Official Journal of the Asian Pacific Society of Respirology
Respirology

INVITED REVIEW SERIES:
HOW TO SET UP PULMONARY SUBSPECIALTY SERVICES

State of the art: How to set up a pulmonary rehabilitation program

SUE JENKINS,[1,2,3] KYLIE HILL[2,3] AND NOLA M. CECINS[1,2,3]

[1]*Physiotherapy Department, Sir Charles Gairdner Hospital,* [2]*School of Physiotherapy and Curtin Health Innovation Research Institute, Curtin University,* and [3]*Lung Institute of Western Australia and Centre for Asthma, Allergy and Respiratory Research, University of Western Australia, Perth, Western Australia, Australia*

ABSTRACT

Pulmonary rehabilitation plays an essential role in the management of symptomatic patients with COPD. The benefits of rehabilitation include a decrease in dyspnoea and fatigue, and improvements in exercise tolerance and health-related quality of life. Importantly, rehabilitation reduces hospitalization for acute exacerbations and is cost-effective. Although most of the evidence for pulmonary rehabilitation has been obtained in patients with COPD, symptomatic individuals with other respiratory diseases have been shown to benefit. In this review we outline a stepwise approach to establish, deliver and evaluate a pulmonary rehabilitation program (PRP) that would be feasible in most settings. Throughout the review we have specified the minimum requirements for a PRP to facilitate the establishment of programs using limited resources. Recommendations for staffing and other resources required for a PRP are presented in the first section. Exercise training is a focus of the section on program delivery as this is the component of rehabilitation that has the strongest level of evidence for benefit. Program considerations for patients with respiratory conditions other than COPD are described. Different approaches for delivering the education component of a PRP are outlined and recommendations are made regarding topics for group and individual sessions. The problems commonly encountered in pulmonary rehabilitation, together with recommendations to avoid these problems and strategies to assist in their resolution, are discussed. The review concludes with recommendations for evaluating a PRP.

Key words: exercise, lung disease, quality of life, rehabilitation.

INTRODUCTION

Pulmonary rehabilitation is an evidence-based, multidisciplinary and comprehensive intervention for patients with chronic lung disease who are symptomatic, and often have decreased daily life activities.[1] The aims of pulmonary rehabilitation are to reduce the symptoms and disability for people with lung disease with the overall goal of optimizing their functional status.

Pulmonary rehabilitation plays an essential role in the management of individuals with COPD.[2–7] Worldwide, COPD is a common and costly disease, and the burden associated with this disease is projected to rise as a result of the ageing population.[8,9] The evidence for rehabilitation in patients with COPD is compelling.[10] The benefits include a decrease in symptoms (dyspnoea and fatigue) and improvements in exercise tolerance and health-related quality of life (HRQoL).[10,11] These benefits have been shown in patients with stable disease and in those recovering from an acute exacerbation.[10,12,13] Importantly, in patients with COPD, rehabilitation reduces hospitalization for an exacerbation and is cost-effective.[14]

The Authors: Dr Sue Jenkins, PhD, is Associate Professor of Cardiopulmonary Science at Curtin University (School of Physiotherapy) and Sir Charles Gairdner Hospital (SCGH, Physiotherapy Department), and head of the Physiotherapy Unit at the Lung Institute of Western Australia (Perth, Western Australia). Dr Jenkins is an author of the Australian and New Zealand Guidelines for the Management of COPD (The COPD-X Plan) and The Pulmonary Rehabilitation Toolkit. Her research interests include exercise testing and training in patients with chronic lung disease. Dr Jenkins has presented pulmonary rehabilitation workshops in many countries within Asia as well as throughout Australia and in New Zealand. Dr Kylie Hill, PhD, is a Research Fellow at Curtin University (School of Physiotherapy). Her research interests relate to pulmonary rehabilitation and exercise training in chronic disease. She is a contributor to The Pulmonary Rehabilitation Toolkit and has presented pulmonary rehabilitation workshops in Canada. Nola Cecins, MSc, is a Senior Physiotherapist at SCGH (Physiotherapy Department) and Curtin University (School of Physiotherapy). Her research interests relate to pulmonary rehabilitation and airway clearance in patients with chronic lung disease. She is a contributor to The Pulmonary Rehabilitation Toolkit and has presented pulmonary rehabilitation workshops throughout Australia.

Correspondence: Sue Jenkins, School of Physiotherapy, Curtin University, GPO Box U1987, Bentley, WA 6845. Email: s.jenkins@curtin.edu.au

Received 27 June 2010; accepted 2 August 2010 (Associate Editor: Stephen G. Spiro).

doi: 10.1111/j.1440-1843.2010.01849.x

A comprehensive pulmonary rehabilitation program (PRP) includes patient assessment, exercise training, education, nutritional intervention and psychosocial support.[1] Exercise training is the component with the strongest level of evidence for benefit;[10] therefore, where resources are scarce, priority should be directed towards offering a program of supervised exercise training.

Although individuals with COPD constitute over 80% of the patients in PRP in Western countries,[15–17] there is evidence that rehabilitation benefits patients with restrictive impairments (interstitial lung disease (ILD), chest wall and neuromuscular disease),[18–25] bronchiectasis,[26,27] asthma[28–30] and individuals undergoing lung resection[31–33] and these conditions are the focus of this review.

This review describes the processes for establishing, delivering and evaluating a PRP but is not intended to provide a comprehensive summary of the pulmonary rehabilitation literature as this is available elsewhere.[1,10,34] Throughout the review we have specified the minimum requirements for a PRP to facilitate the establishment of these programs using limited resources.

ESTABLISHING A PULMONARY REHABILITATION PROGRAM

Funding and promotion

Where possible, dedicated funding should be sought to establish a PRP.

Estimates of the cost of running a PRP have been reported,[35–37] and the cost-effectiveness of a PRP over standard care has been established.[14] These costing estimates vary depending upon the health-care system, existing infrastructure and equipment, staffing and duration of the program. Low cost programs in existing facilities have been shown to be effective.[37,38] Lack of resources ought not to deter clinicians from seeking to establish a PRP. It is possible that funds used to provide existing services that lack a strong evidence base could be reallocated to the establishment of a PRP.

The process of establishing and maintaining a PRP is contingent on key stakeholders (funding providers, referrers and program participants) being informed and regularly reminded of the benefits of such programs. Coordinators of PRP are recommended to maintain a high profile with their stakeholders and provide them with evidence from published studies that programs result in cost savings,[14,36,37,39,40] as well as any evidence that their program decreases health-care utilization. Referrers who are regularly informed of the benefits of rehabilitation are more likely to advocate for the existence of programs.

Staffing

Current position statements recommend that a comprehensive PRP utilizes a multidisciplinary approach.[1,10,41] Table 1 lists the health professionals and their potential contributions in the provision of pulmonary rehabilitation. Models of service provision vary both between and within countries. Availability of staff and resources will ultimately determine the model of service provided.

Table 1 Health-care professionals and their potential roles in pulmonary rehabilitation

Team member	Role
Respiratory physician	Medical assessment and pharmacological management Referral/screening for PRP Oxygen prescription
Physiotherapist†	Exercise testing, prescription and training Musculoskeletal assessment, treatment and advice Airway clearance education Strategies for the management of dyspnoea Inspiratory muscle training Assessment of ambulatory oxygen requirements
Respiratory nurse	Disease-specific education Development of action plans Home visiting and support
Dietitian	Nutritional assessment and advice
Occupational therapist	Assessment and modification of home environment
Pharmacist	Advice/education on respiratory medication and inhaler use
Social worker	Information and access to support services
Psychologist	Psychosocial assessment and treatment for conditions such as anxiety, panic and depression

† In some countries some of these roles may be fulfilled by a physical therapist, respiratory therapist or exercise physiologist.

PRP, pulmonary rehabilitation program.

The minimum staffing requirement for a PRP is a referrer and a health-care professional to supervise exercise testing and training, one of whom may also assume the role of program coordinator.

Program referrer

Patients should be referred to a PRP by a respiratory or general physician who is available to the staff providing the program to discuss any medical problems that arise during rehabilitation and oxygen prescription.

Program coordinator

There is no clear evidence to recommend a specific discipline of health-care professional to coordinate a

PRP. A dedicated program coordinator is required to: process referrals; make appointments for assessments; allocate individuals to exercise classes; produce written materials; facilitate input from the multidisciplinary team; communicate with the referrers; and organize maintenance options for patients upon completion of the program. The program coordinator should be a health-care professional with an interest and knowledge of chronic lung diseases such as a specialist nurse or other health-care worker. However, if the program coordinator is also responsible for prescribing and supervising the exercise training component of the program, a physiotherapist is most appropriate for the role. The program coordinator should contribute to patient assessment as well as the education and self-management sessions. Given the complexity and needs of patients referred to a PRP, a dedicated senior health-care professional is best suited to the role of program coordinator. Providing one person 'ownership' of the PRP is more likely to encourage them to promote the program and modify its content in accordance with the latest research.

Exercise testing and training

The individual responsible for supervising exercise testing and training should be a health-care professional with knowledge of chronic lung diseases, expertise in exercise testing, prescription and training, and competent in cardiopulmonary resuscitation (CPR).[42] Reports of staff-to-patient ratio for exercise training in PRP range from 1:4[43] to 1:8.[44] Patient safety and disease severity are the most important factors to consider when determining this ratio. It is recommended that a single staff member supervises a maximum of 8–10 patients training in one class.[37] In block programs (i.e. where a group of patients start and finish a program together), a higher staff-to-patient ratio is desirable at the start of the program when all patients are unfamiliar with their exercise program. In some settings, specific medico-legal requirements may dictate the staff-to-patient ratio for supervised exercise training.

Facility and equipment

The essential requirements comprise a space for patient assessments that includes a level corridor or walking track suitable to carryout a field walking test. For exercise training, an area is needed such as a gym or large room, and an indoor or outdoor track for walking training. Table 2 lists the equipment required for a PRP. Programs in existing facilities may have access to shared equipment.

Table 2 Equipment required for a pulmonary rehabilitation program

Minimum requirement	Optional
Pulse oximeter	Weights machine/multigym
Polar heart rate monitor	Stationary cycle
Sphygmomanometer	Spirometer
Odometer (for walking test/track)	Glucometer
Stopwatch	Inspiratory muscle training device
Walking track/treadmill	Rollator
Hand weights	
Stairs/step	
Portable oxygen and nasal prongs	

Emergency equipment and response

A first aid kit with a CPR mask, gloves and rescue medications (inhaled short-acting bronchodilator and spacer, glucose replacement, glyceryl trinitrate spray) is recommended.[44] Emergency response in the community setting may comprise phone access to call an ambulance. In hospital settings, staff must be familiar with the emergency response protocol.

