to walk as fast as possible along a 20 m hallway for 6 minutes. Standardised instructions explaining the purpose of the test, symptoms that might arise and reasons to terminate the test were given. Two tests were conducted on the same day separated by about 10 minutes of rest as we found that patients generally recovered from the first test in that time period. Repetition of the tests was to minimise learning effects that may confound the measurements.⁶ No encouragement was given to the patient during the 6MWT as this had been found to confound pre- and post-intervention findings.⁷ Heart rate, blood pressure, SaO₂ and modified Borg dyspnoea rating were monitored before, at the end of, and 5 minutes after the 6MWT.

Disease-specific quality of life was assessed via the Chronic Respiratory Disease Questionnaire (CRDQ) devised by Guyatt et al.⁸ The CRDQ consists of 19 questions mostly requiring responses based on a 7-point Likert scale. The questions determine the effects and impact of the chronic respiratory condition on several psychosocial dimensions, viz. dyspnoea, fatigue, emotional function and perceived mastery or control of the condition. The questionnaire has been shown to be reliable, valid and responsive to change in the English language.⁸ The CRDQ is interviewer-administered, takes about 20 to 30 minutes to complete and has a standardised interviewer script for administering the test. The interviewers also went through a self-study package provided by the original authors.⁸

Statistical Analysis

Pre- and post-PRP maximum oxygen uptake (VO₂max), maximum work rate (WRmax), exercise endurance, exertional dyspnoea score and maximum heart rate during CPET, as well as 6MWT distance were compared using paired *t* tests for significant differences at *P* < 0.05. The 95% confidence interval (CI) was also estimated for the differences. CRDQ scores were compared using Wilcoxon sign rank test. Furthermore, repeated-measure analysis of variance of the VO₂max at 3 months was used to determine if there were significant differences, and post-hoc Duncan's multiple range test was used to determine whether the improvement was maintained or further improvement was obtained.

Results

Of the 51 patients who joined the PRP, 34 of them managed to complete the programme. The characteristics of these 34 patients are shown in Table I. The reasons for attrition from the programme included lack of transportation or family support in 9 patients, disinterest in exercise training in 4 patients, the development of other medical illnesses that rendered 3 patients unsuitable for exercise training, and death unrelated to the PRP in 1 patient. Comparing patients who completed PRP with those who did not, there was no significant difference in age (*P* = 0.071), gender (*P* = 0.84), body weight (*P* = 0.074), FEV₁ (*P* = 0.815), baseline VO₂max (*P* = 0.366), or baseline WRmax (*P* = 0.426) between the 2 groups. Medications that the 31 patients with COPD were receiving at enrolment

TABLE I: CHARACTERISTICS OF PATIENTS WHO COMPLETED THE PRP*

Characteristic	n = 34
Sex (Male/Female)	27/7
Age (y)	67.6 ± 1.9
Ethnicity	
Chinese	27
Malay	4
Indian	1
Others	2
Diagnosis	
Mild COPD (FEV ₁ ≥70% predicted)	1
Moderate COPD (FEV ₁ 50% to 69% predicted)	9
Severe COPD (FEV ₁ <50% predicted)	21
Bronchiectasis	2
Interstitial lung disease	1
Smoking history (pack-years)	43.6 ± 6.4
Body mass index (kg/m ²)	21.2 ± .6

COPD: chronic obstructive pulmonary disease;

PRP: Pulmonary Rehabilitation Programme

* Continuous variables are expressed as mean ± standard deviation; severity of COPD is classified according to the European Respiratory Society guidelines.²¹

included inhaled beta agonists and anti-cholinergic agents and methylxanthines. Twenty-five of these 31 patients (80.6%) were on inhaled steroids and none of them were on oral steroids. No changes were made to the medical treatment in these 31 patients during the 6-week rehabilitation period. Four of the 34 patients (11.8%) who completed PRP were on long-term oxygen therapy.