Location of program

Pulmonary rehabilitation programs are most commonly provided within a hospital outpatient department or community health facility. These centre-based programs enable existing infrastructure to be used and often permit access to a range of health professionals. In the hospital setting, immediate medical support is available making this the most appropriate setting for patients with very severe disease and complex comorbidities, in particular those with significant cardiovascular disease. Patients with mild to moderate respiratory disease and no serious comorbidities can be managed in a community-based PRP.

Depending on the available resources, either a block program, where a group of patients start and finish a program together, or a continuous rolling program in which patients enter and exit a program at different times, can be provided. The group setting provides patients with the opportunity to observe others with lung disease performing exercise and this may provide reassurance, motivation and psychosocial support.

Other locations for PRP include within the patient's home[45,46] and at physiotherapy practices.[28,47] There is also evidence of benefit from inpatient programs for patients with stable lung disease[48] and although these are costly, they provide an option for patients who live in remote areas without access to a local program. Home-based programs are convenient for the patient and may allow easier integration of exercise and physical activity into daily life.[49] However, regular visits by staff to supervise exercise training is resource intensive and patients lack the benefits gained from peer support. Access to a range of health professionals is also usually limited. Regular telephone calls may provide an alternative method for monitoring and

progressing exercise although many patients with severe dyspnoea require direct observation in order to feel confident when exercising and for the progression of exercises to occur.

Telerehabilitation is an emerging method of delivering rehabilitation services to patients in remote settings and may be an option for patients who are unable to leave their home.[50] However, as most of the evidence for pulmonary rehabilitation has been derived from programs offered within hospital outpatient departments,[10,11] where possible, we recommend that options are sought to enable patients to travel to a centre-based program.

DELIVERING A PULMONARY REHABILITATION PROGRAM

Patient selection

Any person with chronic lung disease who, despite optimal medical management, is limited by breathlessness on physical activity should be considered for pulmonary rehabilitation. Current smokers should not be excluded from PRP. Individuals with pre-existing comorbidities that compromise their safe participation in exercise training (e.g. severe neurological dysfunction, unstable cardiovascular disease, recent exertional syncope, severe cognitive impairment) and those who are not motivated to attend a program are unlikely to benefit and should not be referred.

Do all patients with COPD benefit from rehabilitation?

Improvements following rehabilitation have been shown in patients with COPD irrespective of the severity of their disease (i.e. %predicted FEV_1),[51,52] or level of functional impairment (Medical Research Council Grade).[53–55] Age and gender do not affect the outcome from a PRP.[56–58] Other factors that do not appear to influence the magnitude of short-term improvements include psychological or sociodemographic variables or current smoking status; however, these may influence program adherence and completion.[55,56,59] The characteristics of patients who show the greatest improvement in exercise capacity, symptoms or HRQoL following rehabilitation have not been extensively studied.[53,60,61] Furthermore, there is a dissociation between physiologic and HRQoL improvements, with some patients showing large improvements in HRQoL following rehabilitation with little or no change in exercise capacity.[60] No study has examined the characteristics of patients who are most likely to show benefit in terms of a reduction in health-care utilization. Therefore, all patients with COPD who meet the referral criteria for a PRP should be offered rehabilitation.

Referral process

To ensure that the resources allocated to a PRP are optimally utilized, a clear referral process is required.

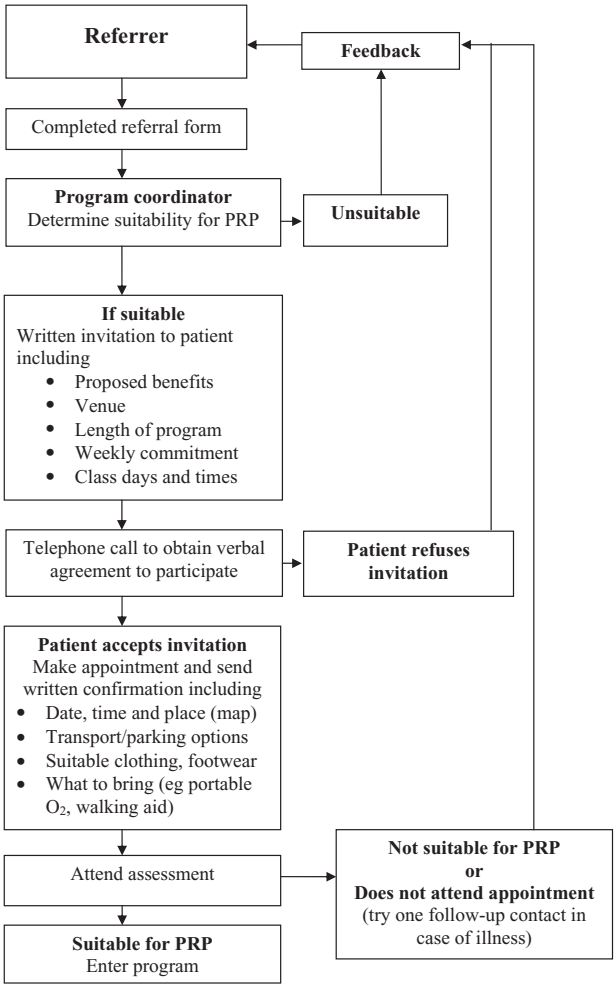

Figure 1 Referral process.

Referral by a respiratory or general physician will ensure that individuals have a medical assessment of their suitability for rehabilitation and that their pharmacological management has been optimized. Endorsement of the PRP by the referrer is likely to positively influence a patient's uptake of the program.[62]

A referral form should be generated[42] and made readily available to the referrers. Figure 1 outlines a suggested referral process. Written consent to participate in a PRP may be a requirement in some health-care systems and can be obtained at the initial assessment.

Communication with the referring physician is essential for ongoing support of the program. If the patient enters the program the referrer must be informed of the results of the baseline and post-program assessments. Furthermore, if a patient declines to participate, or is deemed not suitable for the PRP, the referrer should be informed.

Patient assessment

Upon entry to a PRP, it is essential that all patients are interviewed regarding their relevant past medical

Table 3 Tests and measurements recommended for patient assessment

Test or measurement	Comments
Exercise capacity	
Field-based walking test†	The three tests most commonly used are: (i) six-minute walk test (6MWT);[63] (ii) incremental shuttle walk test (ISWT);[64] and (iii) endurance shuttle walk test (ESWT).[65] At least one of these tests is necessary to evaluate the effect of pulmonary rehabilitation on functional exercise capacity. To account for the known learning effect, measures recorded before a PRP should be the best of two tests.[66,67] Two 6MWTs do not appear to be required at post-program assessment.[68]
	6MWT and ISWT can be used to prescribe initial training intensity.
	MID
	6MWT: ranges from 25 to 54 m,[69–71] approximately 10% of the 6MWD measured before commencing the PRP.
	ISWT: approximately 48 m.[72]
	ESWT: unknown.
Cardiopulmonary exercise test	May be incremental or constant power test, performed on a cycle ergometer or a treadmill.[73]
	MID
	Cycling: exercise time at 75% of peak power during a constant power test: 101s or 34% of the time at baseline assessment.[74]
	Treadmill: unknown.
Health-related quality of life†	
Chronic Respiratory Disease Questionnaire (CRDQ) or Saint George's Respiratory Questionnaire (SGRQ)	CRDQ comprises four domains; dyspnoea, fatigue, emotional function and mastery.[75]
	SGRQ comprises three subscales; symptoms, impact and activity.[76]
	At least one of these HRQoL questionnaires is required.
	CRDQ is more responsive to short-term changes following a PRP than the SGRQ.[77]
	MID
	CRDQ: 0.5 points per item or 10 points for total score.[78]
	SGRQ: 4 points.[79]
Symptoms and mood	
Medical Research Council Scale†	Measures functional limitation resulting from dyspnoea on a scale of 1 to 5.[80] More useful to discriminate between patients than to evaluate effects of a PRP.
	MMRC uses a scale that ranges from 0 to 4.
Hospital Anxiety and Depression Scale	Used to screen for feelings of anxiety and depression.[81]
	Score $\geq$ 11 on the depression or anxiety subscale suggests depression or anxiety is present.[81]
	Assessment of anxiety and depression is essential when there is access to a mental health-care professional.
	MID
	Anxiety and depression subscale: approximately 1.5 points.[82]
Composite measures	
BODE Index	Aggregate score, which comprises measures of BMI, FEV_1, functional limitation resulting from dyspnoea (MMRC Scale) and 6MWD.[83] The BODE index is a strong predictor of survival.[83]

† Indicates that the assessment is essential.

HRQoL, health-related quality of life; MID, minimal important difference in patients with COPD; MMRC, Modified Medical Research Council; PRP, pulmonary rehabilitation program.

history including the presence of any conditions that might affect their ability to participate in exercise training (e.g. severe lower limb arthritis) or education sessions (e.g. profound hearing loss). Furthermore, adequacy of literacy and vision should be ascertained as deficiencies in these areas will reduce an individual's capacity to accurately complete self-report questionnaires and an exercise diary. Smoking status must be recorded and, for individuals who continue to smoke, details of previous attempts to quit are needed. Individuals who have recently quit smoking may be at risk of relapse and may require counselling and support. Details of all medications and oxygen use, including the prescribed flow rate, are necessary. Information is required regarding the amount of physical activity undertaken by each patient. Identification of activities that a patient is no longer able to do due to dyspnoea, but would realistically like to resume on completion of a PRP, will assist with goal setting, motivation and adherence. Information regarding potential barriers to program attendance such as transportation difficulties or family responsibilities is important. Descriptive information such as age, height, weight, FEV_1 and FVC, are required, and may be documented on the referral form.

In addition to the measurements to be made before and after a PRP outlined in Table 3, information related to health-care utilization, particularly the

number of hospital admissions and length of stay in the 12 months before and following the PRP, is needed to evaluate the potential cost savings attributable to the program. Measurements of peripheral muscle strength assist in determining the effects of resistance training. However, obtaining repeatable measurements with the sensitivity to detect a change in strength in an individual patient requires complex equipment that is expensive and beyond the scope of most clinical programs.[84,85] Although measures are available to assess upper limb function[86–88] and balance,[89–91] they are not essential.

On completion of the PRP, patients should be asked to reflect on their achievements and the effect the program has had on symptoms such as dyspnoea, and their daily physical activity. A discussion of strategies to maintain the training-related gains such as adherence to a home exercise program and enrolment in a maintenance PRP is essential. Assessments performed at regular intervals following completion of an initial PRP will assist in determining the extent to which rehabilitation-related gains have been maintained. It is recommended to allow 60–90 min for the initial assessment and 30–45 min for assessments undertaken on completion of a PRP.

Exercise training

Program duration and frequency of training

Although there is no consensus of opinion regarding the optimal duration of an initial PRP, it appears that a minimum of 20 sessions is needed to achieve physiologic benefits.[1,10] Most programs are between 6 and 9 weeks in duration.[15–17] The recommended frequency of training for endurance exercise is at least three times a week of which a minimum of two sessions should be supervised.[1] We recommend two supervised sessions each week and encouraging patients to exercise unsupervised at home on an additional 2 or 3 days.[37]

Supervision of training is essential to ensure that training intensity is progressed. Supervision also allows staff to provide motivation, reassurance and encouragement. Longer programs that include a greater number of supervised sessions may produce greater improvements in exercise tolerance, and be more effective at achieving the behavioural change needed to optimize the longevity of training-related improvements.[10,34] However, it is less clear that outcomes such as dyspnoea and HRQoL are influenced by program duration.[92–94] Longer programs may increase waiting periods to access a program.

Lower limb endurance training

As patients with lung disease commonly avoid walking due to breathlessness and fatigue, training the muscles of ambulation is a mandatory component of a PRP.[10] Walking that is either ground-based or utilizes a treadmill is an essential component of an exercise program as walking is an important activity in daily life. Training using a cycle ergometer is also beneficial as this modality imposes a greater specific load on the quadriceps muscles than walking.[95] However, supervised ground-based walking training results in a significantly greater increase in walking endurance capacity compared with supervised cycle-based training.[96]

Although training at a relatively high intensity (>60% maximal work rate) is needed to achieve a physiologic training benefit,[97] not all patients can tolerate this intensity. Improvements in symptoms, HRQoL and ability to perform some activities of daily living have been shown following training at lower intensities.[98–100]

The intensity for walking training should be based on a field walking test (best of two tests) performed at the baseline assessment. For ground-based walking, most patients can tolerate an intensity equivalent to 80% of the average speed achieved on the six-minute walk test (6MWT), or 75% of the peak speed or 85% of the estimated peak rate of oxygen consumption derived from the incremental shuttle walk test (ISWT).[42,54,101–103] The prescribed intensity (walking speed) may need to be reduced by 0.5 to 1 kph at the commencement of training if a treadmill is used due to the unfamiliarity of walking on this equipment.[42,102] The recommended starting intensity for cycle ergometry training is >60% of the peak power measured on an incremental cycle ergometry test (where this is available), or determined using equations that estimate peak power based on the distance walked on the 6MWT or ISWT.[104–108] After the initial prescription, the intensity for walking and cycling should be adjusted based on patient tolerance with the aim of achieving a dyspnoea score of 3–5 (moderate to severe) or Rating of Perceived Exertion of 12–14 (somewhat hard).[109,110]

The recommended duration for lower limb endurance training is at least 30 min (exclusive of rests).[10] When patients are unable to achieve continuous walking or cycling for 30 min at the prescribed intensity due to intolerable symptoms, frequent rests should be encouraged or interval training used.[111] Very debilitated patients may only tolerate lower limb endurance training for 15–20 min at the start of a program.

Table 4 summarizes the principles of prescription for lower limb endurance training in PRP. More details can be found elsewhere.[42]

Table 4 Recommendations for lower limb endurance training

Prescription for physiologic benefits	
Mode	Walking, cycling
Frequency per week	Two supervised sessions Encourage patients to perform two or three unsupervised sessions
Duration	At least 30 min
Intensity	>60% maximum work rate
Progression	According to symptoms

Table 5 Strategies available to optimize the training load that require minimal resources

Strategy	Evidence	Considerations for clinical practice	How does it work
Interval training	Reduces symptoms during exercise training and improves tolerance of high-intensity exercise.[111] Interval-training is as effective as continuous training.[111]	Interval training involves the patient exercising using a defined work : rest ratio. Early training sessions will require more supervision for the patient to learn the work : rest ratio.	Provides patients with regular breaks of either no load or a reduced load to relieve dyspnoea or local muscle fatigue.
Rollator	Acutely increases 6MWD and reduces dyspnoea on exertion.[112,113]	Most likely to assist people with COPD with a low 6MWD[112] and/or those who needed to rest due to dyspnoea during a 6MWT.	Fixation of the upper limbs allows the accessory muscles to contribute to ventilation, thereby reducing the work of breathing and minimizing dyspnoea.
Supplemental oxygen	When used during an exercise training program, it results in greater benefits in exercise time during a constant load cycling test, but not performance on field-based walking tests or disease-specific HRQoL.[114]	All patients prescribed LTOT should use supplemental oxygen during exercise. Other patients who show profound oxygen desaturation on exertion may benefit as the oxygen offers the opportunity to train at higher exercise intensities.	Reduces ventilatory demand at a given exercise intensity.

6MWT, Six-minute walk test; HRQoL, health-related quality of life; LTOT, long-term oxygen therapy.

Strategies to optimize training load

Achieving the training intensities required to induce a physiologic adaptation may be difficult in patients who experience marked dyspnoea on exertion. For these individuals, strategies should be considered that reduce the ventilatory (i.e. central) limitation to exercise and increase the training stimulus on the peripheral muscles, namely the quadriceps.

The choice of strategy is likely to be based on equipment availability, cost and familiarity of staff with the approach. Table 5 summarizes training strategies that can be easily implemented in clinical practice with minimal cost and equipment. Additional strategies that require specialized equipment, technical expertise and/or a high staff-to-patient ratio include the use of helium[115] or helium-hyperoxia,[116] non-invasive positive pressure ventilation,[117] neuromuscular electrical stimulation,[118,119] ventilatory feedback[120] and partitioning of the exercising muscle mass, such as one-legged cycling.[121] It is important to note that training-related benefits attributable to any of these strategies will not be sustained if the strategy is not incorporated into the home exercise or maintenance programs.

Lower limb strength training

Individuals with COPD have impaired force-generating capacity of their skeletal muscles.[122] This weakness impacts on their capacity to undertake activities of daily living such as climbing stairs and standing up from a low chair, and contributes to exercise intolerance.[123] Therefore, resistance exercises are recommended to increase the strength of the lower limb muscles,[10] particularly the quadriceps, and to combat the age-related decline in muscle mass.

Most resistance training programs for patients with COPD[124] have been extrapolated from those recommended in healthy individuals.[125] Strength training should take place two or three times each week with at least one day of rest between sessions. Functional exercises that strengthen the lower limbs (e.g. sit-to-stand, step-ups and wall squats) are recommended for PRP with limited equipment and also because they can be undertaken easily in the home. Training should commence by performing one set of 8–12 repetitions of each exercise and progressed by increasing the number of sets from one to three,[126] and thereafter increasing the load using hand weights. Muscle loading may be achieved using a multigym if available. It is important to warn patients regarding delayed onset muscle soreness.

Strength training represents an adjunct to, not a replacement for, endurance training. However, in individuals who are very deconditioned (e.g. following prolonged hospitalization for an acute exacerbation) or with marked dyspnoea on minimal exertion, it may be appropriate to allocate more time to resistance exercises as they are associated with less ventilatory load[127] and cause less dyspnoea, and may be better tolerated than endurance exercises.

Upper limb training (endurance and strength)

Many patients with moderate to severe COPD report dyspnoea during activities that involve using their arms such as showering, dressing and carrying groceries. Therefore, it is important that arm exercises are included in the training program[10] to improve arm exercise capacity.[128] Both endurance and resistance exercises should be prescribed. It is important that overhead arm exercises are progressed carefully and the health-care professional responsible for supervising the exercise program monitors individuals closely for symptoms of shoulder and neck pain.

Unsupported endurance arm exercises (e.g. arm raises) are preferable to supported arm exercise (e.g. arm cycle ergometry).[129] Asking the patient to lift their arms alternately overhead 15 times holding a light weight (e.g. 1–2 kg) is an example of a simple unsupported endurance arm exercise. As with lower limb endurance exercise, progression of exercise intensity should be titrated according to symptoms of dyspnoea and local muscle fatigue.[130] Resistance exercises are needed to strengthen the shoulder and arm muscles and can be performed using free weights or a multigym if available. In contrast with endurance exercise, resistance exercises are characterized by higher weights and lower repetitions.[126] The principles of prescription and progression described for lower limb strength training can be applied for upper limb strength training.

Other strategies to manage dyspnoea during exercise: pursed lips breathing, exhalation on effort and forward-lean position

The evidence to support breathing exercises in people with chronic lung disease is limited.[131,132] However, some patients with moderate to severe COPD may derive benefit from breathing strategies and those who gain benefit should be encouraged to use them to minimize dyspnoea and be provided with a simple explanation why they are beneficial.

Pursed lips breathing is spontaneously adopted by some patients with COPD during exertion and when recovering from activity. The technique aims to prevent airway closure. Pursed lips breathing reduces respiratory rate by prolonging expiratory time in patients with COPD.[133–135] Patients who are most likely to benefit tend to adopt the technique spontaneously.[136–138]

Some patients breath-hold during specific activities and this exacerbates dyspnoea and reduces their ability to continue the activity. Instructing patients to exhale, for example when bending down or when standing up from a chair, may be a useful strategy to avoid breath-holding.[131]

Although there is little evidence to support the use of techniques such as breathing control some patients find it useful during periods of acute dyspnoea.[131,132] Deep breathing exercises and thoracic expansion exercises are not strategies for dyspnoea management and therefore are not indicated for this purpose. The role of these exercises is to assist with airway clearance, where indicated.

The forward-lean position, especially if this is combined with fixation of the shoulder girdle, often provides some relief from dyspnoea. This position optimizes recruitment of the accessory muscles of respiration and improves the mechanical advantage of the diaphragm.[139–141] Individuals with COPD often adopt this position when recovering from bouts of physical activity. When walking, fixation of the shoulder girdle is achieved by placing hands on hips, placing hands or thumbs in pockets, or by use of a rollator.

Flexibility and stretching exercises

These exercises aim to increase muscle length and joint range of movement, and to prevent the risk of exercise-related injury and delayed onset muscle soreness.[142] However, the exercise intensity that patients with moderate to severe respiratory disease can achieve will be constrained by their ventilatory limitations and hence the risk of exercise-related injury is likely to be considerably lower than in a healthy population.

These exercises should be carried out for a maximum of 5–10 min within each exercise class as the focus of training must be on exercises to improve endurance and strength.[1,10,34]

Flexibility exercises, such as rotation of the thoracic spine, may help to maintain thoracic mobility. Stretching exercises should focus on lengthening the accessory muscles of respiration such as the pectoral muscles, which may be shortened due to the prolonged use of a forward-lean position to alleviate breathlessness. Lower limb stretches, for example of the calf or quadriceps muscles, are only indicated for individuals considered to be at risk of injury or muscle soreness.