Seven patients were prescribed exercise training intensities based on their anaerobic threshold achieved during baseline CPET. These patients had no problems training at such workloads. Of the remaining 27 patients who were prescribed training intensity at 80% of their maximal work rates, 5 could not tolerate and they were consequently started on interval training. Four of these 5 patients had required supplemental oxygen therapy during exercise.

Table II shows the physiological parameters of the patients at baseline and the differences at the end of PRP. Among the resting ventilatory measurements, forced expiratory volume in one second (FEV₁), the ratio of FEV₁ to forced vital capacity (FEV₁/FVC), lung volumes and MVV did not change significantly after PRP. Minute ventilation at peak exercise (V_Emax) improved significantly

following PRP, as did maximal inspiratory pressure (MIP) which showed a small but significant increase. Both VO₂max and WRmax improved significantly after PRP by 132.4 mL kg⁻¹ min⁻¹ and 10.7 W, respectively. While maximal heart rate did not increase significantly, exertional dyspnoea (maximal Borg rating) decreased significantly by 1.2 ± .5 [95% CI 1.0, 2.3] (*P* < 0.038) despite patients generally exercising at higher maximal work-loads during incremental CPET after PRP. 6MWT distance improved significantly by a mean of 67.3 m (*P* < 0.0001). Exercise endurance at a constant work-rate (CWR) of 80% initial WRmax was measured for 23 patients who agreed to come on a separate day for exercise testing. The duration of exercise at CWR in these patients increased significantly from 10.1 ± 2.8 minutes before PRP to 20.3 ± 3.0 minutes at the end of PRP (*P* < 0.0001).

CRDQ scores were obtained from 20 of the 34 patients who understood English and had adequate comprehension of the questionnaire. All domains of the CRDQ improved significantly and the total scores increased by over 20 points at the end of the PRP (Table III).

Seventeen patients returned for follow-up assessment 3 months after PRP. Of the other 17 patients, 6 were awaiting

TABLE II: BASELINE PHYSIOLOGIC VALUES AND CHANGES ON COMPLETION OF PRP*

Variable	Baseline	Post-PRP	Difference	[95% CI]	<i>P</i> value
FEV ₁ (L)	0.87 ± 0.3	0.87 ± 0.3	0.0 ± 0.18	[-6.2, 6.9]	0.913
FEV ₁ /FVC (%)	49.8 ± 17.0	46.3 ± 16.5	-3.5 ± 3.2	[-6.2, 1.0]	0.498
MVV (L)	28.4 ± 2.0	30.9 ± 2.2	2.4 ± 1.2	[0.4, 4.9]	0.053
TLC (L)	5.5 ± 0.2	7.1 ± 1.5	1.6 ± 1.5	[-1.7, 5.2]	0.296
RV/TLC (%)	67.9 ± 2.8	66.9 ± 2.6	-1.0 ± 3.6	[-6.3, 8.3]	0.780
V _E max (L min ⁻¹)	32.2 ± 1.5	37.2 ± 1.5	5.0 ± 1.2	[2.9, 8.1]	<0.0001
MIP (cm H ₂ O)	31.6 ± 3.1	36.7 ± 3.1	4.1 ± 2.0	[1.0, 8.2]	0.023
MEP (cm H ₂ O)	64.3 ± 5.1	72.4 ± 5.1	8.2 ± 5.1	[-2.0, 18.4]	0.120
VO ₂ max (mL kg ⁻¹ min ⁻¹)	791.8 ± 31.2	924.2 ± 34.8	132.4 ± 29.4	[72.1, 192.7]	<0.0001
WRmax (W)	29.0 ± 3.3	40.0 ± 3.0	10.7 ± 2.4	[6.0, 15.4]	<0.0001
HRmax (min ⁻¹)	125.2 ± 3.7	127.9 ± 3.1	2.7 ± 3.2	[-3.4, 8.8]	0.379
Maximum Borg rating	5.8 ± 0.5	4.7 ± 0.6	-1.2 ± 0.5	[-2.3, -0.1]	0.038
6MWT (m)	275.6 ± 15.0	342.9 ± 13.1	67.3 ± 8.5	[50.1, 84.5]	<0.0001