Inspiratory muscle training

Inspiratory muscle training (IMT) is not recommended as a routine component of a PRP,[10] as the addition of IMT to a program of whole body exercise training does not confer additional benefits in exercise capacity, dyspnoea or HRQoL.[143] However, as IMT performed in isolation reduces dyspnoea and confers small gains in exercise capacity and HRQoL,[144,145] it should be considered for individuals who are unable to participate in whole body exercise training due to comorbidites such as severe musculoskeletal pain. Threshold loading devices are recommended for IMT as the training load imposed is largely independent of the patient's breathing pattern.[146] Loads $\geq$30% of an individual's maximum inspiratory pressure are needed to confer benefit,[147] and an interval-based training approach, where work periods are interspersed with regular rest periods, is recommended to optimize the load that can be tolerated.[148,149]

Safety during exercise

It is important to note that both exercise testing and training are generally considered safe for individuals with chronic lung disease. Specifically, in a study of more than 600 patients referred to a PRP who underwent a 6MWT before exercise training, adverse events were observed during 28 (5%) tests, of which the most common event (20 tests) was profound transient oxygen desaturation (oxygen saturation [SpO_2]<80%).[150] Furthermore, although dozens of studies have investigated exercise training in patients with symptomatic lung disease, to our knowledge no serious adverse events, such as myocardial infarction or death, have been documented during a supervised exercise class. Nevertheless, it is prudent that patients are screened and monitored to identify abnormal responses during exercise testing and training.

Patients must be screened for the presence of comorbidities that may compromise their safety during exercise, such as symptomatic ischaemic heart disease, by both the referrer and the health-care professional responsible for supervising the training. Measurements of heart rate, SpO_2 and dyspnoea at rest are needed before commencing an exercise test or training session. Delaying exercise testing and training should be considered for individuals with an abnormal resting heart rate (i.e. <50 or ≥125 bpm), SpO_2 <90% or excessive dyspnoea (scores on the Borg scale ≥ 4). Exercise must be stopped immediately for any individual who develops chest pain, evidence of a new cardiac arrhythmia, dizziness or nausea. Monitoring of heart rate and SpO_2 is necessary throughout an exercise test. During supervised training, SpO_2 and heart rate should be measured upon completion of walking training and after cycling and step-ups in those patients who show significant desaturation when walking. Consideration should be given to terminating an exercise test or asking individuals to rest during training if they show: (i) an increase in their heart rate such that it approaches their age predicted maximum; (ii) a decrease in SpO_2 to ≤85%; or (iii) marked wheeze. Profound desaturation is more likely to occur during walking compared with cycling exercise in patients with COPD.[151–153]

Patients ought to be instructed to bring any prescribed short-acting bronchodilators or vasodilators (e.g. glyceryl trinitrate) to every exercise testing or training session. Furthermore, individuals with diabetes should be instructed to bring along glucose supplements to independently manage any hypoglycaemic episodes.

Impact of comorbidities on exercise training

Patients referred to PRP often have one or more comorbidities[154] that may impact on their ability to exercise.

Musculoskeletal problems. Osteoporosis and arthrosis are present in many patients referred to PRP.[154,155] Land-based exercise may exacerbate pain associated with these conditions. A history of any musculoskeletal problems should be documented at assessment and care taken when prescribing exercises. The initial prescription requires modification to address these problems and progression of exercises should only occur after the patient has completed at least two supervised sessions without any increase in pain. The use of appropriate footwear is essential for walking training. It is possible that water-based exercise may be more effective for individuals who are severely limited by musculoskeletal pain. Physical training in water is feasible and effective in patients with COPD.[156,157]

Body composition abnormalities. Some patients with COPD referred to PRP have abnormalities in body composition. Patients may be underweight (with depleted fat free mass)[158] or overweight/obese.[159] These conditions may necessitate modification of the exercise training program. The underweight patient will require nutritional advice (with possible caloric supplementation) to ensure that the extra physical activity does not lead to further weight loss. For the overweight or obese patient, it may be difficult to participate in exercise training due to concurrent lower limb musculoskeletal problems and specialized exercise equipment may be required. Nutritional advice for weight loss is necessary during the training program as exercise alone is unlikely to significantly reduce body weight.

Peripheral arterial disease. Intermittent claudication may be the symptom that limits walking in some patients who participate in a PRP. To gain optimal improvements in their claudication symptoms these patients should be encouraged to walk beyond the onset of pain for as long as they can tolerate. The recommended duration and frequency of walking training is at least 30 min and 3 days per week, respectively.[160,161]

Exercise training for patients with respiratory conditions other than COPD

Exercise training regimens for these patients have been based on protocols shown to be effective in patients with COPD;[19,20,26,27,30,162] however, some modifications are required to ensure the safety and suitability of the exercise prescription. Furthermore, the content of the education component within the PRP requires adaptation.

Interstitial lung disease

Interstitial lung disease comprises a heterogeneous group of conditions with variable prognosis. In addition to exertional dyspnoea and fatigue, a non-productive cough can be troublesome during exercise especially in patients with IPF.[25,163] Oxygen requirements are variable among patients with ILD with some patients maintaining acceptable oxygen

saturation at rest but displaying rapid and profound desaturation during exercise despite the use of interval training. Desaturation is especially likely to occur when exercise involves large muscle groups, in particular walking[108] and is often observed in the absence of significant dyspnoea. Some patients with very severe disease are likely to require high flow supplementary oxygen; these patients should be managed within a hospital-based PRP.

Non-cystic fibrosis bronchiectasis

Exercise training in this patient population may have the additional benefit of enhancing airway clearance. In the group setting, patients should be encouraged to huff to clear secretions and it is important that the health-care professional responsible for supervising the class informs other patients that cough and expectoration are normal occurrences during exercise in people with bronchiectasis.

Asthma

In some individuals it can be difficult to distinguish between asthma and COPD as these two conditions may coexist.[2] Long-standing asthma on its own can lead to fixed airflow obstruction.[164] When optimally managed, many individuals with asthma can tolerate high-intensity training and can be appropriately managed in community-based programs. Oxygen desaturation during exercise is uncommon in people with asthma.[30,165] The use of inhaled bronchodilators before exercise, a warm-up period of low intensity exercise and the use of interval training are recommended to reduce symptoms during exercise.[166,167] Patients with asthma may be very sensitive to odours, for example from perfume or cologne, therefore in the class setting all patients should be instructed to avoid using these products.

Surgical lung resection

Individuals who report dyspnoea on exertion or reduced exercise tolerance before or after surgical resection for lung cancer should be referred to a PRP. Preliminary data suggest that supervised exercise training improves exercise capacity and HRQoL in these individuals.[31–33] Special considerations in this patient population relate to timing of rehabilitation following surgical resection, the management of postoperative pain and the impact concurrent therapy (i.e. chemotherapy or radiotherapy) may have on program attendance. Although a graduated walking program is recommended in the immediate postoperative period, participation in an outpatient PRP should be considered when the wound has healed and medical clearance has been obtained to exercise (usually about 30 days postoperatively). Arm exercises are necessary to improve shoulder range of movement and the strength of muscles affected by the surgery. These exercises may need to be modified to minimize discomfort with overhead activities. Patients who experience difficulty attending exercise classes due to radiation or chemotherapy treatments should be offered a longer program.

Maintenance of benefits from exercise training

Transferring exercise into the home setting

Implementation of a home exercise program during a PRP has two purposes. First, it will optimize the training stimulus by encouraging the patient to exercise in addition to the supervised sessions. Second, it should improve adherence to exercise training upon completion of the supervised program. For these reasons, it is essential that a home exercise program be implemented at an early stage during a PRP.

The home exercise program should commence after the patient has attended a minimum of two supervised sessions thereby allowing time to resolve any problems (e.g. delayed onset muscle soreness or aggravation of any pre-existing musculoskeletal conditions) that may arise during training. While attending supervised sessions (minimum of two per week) we recommend an additional two or three unsupervised exercise sessions each week.

To assist with the uptake of exercise in the home setting, it is important for the exercises prescribed in the home program to closely resemble those undertaken in the supervised classes. Written material with descriptions and pictures of each exercise are essential within the home program. The prescription for each exercise (e.g. duration for endurance exercise, and weight and number of repetitions for resistance exercise) should be individualized based on performance during the supervised sessions. A diary is needed to monitor adherence with the home program and reviewed at regular intervals (e.g. every 2 weeks) to progress the exercises in accordance with the supervised sessions. Barriers to completing the home exercise program should be discussed with the health-care professional supervising the exercise classes and solutions sought during a group 'problem-solving' activity.

It is essential that the home program includes information regarding when 'not' to exercise (e.g. when experiencing flu-like symptoms, irregular heart beat or palpitations) and instructions when medical advice should be sought. Precautions for exercise must also be included, in particular for patients with asthma. These include avoiding exercise in environments with high levels of atmospheric pollution or high pollen count, and in cold and dry or windy conditions.[166,167]

Post-rehabilitation strategies

Studies suggest that improvements in exercise capacity and health status following short-term (6–8 weeks) PRP are maintained for approximately 6 months but diminish in the following 6–12 months.[29,168–170] To maintain the benefits gained following a PRP, patients

Table 6 Suggested maintenance strategies

Strategy
Unsupervised home exercise program with regular follow-up testing (e.g. 3 or 6 monthly).
Once weekly supervised exercise program in low-cost community setting plus home exercise program.
For patients with complex comorbidities (e.g. severe cardiovascular disease), high oxygen therapy requirements for exercise or frequent hospital admissions, a hospital-based maintenance exercise class (once per week) may be necessary.
Provision of booster programs following an acute exacerbation.

need to remain physically active. Respiratory exacerbations are the most common reason reported for non-adherence to home exercise programs.[171,172]

Post-rehabilitation strategies that include telephone support and regular supervised sessions,[171,173] and repeated PRP,[174] show modest effects on long-term outcomes. However, one study showed that a self-selected group of patients who continued to attend a weekly maintenance exercise program, supervised by a physiotherapist, following an initial PRP adhered to their home exercise program and maintained the benefits of the initial program for up to 18 months.[172] Another study showed that home exercise training (with or without a weekly supervised session) combined with regular follow-up testing enabled patients with moderate COPD to maintain improvements in exercise capacity and HRQoL for 12 months following an initial 8-week PRP.[175] Both of these studies incorporated walking training, an exercise that is easily replicated in the home setting.

Table 6 summarizes suggested maintenance strategies. Although the optimal method to facilitate adherence to a regular exercise program following completion of an initial PRP is unclear we recommend that patients are encouraged to continue their home exercise program 3–5 times each week.

Patient education

Patient education is considered to be a core component of a comprehensive PRP although it is difficult to determine its benefits on health outcomes.[1] Traditionally, in centre-based programs, information on different topics related to lung disease has been presented using a lecture style format. While this didactic style of education may increase knowledge[176] improvements in other outcomes are minimal.[168,177] Recently, education within PRP has begun to focus on promoting self-management skills. These are the skills required by patients to monitor their condition, make appropriate management decisions, interact with health professionals, adhere to recommended medical regimens, and participate in activities that promote health such as physical activity, regular exercise and good nutrition. It is recommended that staff that provide PRP undergo training to develop the necessary skills to assist patients to achieve behavioural change.