* Values are expressed as mean ± standard deviation

6MWT: 6-minute walk test; FEV₁: forced expiratory volume in one second; FVC: forced vital capacity; HRmax: heart rate at maximal exercise; MEP: maximal expiratory pressure; MIP: maximal inspiratory pressure; MVV: maximal voluntary ventilation; PRP: Pulmonary Rehabilitation Programme; RV: residual volume; TLC: total lung capacity; V_Emax: minute ventilation at maximal exercise; VO₂max: maximum oxygen uptake; WRmax: maximum work rate

TABLE III: BASELINE CRDQ SCORES AND CHANGES ON COMPLETION OF PRP IN 20 PATIENTS*

Variable	Baseline	Post-PRP	Difference	Z-value	<i>P</i> value
Dyspnoea	18.9 ± 1.4	24.9 ± 1.1	6.0 ± 1.3	-3.423	0.01
Emotional function	35.3 ± 2.0	40.3 ± 1.2	5.0 ± 1.3	-3.063	0.002
Fatigue	15.5 ± 0.9	21.1 ± 0.8	5.6 ± 1.0	-3.730	<0.0001
Mastery	19.4 ± 1.9	23.0 ± 0.8	3.6 ± 1.1	-3.083	0.002
Total scores	89.1 ± 4.5	109.1 ± 3.2	20.1 ± 4.1	-3.725	<0.0001

* Values are expressed as mean ± standard deviation

TABLE IV: COMPARISON OF VALUES AT BASELINE, IMMEDIATE POST-PRP AND 3-MONTH POST-PRP IN 17 PATIENTS*

Variable	Pre-PRP	Immediate Post-PRP	3 months after PRP	P value
FEV ₁ predicted (%)	0.89 ± 0.31	0.92 ± 0.32	0.86 ± 0.32	0.967
FEV ₁ /FVC predicted (%)	49.5 ± 16.3	45.6 ± 13.8	45.2 ± 18.3	0.419
MVV (L)	26.9 ± 2.4	29.7 ± 2.3	28.9 ± 2.1	0.683
TLC (L)	5.6 ± 0.3	8.3 ± 2.6	5.6 ± 0.3	0.300
RV/TLC (%)	63.4 ± 2.3	68.9 ± 4.3	65.1 ± 1.9	0.824
V _E max (L min ⁻¹)	30.1 ± 1.9	36.5 ± 2.0	38.2 ± 2.1	0.022
MIP (cmH ₂ O)	27.5 ± 4.1	31.6 ± 3.1	30.6 ± 3.1	0.491
MEP (cmH ₂ O)	63.2 ± 8.2	70.4 ± 7.1	60.2 ± 5.1	0.340
VO ₂ max (mL kg ⁻¹ min ⁻¹)	748.8 ± 44.7	910.5 ± 51.4	937.4 ± 52.4	0.005
WRmax (W)	27.3 ± 3.8	40.9 ± 3.5	40.3 ± 3.6	0.010
HRmax (min ⁻¹)	118.6 ± 4.8	125.1 ± 4.1	123.1 ± 4.5	0.780
Maximum Borg rating	6.3 ± 0.8	5.1 ± 0.8	5.1 ± 0.8	0.267

* Values are expressed as mean ± standard deviation

6MWT: 6-minute walk test; FEV₁: forced expiratory volume in one second; FVC: forced vital capacity; HRmax: heart rate at maximal exercise; MEP: maximal expiratory pressure; MIP: maximal inspiratory pressure; MVV: maximal voluntary ventilation; PRP: Pulmonary Rehabilitation Programme; RV: residual volume; TLC: total lung capacity; V_Emax: minute ventilation at maximal exercise; VO₂max: maximum oxygen uptake; WRmax: maximum work rate

assessment while the rest had defaulted follow-up assessment at 3 months. The results of the 17 patients who returned for follow-up assessment 3 months after PRP are shown in Table IV. The improvements gained in VO₂max, WRmax and V_Emax immediately following PRP were maintained 3 months after PRP. Post-hoc Duncan's multiple range tests demonstrated significant differences in these 3 variables between pre-PRP and post-PRP, as well as between pre-PRP and 3 months after PRP, but not between post-PRP and 3 months after PRP.