Table 7 Education topics

Topics suitable for group sessions	Topics that require individual consultation
Information about the lungs, lung diseases and respiratory medications†	Smoking cessation†
Exacerbations: prevention and management including action plans†	Inhaler technique†
Benefits of physical activity and exercise†	Nutrition†
Causes and management of breathlessness†	Oxygen therapy
Coping with chronic lung disease, management of depression, anxiety and panic attacks†	Instruction in airway clearance techniques
Communication with health professionals†	Issues related to travelling with lung disease
Community resources including home care options†	Sexuality issues
	Continence issues
	Advanced care planning and end-of-life decision-making

† Recommended minimum requirements.

Some facilities will not have the resources to provide group education sessions; this should not be a barrier to the setting up of a PRP as the rehabilitation component with the strongest level of evidence for benefit is exercise training.[10]

The format for the delivery of education within a PRP will vary depending on staff availability and expertise. Possible options include: a formal education component with members of the multidisciplinary team facilitating group sessions that are timetabled to run before or after exercise classes; informal sessions integrated within the exercise classes that are facilitated by the staff member responsible for supervising the class, or provision of written information to patients. Education may also be delivered as part of a generic or disease specific self-management program.[178,179]

Table 7 lists suggestions of topics for education sessions within a PRP.[15–17,42] For group sessions, the content should not be disease specific unless all participants have the same respiratory diagnosis. Group sessions do not replace the need for individual education. For example, nutritional advice should be given on an individual basis as within a group there are likely to be both underweight and overweight patients and those who have special dietary requirements.

Education sessions should encourage interaction among participants by incorporating problem solving discussions. This provides participants with the opportunity to discuss how they would apply the knowledge gained to practical situations (i.e. how to cope with severe breathlessness in a public place). It is

important to include goal-setting, decision-making and individual's successes in self-management within the sessions to assist in improving self-efficacy. Practical demonstrations and the use of diagrams, models (e.g. of the lungs) and videos can be helpful. Written material is required to accompany the education sessions; however, lengthy booklets with large amounts of text are not appropriate. Most national

Table 8 Troubleshooting and recommendations

Problem	Recommendations
Poor uptake of pulmonary rehabilitation	
Reasons cited for non-participation in a PRP include: transport difficulties; work commitments; patient considers they are too ill, will not benefit or that the program will be too difficult.[53,59,172]	Ensure referring physician is enthusiastic about participation and advocates the importance and benefits of pulmonary rehabilitation to patients.[62,180] Provide clear and adequate information on the benefits of participation in simple, meaningful terms at the time of invitation. For some patients, this information is essential to overcome any anxieties associated with attending a program.[62]
Poor attendance at programs	
Likely to result in suboptimal benefits for an individual and waste valuable health-care resources Factors associated with poor attendance include: current smoking status;[53,55,59] long journey to the program;[55] social isolation (e.g. living alone);[59] frequent exacerbations requiring hospital admission;[55] severe dyspnoea (MRC Grade 5)[55] and depression.[53] Age, gender and severity of airflow limitation (FEV_1 % predicted) are not predictors of attendance.[55,59] Respiratory and non-respiratory related illness, transport issues and personal/social concerns such as family illness, are reasons reported for non-completion of PRP.[53,59,172]	Patients with risk factors for poor attendance should not be excluded from programs. Identify barriers to participation at program entry and offer support to overcome the barriers. Offer current smokers pharmacological help and smoking cessation counselling. If possible, refer patients to a PRP closest to their home. Schedule classes to avoid peak traffic times and thus reduce journey time. Overcome difficulties with transport/journey time for patients without personal or family transport by offering subsidized options where available (e.g. taxis or hospital transport) and accessible parking. Consider one supervised session each week and three or four unsupervised sessions for patients unable to attend two sessions each week. Extend program for patients who miss sessions due to illness (e.g. acute exacerbations). Consider home-based programs for severely dyspnoeic patients.
Frequent flyers	
Some patients, despite completion of a PRP, experience ongoing problems (e.g. readmission to hospital with subsequent deconditioning, social problems affecting their ability to exercise) and are re-referred to a program.	At commencement of a PRP, clearly state program duration and the expectation that the patient will complete the program. 'Graduate' patients by providing an appointment for reassessment at the completion of the program and to discuss maintenance options. Provide details about additional support, e.g. local or internet-based patient support groups. Offer shorter 'booster' programs (e.g. 4-week duration) following severe exacerbations to revise patient's home exercise program and re-establish a regular exercise regimen.
Anxious or depressed patient	
Some patients are anxious about attending an 'exercise program' fearing that they will lose control of their breathing in a public situation. Patients may be concerned that they will contract infections from other patients in the program.	Be aware of patient anxiety before entry into a PRP and reassure the patient that they will cope in the program and are likely to benefit. Explain the benefits of group support and improved self-confidence associated with PRP. Orientate patients to the facility, including the location of chairs and toilets. Invite patients to observe an exercise class before participating. Arrange referral to a mental health professional if available. Encourage good cough/sneeze etiquette and respiratory hygiene (e.g. disposing of used tissues appropriately) during the classes. Hand washing and cleaning of exercise equipment should be undertaken in accordance with facility-based protocols. Educate patients entering a PRP about the signs and symptoms of respiratory infection and not to attend classes during the acute stage of an infection.

PRP, pulmonary rehabilitation program.

lung foundations and societies are sources of material for patient education.

Patient support groups

Support groups for patients with chronic lung disease provide an environment for patients and carers to share information, friendship, experiences and encouragement. Patients can take a more active role in their health management with the advice and support of others in a similar situation. These groups are either run entirely by the members or facilitated by a health-care professional. Following a PRP patients should be introduced to existing support groups or encouraged to consider establishing a group if one does not exist. Internet-based support groups also exist for people with lung disease.

Troubleshooting common problems encountered in pulmonary rehabilitation programs

The problems commonly encountered in pulmonary rehabilitation include: low uptake of programs; poor attendance of patients in PRP; patients being re-referred despite completing a program (i.e. frequent flyers); and managing patients who are very anxious or depressed. Table 8 provides recommendations to avoid these problems and strategies to assist in their resolution.

EVALUATING A PULMONARY REHABILITATION PROGRAM

Evaluation of a PRP is an essential component of continuous quality improvement. Each program should be evaluated in terms of: (i) referral and attendance patterns; (ii) outcomes such as exercise capacity and HRQoL in the patient cohort; and (iii) patient feedback.

At 12-monthly intervals, the coordinator should review the program by summarizing the number of referrals, uptake of pulmonary rehabilitation (i.e. the number who attend baseline assessment and enrol in the program), attendance (i.e. the average number of supervised sessions completed) and attrition (i.e. the number who drop-out of the program). Reasons for poor uptake, attendance and attrition should be noted and, where possible, strategies implemented to improve these factors.

The average change for outcomes such as exercise capacity and HRQoL should be calculated for patients grouped according to respiratory diagnosis (e.g. COPD, ILD, etc.). Where appropriate, the magnitude of change for these outcomes can be compared with the established minimal important difference (see Table 3). For example, those programs that use the CRDQ to measure HRQoL should aim to achieve an average increase of 10 points for the total score.[78] Programs that achieve an average increase of $\geq$10 points in the CRDQ can be confident that the improvement was large enough to be noticed by the average patient. Staff involved in these programs should also aim to compare the average change observed in their program with other programs. This can be achieved by comparing changes with those reported in the literature, at conference presentations or by contacting coordinators of other local PRP.

On program completion, it useful to ask patients to complete a satisfaction questionnaire.[42] Questions should focus on the content of the PRP and offer the opportunity to expand on answers if required. Allowing patients to give feedback anonymously may increase response rate and the amount of information provided.

CONCLUSIONS

The global burden of lung disease is increasing, in part due to earlier detection and the ageing population. Low-cost strategies to improve the health of individuals with lung disease are necessary. Pulmonary rehabilitation is an intervention for which there is compelling evidence of benefit and one that has been shown to be cost-effective. This review has provided a stepwise approach to enable clinicians to establish, deliver and evaluate a PRP.

REFERENCES

1 Nici L, Donner C, Wouters E *et al*. American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation. *Am. J. Respir. Crit. Care Med.* 2006; **173**: 1390–413.
2 Global Initiative for Chronic Obstructive Lung Disease. Global Strategy for the diagnosis, management, and prevention of chronic obstructive lung disease (Updated 2009). [Accessed 22 May 2010.] Available from URL: http://www.goldcopd.com/GuidelinesResources
3 Abramson M, Crockett AJ, Frith PA *et al*. The COPD-X Plan: Australian and New Zealand Guidelines for the management of Chronic Obstructive Pulmonary Disease. 2009. [Accessed 22 May 2010.] Available from URL: http://www.copdx.org.au/guidelines
4 National Institute for Clinical Excellence. Chronic obstructive pulmonary disease. Management of chronic obstructive pulmonary disease in adults in primary and secondary care. 2004. National Collaborating Centre for Chronic Conditions. [Accessed 5 Jun 2010.] Available from URL: http://www.nice.org.uk/CG012NICEguideline
5 The Japanese Respiratory Society. *Guidelines for the Diagnosis and Treatment of COPD (Chronic Obstructive Pulmonary Disease)*, 2nd edn. The Japanese Respiratory Society, Tokyo, 2004; 1–36.
6 O'Donnell DE, Aaron S, Bourbeau J *et al*. Canadian Thoracic Society recommendations for management of chronic obstructive pulmonary disease—2007 update. *Can. Respir. J.* 2007; **14**: 5B–32B.
7 American Thoracic Society/European Respiratory Society. Standards for the diagnosis and management of patients with COPD. 2004. [Accessed 29 May 2010.] Available from URL: http://www.thoracic.org/clinical/copd-guidelines
8 Lopez AD, Shibuya K, Rao C *et al*. Chronic obstructive pulmonary disease: current burden and future projections. *Eur. Respir. J.* 2006; **27**: 397–412.