Discussion

The present study has shown that pulmonary rehabilitation can reduce dyspnoea and improve functional ability and quality of life in patients with chronic respiratory disease without significantly altering ventilatory defects measured at rest. Simple physiologic parameters of pulmonary function such as forced expiratory volume have traditionally been used to define the severity of disease processes involving the lung. Recently, however, there has been increasing recognition that these basic indices do not adequately characterise the degree of functional impairment that the disease process imposes on the individual.⁹ Furthermore, the change in such simple parameters may not adequately characterise the response to a therapeutic intervention such as pulmonary rehabilitation. Ultimately, it is the integrated influence of multiple factors e.g. pulmonary mechanics, pulmonary circulation, cardiac, peripheral muscle and psychosocial factors that determine an individual patient's functional level. Unfortunately, measures that objectively assess functional outcome in patients with chronic respiratory ailments "are in short supply".¹⁰ Two general categories of testing which may serve this integrative role include subjective symptom and

quality of life questionnaires and various types of exercise testing. Both these categories of tests were used in the present study and our results compare favourably with those of previous studies. In a meta-analysis of respiratory rehabilitation in COPD patients,³ the overall treatment effect on 2 important features of health-related quality of life, dyspnoea and mastery were 1.0 (95% CI 0.6-1.5) and 0.8 (0.5-1.2) respectively and the minimal clinically important difference was determined to be 0.5. The overall effect was 55.7 m (27.8-92.8) for 6MWT and 8.3 W (2.8-16.5) for maximum exercise capacity (incremental CPET) in the meta-analysis.³ The improvement in quality of life assessment and the increase in functional exercise capacity of our patients exceeded these values after PRP. The improvement in 6-minute walking distance in the present study also exceeded the minimal difference estimated to be clinically significant as determined by 2 previous studies of 30 m and 54 m.^{11,12} In the present study, a marked improvement in exercise endurance at submaximal workload was observed in a sub-group of patients and the effect would have been greater had a maximum time limit of 30 minutes not been imposed on performance of the test after PRP. Compared to submaximal exercise testing, the increment in peak VO₂ and work-rate was more modest and this is comparable to the observation of other studies on pulmonary rehabilitation in general.^{1,13} Nonetheless, submaximal exercise tests, such as constant workload endurance testing, have been considered by some investigators to be a more meaningful measure in patients with chronic respiratory disorders than maximal test performance, as the functional capacities required for activities of daily living are generally at submaximal levels.

It is noteworthy that the proportion of patients who did

not complete the PRP in this study is rather high (33.3%). This may be related to the fact that our patients are generally more incapacitated at baseline compared with those of previous studies. For instance, in a large randomised clinical trial¹⁴ conducted previously, the mean baseline VO_2max and exercise endurance was 1240 mL/min and 12.4 minutes, respectively. In another controlled study,¹⁵ the baseline 6MWT distance was 366 m. Furthermore, the majority of patients who did not complete PRP had cited the lack of transportation or caregiver support as the commonest reasons cited for inability to attend rehabilitation sessions. Therefore, the most likely reason for the high dropout rate in these patients is severe disability at baseline coupled with inadequate provision for outpatient rehabilitation. Perhaps an initial period of in-patient pulmonary rehabilitation followed by a PRP on an outpatient basis for more disabled patients can improve the completion rate of the programme.¹³ Currently, referral for pulmonary rehabilitation is too often reserved for those with far-advanced lung disease.¹ Although these patients can still benefit considerably from pulmonary rehabilitation, referral at an earlier stage would allow for earlier preventive strategies, greater latitude in the exercise prescription and, perhaps, better long-term adherence with maintenance exercise. No tests or questionnaire can identify the appropriate stage for referral. As a rule, it is preferable to choose patients with moderate to moderately severe disease for whom the prevention of disabling effects of end-stage respiratory failure is desired.