9 Buist AS, McBurnie MA, Vollmer WM *et al*. International variation in the prevalence of COPD (The BOLD Study): a population-based prevalence study. *Lancet* 2007; **370**: 741–50.
10 Ries AL, Bauldoff GS, Carlin BW *et al*. Pulmonary rehabilitation. Joint AACP/AACVPR evidence-based clinical practice guidelines. *Chest* 2007; **131**: 4S–42S.
11 Lacasse Y, Goldstein R, Lasserson TJ *et al*. Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database Syst. Rev.* 2006; **4**: CD003793.
12 Puhan M, Scharplatz M, Troosters T *et al*. Pulmonary rehabilitation following exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst. Rev.* 2009; **1**: CD005305.
13 Seymour JM, Moore L, Jolley CJ *et al*. Outpatient pulmonary rehabilitation following acute exacerbations of COPD. *Thorax* 2010; **65**: 423–8.
14 Griffiths TL, Phillips CJ, Davies S *et al*. Cost effectiveness of an outpatient multidisciplinary pulmonary rehabilitation program. *Thorax* 2001; **56**: 779–84.
15 Yohannes AM, Connolly MJ. Pulmonary rehabilitation programmes in the UK: a national representative survey. *Clin. Rehabil.* 2004; **18**: 444–9.
16 Brooks D, Sottana R, Bell B *et al*. Characterization of pulmonary rehabilitation programs in Canada in 2005. *Can. Respir. J.* 2007; **14**: 87–92.
17 O'Neill B, Elborn JS, MacMahon J *et al*. Pulmonary rehabilitation and follow-on services: a Northern Ireland survey. *Chron. Respir. Dis.* 2008; **5**: 149–54.
18 Foster S, Thomas HM. Pulmonary rehabilitation in lung disease other than chronic obstructive pulmonary disease. *Am. Rev. Respir. Dis.* 1990; **141**: 601–4.
19 Holland AE, Hill CJ, Conron M *et al*. Short term improvement in exercise capacity and symptoms following exercise training in interstitial lung disease. *Thorax* 2008; **63**: 549–54.
20 Nishiyama O, Kondoh Y, Kimura T *et al*. Effects of pulmonary rehabilitation in patients with idiopathic pulmonary fibrosis. *Respirology* 2008; **13**: 394–9.
21 Holland A, Hill C. Physical training for interstitial lung disease. *Cochrane Database Syst. Rev.* 2008; **4**: CD006322.
22 Ferreira A, Garvey C, Connors GL *et al*. Pulmonary rehabilitation in interstitial lung disease. Benefits and predictors of response. *Chest* 2009; **135**: 442–7.
23 Spruit MA, Janssen DJA, Franssen FME *et al*. Rehabilitation and palliative care in lung fibrosis. *Respirology* 2009; **14**: 781–7.
24 Salhi B, Troosters T, Behaegel M *et al*. Effects of pulmonary rehabilitation in patients with restrictive lung diseases. *Chest* 2010; **137**: 273–9. DOI 10.1378/chest.09-0241.
25 Kozu R, Senjyu H, Jenkins SC *et al*. Differences in response to pulmonary rehabilitation in idiopathic pulmonary fibrosis and chronic obstructive pulmonary disease. *Respiration* 2010; doi:10.1159/000315475.
26 Jenkins S, Cecins N. Benefits of exercise training in patients with interstitial lung disease and bronchiectasis. *Respirology* 2002; **7**: A4.
27 Newall C, Stockley RA, Hill SL. Exercise training and inspiratory muscle training in patients with bronchiectasis. *Thorax* 2005; **60**: 943–8.
28 Cambach W, Chadwick-Straver RVM, Wagenaar RC *et al*. The effects of a community-based pulmonary rehabilitation programme on exercise tolerance and quality of life: a randomized controlled trial. *Eur. Respir. J.* 1997; **10**: 104–13.
29 Foglio K, Bianchi L, Bruletti G *et al*. Long-term effectiveness of pulmonary rehabilitation in patients with chronic airway obstruction. *Eur. Respir. J.* 1999; **13**: 125–32.
30 Turner S, Eastwood P, Cook A *et al*. Improvements in symptoms and quality of life following exercise training in older adults with moderate to severe persistent asthma. *Respiration* 2010; doi:10.1159/000315142.
31 Cesario A, Ferri L, Galetta D *et al*. Post-operative respiratory rehabilitation after lung resection for non-small cell lung cancer. *Lung Cancer* 2007; **57**: 175–80.
32 Jones LW, Peddle CJ, Eves ND *et al*. Effects of presurgical exercise training on cardiorespiratory fitness among patients undergoing thoracic surgery for malignant lung lesions. *Cancer* 2007; **110**: 590–8.
33 Jones LW, Eves ND, Peterson BL *et al*. Safety and feasibility of aerobic training on cardiopulmonary function and quality of life in postsurgical nonsmall cell lung cancer patients: a pilot study. *Cancer* 2008; **113**: 3430–9.
34 Troosters T, Casaburi R, Gosselink R *et al*. State of the Art. Pulmonary rehabilitation in chronic obstructive pulmonary disease. *Am. J. Respir. Crit. Care Med.* 2005; **172**: 19–38.
35 Singh SJ, Smith DL, Hyland ME *et al*. A short outpatient pulmonary rehabilitation programme: immediate and longer term effects on exercise performance and quality of life. *Respir. Med.* 1998; **92**: 1146–54.
36 Golmohammadi K, Jacobs P, Sin DD. Economic evaluation of a community-based pulmonary rehabilitation program for chronic obstructive pulmonary disease. *Lung* 2004; **182**: 187–96.
37 Cecins N, Geelhoed E, Jenkins SC. Reduction in hospitalisation following pulmonary rehabilitation in patients with COPD. *Aust. Health Rev.* 2008; **32**: 415–22.
38 Hui KP, Hewitt AB. A simple pulmonary rehabilitation program improves health outcomes and reduces hospital utilization in patients with COPD. *Chest* 2003; **124**: 94–7.
39 Goldstein RS, Gort EH, Guyatt GH *et al*. Economic analysis of respiratory rehabilitation. *Chest* 1997; **112**: 370–9.
40 Rubi M, Renom F, Ramis F *et al*. Effectiveness of pulmonary rehabilitation in reducing health resources use in chronic obstructive pulmonary disease. *Arch. Phys. Med. Rehabil.* 2010; **91**: 364–8.
41 Frith PA. A manual for pulmonary rehabilitation in Australia: evidence base and standards. 2008. [Accessed 29 May 2010.] Available from URL: http://www.lungfoundation.com.au/docs/copd/rehab_standards_v3
42 Alison J, Barrack C, Cafarella P *et al*. The Pulmonary Rehabilitation Toolkit. 2009. [Accessed 29 May 2010.] Available from URL: http://www.pulmonaryrehab.com.au
43 Hoberty PD, Chiu CY, Hoberty RJ. Staffing exercise sessions in pulmonary rehabilitation. *Respir. Care* 2001; **46**: 694–7.
44 British Thoracic Society. Pulmonary rehabilitation. *Thorax* 2001; **56**: 827–34.
45 Hernandez MTE, Rubio TM, Ruiz FO *et al*. Results of a home-based training program for patients with COPD. *Chest* 2000; **118**: 106–14.
46 Maltais F, Bourbeau B, Shapiro S *et al*. Effects of home-based pulmonary rehabilitation in patients with chronic obstructive pulmonary disease. *Ann. Intern. Med.* 2008; **149**: 869–78.
47 van Wetering CR, Hoogendoorn M, Mol SJM *et al*. Short- and long-term efficacy of a community-based COPD management programme in less advanced COPD: a randomised controlled trial. *Thorax* 2010; **65**: 7–13.
48 Goldstein RS, Gort EH, Stubbing D *et al*. Randomised controlled trial of respiratory rehabilitation. *Lancet* 1994; **344**: 1394–7.
49 Rochester C. Which pulmonary rehabilitation program is best for your patient? *J. Respir. Dis.* 2000; **21**: 539–46.
50 McCue M, Fairman A, Pramuka M. Enhancing quality of life through telerehabilitation. *Phys. Med. Rehabil. Clin. N. Am.* 2010; **21**: 195–205.
51 Berry MJ, Rejeski WJ, Adair NE *et al*. Exercise rehabilitation and chronic obstructive pulmonary disease stage. *Am. J. Respir. Crit. Care Med.* 1999; **160**: 1248–53.
52 Chavannes N, Vollenberg JJH, van Schyck CP *et al*. Effects of physical activity in mild to moderate COPD: a systematic review. *Br. J. Gen. Pract.* 2002; **52**: 574–8.
53 Garrod R, Marshall J, Barley E *et al*. Predictors of success and failure in pulmonary rehabilitation. *Eur. Respir. J.* 2006; **27**: 788–94.

54 Evans RA, Singh SJ, Collier R *et al*. Pulmonary rehabilitation is successful for COPD irrespective of MRC dyspnoea grade. *Respir. Med.* 2009; **103**: 1070–5.
55 Sabit R, Griffiths TL, Watkins AJ *et al*. Predictors of poor attendance at an outpatient pulmonary rehabilitation programme. *Respir. Med.* 2008; **102**: 819–24.
56 Trappenburg JC, Troosters T, Spruit MA *et al*. Psychosocial conditions do not affect short-term outcomes of multidisciplinary rehabilitation in chronic obstructive pulmonary disease. *Arch. Phys. Med. Rehabil.* 2005; **86**: 1788–92.
57 Haave E, Skumlien S, Hyland ME. Gender considerations in pulmonary rehabilitation. *J. Cardiopulm. Rehabil. Prev.* 2008; **28**: 215–19.
58 Di Meo F, Pedone C, Lubich S *et al*. Age does not hamper the response to pulmonary rehabilitation of COPD patients. *Age Ageing* 2008; **37**: 530–5.
59 Young P, Dewse M, Fergusson W *et al*. Respiratory rehabilitation in chronic obstructive pulmonary disease: predictors of nonadherence. *Eur. Respir. J.* 1999; **13**: 855–9.
60 Troosters TRG, Decramer M. Exercise training in COPD: how to distinguish responders from nonresponders. *J. Cardpulm. Rehabil.* 2001; **12**: 10–17.
61 ZuWallack RL, Patel K, Reardon JZ *et al*. Predictors of improvement in the 12-minute walking distance following a six-week outpatient pulmonary rehabilitation program. *Chest* 1991; 805–8.
62 Bulley C, Donaghy M, Howden S *et al*. A prospective qualitative exploration of views about attending pulmonary rehabilitation. *Physiother. Res. Int.* 2009; **14**: 181–92.
63 American Thoracic Society. ATS Statement: guidelines for the six-minute walk test. *Am. J. Respir. Crit. Care Med.* 2002; **166**: 111–17.
64 Singh SJ, Morgan MDL, Scott S *et al*. Development of a shuttle walking test of disability in patients with chronic airways obstruction. *Thorax* 1992; **47**: 1019–24.
65 Revill SM, Morgan MDL, Singh SJ *et al*. The endurance shuttle walk: a new field test for the assessment of endurance capacity in chronic obstructive pulmonary disease. *Thorax* 1999; **54**: 213–22.
66 Eiser N, Willsher D, Dore CJ. Reliability, repeatability and sensitivity to change of externally and self-paced walking tests in COPD patients. *Respir. Med.* 2003; **97**: 407–14.
67 Jenkins S, Cecins NM. Six-minute walk test in pulmonary rehabilitation: do all patients need a practice test? *Respirology* 2010; **15**: 1192–6.
68 Spencer LM, Alison JA, McKeough ZJ. Six-minute walk test as an outcome measure: are two six-minute walk tests necessary immediately after pulmonary rehabilitation and at three-month follow-up? *Am. J. Phys. Med. Rehabil.* 2008; **87**: 224–8.
69 Holland AE, Hill CJ, Rasekaba T *et al*. Updating the minimal important difference for six-minute walk distance in patients with chronic obstructive pulmonary disease. *Arch. Phys. Med. Rehabil.* 2010; **91**: 221–5.
70 Puhan MA, Mador MJ, Held U *et al*. Interpretation of treatment changes in six-minute walk distance in patients with COPD. *Eur. Respir. J.* 2008; **32**: 637–43.
71 Redelmeier DA, Bayoumi AM, Goldstein RS *et al*. Interpreting small differences in functional status: the six minute walking test in chronic lung disease patients. *Am. J. Respir. Crit. Care Med.* 1997; **155**: 1278–82.
72 Singh SJ, Jones PW, Evans R *et al*. The minimum clinically important improvement for the incremental shuttle walking test. *Thorax* 2008; **63**: 775–7.
73 American Thoracic Society/American College of Chest Physicians. ATS/ACCP statement on cardiopulmonary exercise testing. *Am. J. Respir. Crit. Care Med.* 2003; **167**: 211–77.
74 Puente-Maestu L, Villar F, de Miguel J *et al*. Clinical relevance of constant power exercise duration changes in COPD. *Eur. Respir. J.* 2009; **34**: 340–5.
75 Guyatt G. Measuring health status in chronic airflow limitation. *Eur. Respir. J.* 1988; **1**: 560–4.
76 Jones PW. Health status measurement in chronic obstructive pulmonary disease. *Thorax* 2001; **56**: 880–7.
77 Singh SJ, Sodergren SC, Hyland ME *et al*. A comparison of three disease-specific and two generic health-status measures to evaluate the outcome of pulmonary rehabilitation in COPD. *Respir. Med.* 2001; **95**: 71–7.
78 Jaeschke R, Singer J, Guyatt GH. Measurement of health status. Ascertaining the minimal clinically important difference. *Control. Clin. Trials* 1989; **10**: 407–15.
79 Jones PW. Interpreting thresholds for a clinically significant change in health status in asthma and COPD. *Eur. Respir. J.* 2002; **19**: 398–404.
80 Bestall JC, Paul EA, Garrod R *et al*. Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. *Thorax* 1999; **54**: 581–6.
81 Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr. Scand.* 1983; **67**: 361–70.
82 Puhan MA, Frey M, Buchi S *et al*. The minimal important difference of the hospital anxiety and depression scale in patients with chronic obstructive pulmonary disease. *Health Qual. Life Outcomes* 2008; **6**: doi: 10-1186/147-7256-6.46
83 Celli BR, Cote CG, Marin JM *et al*. The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. *N. Engl. J. Med.* 2004; **350**: 1005–12.
84 Bohannon RW. Measuring knee extensor muscle strength. *Am. J. Phys. Med. Rehabil.* 2001; **80**: 13–18.
85 O'Shea SD, Taylor NF, Paratz JD. Measuring muscle strength for people with chronic obstructive pulmonary disease: retest reliability of hand-held dynamometry. *Arch. Phys. Med. Rehabil.* 2007; **88**: 32–6.
86 Takahashi T, Jenkins SC, Strauss GR *et al*. A new unsupported upper limb exercise test for patients with chronic obstructive pulmonary disease. *J. Cardpulm. Rehabil.* 2003; **23**: 430–7.
87 Zhan S, Cerny FJ, Gibbons WJ *et al*. Development of an unsupported arm exercise test in patients with chronic obstructive pulmonary disease. *J. Cardpulm. Rehabil.* 2006; **26**: 180–7.
88 Hill CJ, Denehey L, Holland AE *et al*. Measurement of functional activity in chronic obstructive pulmonary disease: the grocery shelving task. *J. Cardiopulm. Rehabil. Prev.* 2008; **28**: 402–9.
89 Smith MD, Chang AT, Seale HE *et al*. Balance is impaired in people with chronic obstructive pulmonary disease. *Gait Posture* 2010; **31**: 456–60.
90 Berg KO, Wood-Dauphinee SL, Williams JL *et al*. Measuring balance in the elderly: validation of an instrument. *Can. J. Public Health.* 1992; **83**: S7–11.
91 Beauchamp MK, Hill K, Goldstein RS *et al*. Impairments in balance discriminate fallers from non-fallers in COPD. *Respir. Med.* 2009; **103**: 1885–9.
92 Bendstrup KE, Ingemann Jensen J, Holm S *et al*. Out-patient rehabilitation improves activities of daily living, quality of life and exercise tolerance in chronic obstructive pulmonary disease. *Eur. Respir. J.* 1997; **10**: 2801–6.
93 Rossi G, Florini F, Romagnoli M *et al*. Length and clinical effectiveness of pulmonary rehabilitation in outpatients with chronic airway obstruction. *Eur. Respir. J.* 2005; **127**: 105–9.
94 ZuWallack R, Hashim A, McCuske C *et al*. The trajectory of change over multiple outcome areas during comprehensive outpatient pulmonary rehabilitation. *Chron. Respir. Dis.* 2006; **3**: 11–18.
95 Man WD-C, Mohamed G, Soliman G *et al*. Symptoms and quadriceps fatigability after walking and cycling in chronic obstructive pulmonary disease. *Am. J. Respir. Crit. Care Med.* 2003; **168**: 562–7.
96 Leung RWM, Alison JA, McKeough ZJ *et al*. Ground walking training improves functional exercise capacity more than cycle

training in people with chronic obstructive pulmonary disease (COPD): a randomised trial. *J. Physiother.* 2010; **56**: 105–12.
97 Casaburi R, Patessio A, Ioli F *et al*. Reductions in exercise lactic acidosis and ventilation as a result of exercise training in patients with obstructive lung disease. *Am. Rev. Respir. Dis.* 1991; **143**: 9–18.
98 Clark CJ, Cochrane L, Mackay E. Low intensity peripheral muscle conditioning improves exercise tolerance and breathlessness in COPD. *Eur. Respir. J.* 1996; **9**: 2590–6.
99 Normandin EA, McCusker C, Connors M *et al*. An evaluation of two approaches to exercise conditioning in pulmonary rehabilitation. *Chest* 2002; **121**: 1085–91.
100 Puente-Maestu L, Sanz ML, Sanz P *et al*. Comparison of effects of supervised versus self-monitored training programmes in patients with chronic obstructive pulmonary disease. *Eur. Respir. J.* 2000; **15**: 517–25.
101 Punzal PA, Ries AL, Kaplan RM *et al*. Maximum intensity exercise training in patients with chronic obstructive pulmonary disease. *Chest* 1991; **100**: 618–23.
102 Jenkins SC. 6-Minute walk test in patients with COPD – clinical applications in pulmonary rehabilitation. *Physiotherapy* 2007; **93**: 175–82.
103 Singh SJ, Morgan MDL, Hardman AE *et al*. Comparison of oxygen uptake during a conventional treadmill test and the shuttle walking test in chronic airflow limitation. *Eur. Respir. J.* 1994; **7**: 2016–20.
104 Arnardottir R-H, Emtner M, Hedenstron H *et al*. Peak exercise capacity estimated from shuttle walking test in patients with COPD: a methodological study. *Respir. Res.* 2006; **7**.
105 Hill K, Jenkins SC, Cecins N *et al*. Estimating maximum work rate during incremental cycle ergometry testing from 6-minute walk distance in patients with chronic obstructive pulmonary disease. *Arch. Phys. Med. Rehabil.* 2008; **89**: 1782–7.
106 Luxton N, Alison JA, Wu J *et al*. Relationship between field walking tests and incremental cycle ergometry in COPD. *Respirology* 2008; **13**: 856–62.
107 Holland AE, Hill K, Alison JA *et al*. Estimating peak work rate during incremental cycle ergometry from the 6-minute walk distance: differences between reference equations. *Respiration* 2010; doi: 10.1159/000308464.
108 Kozu R, Jenkins S, Senjyu H *et al*. Peak power estimated from 6-minute walk distance in Asian patients with idiopathic pulmonary fibrosis and chronic obstructive pulmonary disease. *Respirology* 2010; doi: 10.111/j.1440- 1843.2010.01744.x.
109 Borg G. Perceived exertion as an indicator of somatic stress. *Scand. J. Rehabil. Med.* 1970; **2**: 92–8.
110 Borg GAV. Psychophysical bases of perceived exertion. *Med. Sci. Sports Exerc.* 1982; **14**: 377–81.
111 Beauchamp MK, Dolmage TE, Nonoyama M *et al*. Interval versus continuous training in individuals with COPD. *Thorax* 2010; **65**: 157–64.
112 Solway S, Brooks D, Lau L *et al*. The short-term effect of a rollator on functional exercise capacity among individuals with severe COPD. *Chest* 2002; **122**: 56–65.
113 Probst VS, Troosters T, Coosermans I *et al*. Mechanisms of improvement in exercise capacity using a rollator in patients with COPD. *Chest* 2004; **126**: 1102–7.
114 Nonoyama ML, Brooks D, Lacasse Y *et al*. Oxygen therapy during exercise training in chronic obstructive pulmonary disease. *Cochrane Database Syst. Rev.* 2007; **2**: CD005372.
115 Laude EA, Duffy NC, Bavestock C *et al*. The effect of helium and oxygen on exercise performance in chronic obstructive pulmonary disease: a randomised crossover trial. *Am. J. Respir. Crit. Care Med.* 2006; **173**: 865–70.
116 Eves ND, Sandmeyer LC, Wong EY *et al*. Helium-hyperoxia: a novel intervention to improve the benefits of pulmonary rehabilitation for patients with COPD. *Chest* 2009; **135**: 609–18.
117 Hawkins P, Johnson LC, Nikoletou D *et al*. Proportional assist ventilation as an aid to exercise training in severe chronic obstructive pulmonary disease. *Thorax* 2002; **57**: 853–9.
118 Vivodtzev I, Lacasse Y, Maltais M. Neuromuscular electrical stimulation of the lower limbs in patients with chronic obstructive pulmonary disease. *J. Cardiopulm. Rehabil. Prev.* 2008; **28**: 79–91.
119 Sillen MJ, Speksnijder CM, Eterman RM *et al*. Effects of neuromuscular stimulation of muscles of ambulation in patients with chronic heart failure or COPD: a systematic review of the English-language literature. *Chest* 2009; **136**: 44–61.
120 Collins EG, Langbein WE, Fehr L *et al*. Can ventilation-feedback training augment exercise tolerance in patients with chronic obstructive pulmonary disease? *Am. J. Respir. Crit. Care Med.* 2008; **177**: 844–52.
121 Dolmage TE, Goldstein RS. Effects of one-legged exercise training of patients with COPD. *Chest* 2008; **133**: 370–6.
122 Gosselink R, Troosters T, Decramer M. Distribution of muscle weakness in patients with stable chronic obstructive pulmonary disease. *J. Cardpulm. Rehabil.* 2000; **20**: 353–60.
123 Gosselink R, Troosters T, Decramer M. Peripheral muscle weakness contributes to exercise limitation in COPD. *Am. J. Respir. Crit. Care Med.* 1996; **153**: 976–80.
124 O'Shea SD, Taylor NF, Paratz JD. Progressive resistance exercise improves muscle strength and may improve elements of performance of daily activities for people with COPD: a systematic review. *Chest* 2009; **135**: 1269–83.
125 Chodzko-Zajko WJ, Proctor DN, Fiatarone Dingh MA *et al*. American College of Sports Medicine Position Standards. Exercise and physical activity for older adults. *Med. Sci. Sports Exerc.* 2009; **41**: 1510–30.
126 Storer TW. Exercise in chronic pulmonary disease: resistance exercise prescription. *Med. Sci. Sports Exerc.* 2001; **33**: S680–92.
127 Probst VS, Troosters T, Pitta F *et al*. Cardiopulmonary stress during exercise training in patients with COPD. *Eur. Respir. J.* 2006; **27**: 1110–18.
128 Janaudis-Ferreira T, Hill K, Goldstein R *et al*. Arm exercise training in patients with chronic obstructive pulmonary disease. A systematic review. *J. Cardiopulm. Rehabil. Prev.* 2009; **29**: 277–83.
129 Martinez FJ, Vogel PD, Dupont DN *et al*. Supported arm exercise vs unsupported arm exercise in the rehabilitation of patients with severe chronic airflow obstruction. *Chest* 1993; **103**: 1397–402.
130 McKeough ZJ, Alison JA, Bye PTP. Arm exercise capacity and dyspnea ratings in subjects with chronic obstructive pulmonary disease. *J. Cardpulm. Rehabil.* 2003; **23**: 218–25.
131 Gosselink R. Breathing techniques in patients with chronic obstructive pulmonary disease (COPD). *Chron. Respir. Dis.* 2004; **1**: 163–72.
132 Bott J, Blumenthal S, Buxton M *et al*. Guidelines for the physiotherapy management of the adult, medical, spontaneously breathing patient. *Thorax* 2009; **64** (Suppl. 1): i1–51.
133 Breslin EH. The pattern of respiratory muscle recruitment during pursed-lips breathing. *Chest* 1992; **101**: 75–8.
134 Tiep BL, Burns M, Kao D *et al*. Pursed lips breathing training using ear oximetry. *Chest* 1986; **90**: 218–21.
135 Ingram RH, Schilder DP. Effect of pursed lips breathing on the pulmonary pressure-flow relationship in obstructive lung disease. *Am. Rev. Respir. Dis.* 1967; **96**: 381–8.
136 Mueller RE, Petty TL, Filley GF. Ventilation and arterial blood gas changes induced by pursed lips breathing. *J. Appl. Physiol.* 1970; **28**: 784–9.
137 Garrod R, Dallimore K, Cook J *et al*. An evaluation of the acute impact of pursed lips breathing on walking distance in nonspontaneous pursed lips breathing chronic obstructive pulmonary disease patients. *Chron. Respir. Dis.* 2005; **2**: 67–72.
138 Spahija J, de Marchie M, Grassino A. Effects of imposed pursed-lips breathing on respiratory mechanics and dyspnea at rest and during exercise in COPD. *Chest* 2005; **128**: 640–50.
139 Barach AL. Chronic obstructive pulmonary disease: postural relief of dyspnea. *Arch. Phys. Med. Rehabil.* 1974; **55**: 494–504.