Of the various components of a PRP, exercise training is the only one demonstrated in controlled clinical trials to enhance exercise endurance, dyspnoea and quality of life.¹ Typically, a patient's level of exertional dyspnoea is markedly reduced after exercise training. Previously, the benefits gained after pulmonary rehabilitation were thought to be purely psychological i.e. patients have become "desensitised" to their symptoms with frequent episodes of breathlessness brought on during exercise training and the benefits are reflected in improved outcomes as these measures are all motivation-dependent. On the contrary, evidence suggestive of a physiological training response in COPD patients undergoing exercise training now exists. Firstly, reductions in lactic acidosis and minute ventilation at identical workloads can be observed after a period of exercise training and there is good correlation between the decrease in lactic acidosis and the reduction in minute ventilation.¹⁶ Secondly, there is evidence of muscle adaptation to endurance training in patients with COPD.¹⁷ Muscle biopsies of trained patients but not those of control subjects manifested significant increases in oxidative enzymes.

Not only is there controversy regarding the mechanism/s

of improvement with exercise training, the optimal exercise prescription guidelines for exercise training in patients with respiratory impairment also cannot be defined with certainty at this time. Until recently, the prevailing thought has been that patients with advanced lung disease have a ventilatory limitation that precludes exercise training at sufficient intensity necessary for beneficial physiologic adaptations. The landmark study by Casaburi et al¹⁶ demonstrated that not only can anaerobic metabolism and an early onset of lactic acidosis be observed in exercise training of patients with COPD but that greater improvements in maximal and submaximal exercise responses can be obtained after exercise training at high (60% of maximal work rate, above the anaerobic threshold) compared with low (30% of maximal work rate) exercise levels. Two recent studies investigating this issue of exercise training intensity for pulmonary rehabilitation yielded seemingly controversial results. Casaburi et al¹⁸ found that patients with severe COPD can endure a rigorous training program (near VO_2max) with significant improvement in physiologic variables and overall exercise tolerance. Maltais et al,¹⁹ on the other hand, found that most patients with moderate or severe COPD were unable to endure high intensity training and the majority trained at 60% of the maximum work rate. Nonetheless, the latter study showed that high intensity training was not necessary to achieve physiologic and overall improvement in exercise capacity. In our centre, we further individualise exercise training intensity based on whether patients can achieve an anaerobic threshold (AT) during incremental exercise testing. The basis for prescribing exercise training intensities higher than necessary for patients to achieve anaerobic metabolism is to ensure that an adequate physiological training stimulus (presumably from lactic acidosis during sustained exercise) can be achieved during exercise training. However, as the AT could not be determined during non-invasive CPET for many patients in this study, this strategy can only be applied to a proportion of patients. Although exercise testing has been recommended for selection of physically deconditioned patients with low AT who are most likely to benefit from exercise training during rehabilitation,²⁰ currently there are no guidelines for exercise prescription based on direct measurement of AT during CPET. Further studies concerning the measurement of AT to directly target exercise training intensity as well as the role of interval exercise training in patients with lung disease who are unable to perform continuous exercise during pulmonary rehabilitation are necessary.

Conclusions

Patients who completed a 6-week out-patient PRP at our centre showed significant improvement in functional capacity. The benefits achieved from this programme

extended beyond an increase in exercise ability to include reduction of dyspnoea and improvement in health status in those patients for whom such measures could be quantified. Comprehensive pulmonary rehabilitation is an effective part of care and should be considered in patients with COPD who remain symptomatic or continue to have decreased function despite standard medical management. Pulmonary rehabilitation may also be beneficial to patients with chronic respiratory disease other than COPD.

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