140 Sharp JT, Drutz WS, Moisan T *et al*. Postural relief of dyspnea in severe chronic obstructive pulmonary disease. *Am. Rev. Respir. Dis.* 1980; **122**: 201–11.
141 O'Neill S, McCarthy DS. Postural relief of dyspnoea in severe chronic airflow limitation: relationship to respiratory muscle strength. *Thorax* 1983; **38**: 595–600.
142 Weerapong P, Hume PA, Kolt GS. Stretching: mechanisms and benefits for sport performance and injury prevention. *Phys. Ther. Rev.* 2004; **9**: 189–206.
143 O'Brien K, Geddes L, Reid D *et al*. Inspiratory muscle training compared with other rehabilitation interventions in chronic obstructive pulmonary disease: a systematic review update. *J. Cardiopulm. Rehabil. Prev.* 2008; **28**: 128–41.
144 Lotters F, van Tol B, Kwakkel G *et al*. Effects of controlled inspiratory muscle training in patients with COPD: a meta-analysis. *Eur. Respir. J.* 2002; **20**: 570–6.
145 Geddes EL, O'Brien K, Reid WD *et al*. Inspiratory muscle training in adults with chronic obstructive pulmonary disease: an update of a systematic review. *Respir. Med.* 2008; **102**: 1715–29.
146 Eastwood PR, Hillman DR. A threshold loading device for testing of inspiratory muscle performance. *Eur. Respir. J.* 1995; **8**: 463–6.
147 Larson JL, Kim MJ, Sharp JT *et al*. Inspiratory muscle training with pressure threshold breathing device in patients with chronic obstructive pulmonary disease. *Am. Rev. Respir. Dis.* 1988; **138**: 689–96.
148 Hill K, Jenkins SC, Philippe DL *et al*. High-intensity inspiratory muscle training in chronic obstructive pulmonary disease. *Eur. Respir. J.* 2006; **27**: 1119–28.
149 Hill K, Cecins NM, Eastwood PR *et al*. Inspiratory muscle training for patients with chronic obstructive pulmonary disease: a practical guide for clinicians. *Arch. Phys. Med. Rehabil.* 2010; **91**: 1466–70.
150 Jenkins S, Cecins N. Six minute walk test: observed adverse events and oxygen desaturation in a large cohort of patients with chronic lung disease. *Int. Med. J. Int. Med. J.* 2010; e-pub. doi: 10.1111/j.1445-5994.2010.02169.x.
151 Turner SE, Eastwood PR, Cecins NM *et al*. Physiologic responses to incremental and self-paced exercise in COPD. A comparison of three tests. *Chest* 2004; **126**: 766–73.
152 Poulain M, Durand F, Palomba B *et al*. 6-Minute walk testing is more sensitive than maximal incremental cycle testing for detecting oxygen desaturation in patients with COPD. *Chest* 2003; **123**: 1401–7.
153 Hsia D, Casaburi R, Pradhan A *et al*. Physiologic responses to linear treadmill and cycle ergometer exercise in COPD. *Eur. Respir. J.* 2009; **34**: 605–15.
154 Crisafulli E, Costi S, Luppi F *et al*. Role of comorbidities in a cohort of patients with COPD undergoing pulmonary rehabilitation. *Thorax* 2008; **63**: 487–92.
155 Crisafulli E, Gorgone P, Vagaggini B *et al*. Efficacy of standard rehabilitation in COPD outpatients with co-morbidities. *Eur. Respir. J.* 2010; doi:10.1183/09031936.00203809.
156 Wadell K, Sundelin G, Henriksson-Larson B *et al*. High intensity physical group training in water – an effective training modality for patients with COPD. *Respir. Med.* 2004; **98**: 428–38.
157 McNamara RJ, Alison JA, McKenzie DK *et al*. Water-based exercise improves exercise capacity in people with COPD with physical co-morbid conditions. *Respirology* 2010; **15** (Suppl. 1): A24.
158 Vermeeren MAP, Creutzberg EC, Schols AM *et al*. Prevalence of nutritional depletion in a large out-patient population of patients with COPD. *Respir. Med.* 2006; **100**: 1349–55.
159 Poulain M, Doucet M, Major GC *et al*. The effect of obesity on chronic respiratory diseases: pathophysiology and therapeutic strategies. *Can. Med. Assoc. J.* 2006; **174**: 1293–9.
160 Watson L, Ellis B, Leng GC. Exercise for intermittent claudication. *Cochrane Database Syst. Rev.* 2008; **4**: CD000990.
161 Gardner AW, Afaq A. Management of lower extremity peripheral arterial disease. *J. Cardiopulm. Rehabil. Prev.* 2008; **28**: 349–57.
162 Lee AL, Cecins N, Hill CJ *et al*. The effects of pulmonary rehabilitation in patients with non-cystic fibrosis bronchietasis: protocol for a randomized controlled trial. *BMC Pulm. Med.* 2010; **10**: 5.
163 Swigris JJ, Stewart AL, Gould MK *et al*. Patients' perspectives on how idiopathic pulmonary fibrosis affects the quality of their lives. *Health Qual. Life Outcomes* 2005; **3**: 61.
164 Lange P, Parner J, Vestbo J *et al*. A 15-year follow-up study of ventilatory function in adults with asthma. *N. Engl. J. Med.* 1998; **339**: 1194–200.
165 Hughes JMB. Assessing gas exchange. *Chron. Respir. Dis.* 2007; **4**: 205–14.
166 Storms WW. Asthma associated with exercise. *Immunol. Allergy Clin. N. Am.* 2005; **25**: 31–43.
167 Weiler JM, Bonini S, Coifman R *et al*. American academy of allergy, asthma & immunology work group report: exercise-induced asthma. *J. Allergy Clin. Immunol.* 2007; **119**: 1349–58.
168 Ries AL, Kaplan RM, Limberg TM *et al*. Effects of pulmonary rehabilitation on physiologic and psychosocial outcomes in patients with chronic obstructive pulmonary disease. *Ann. Intern. Med.* 1995; **122**: 823–32.
169 Griffiths TL, Burr ML, Campbell IA *et al*. Results at 1 year of outpatient multidisciplinary pulmonary rehabilitation: a randomised controlled trial. *Lancet* 2000; **355**: 362–8.
170 Bestall JC, Paul EA, Garrod R *et al*. Longitudinal trends in exercise capacity and health status after pulmonary rehabilitation in patients with COPD. *Respir. Med.* 2003; **97**: 173–80.
171 Brooks D, Krip B, Mangovski-Alzamora S *et al*. The effect of postrehabilitation programs among individuals with chronic obstructive pulmonary disease. *Eur. Respir. J.* 2002; **20**: 20–9.
172 Cockram J, Cecins N, Jenkins S. Maintaining exercise capacity and quality of life following pulmonary rehabilitation. *Respirology* 2006; **11**: 98–104.
173 Ries AL, Kaplan RM, Myers R *et al*. Maintenance after pulmonary rehabilitation in chronic lung disease. *Am. J. Respir. Crit. Care Med.* 2003; **167**: 880–8.
174 Foglio K, Bianchi L, Ambrosino N. Is it really useful to repeat outpatient pulmonary rehabilitation programs in patients with airway obstruction? A 2-year controlled study. *Chest* 2001; **119**: 1696–704.
175 Spencer LM, Alison JA, McKeough ZJ. Maintaining benefits following pulmonary rehabilitation: a randomised controlled trial. *Eur. Respir. J.* 2010; **35**: 571–7.
176 White R, Walker P, Roberts S *et al*. Bristol COPD Knowledge Questionnaire (BCKQ): testing what we teach patients about COPD. *Chron. Respir. Dis.* 2006; **3**: 123–32.
177 Norweg AM, Whitson J, Malgady R *et al*. The effectiveness of different combinations of pulmonary rehabilitation program components. A randomized controlled trial. *Chest* 2005; **128**: 663–72.
178 Lorig KR, Sobel DS, Stewart AL *et al*. Evidence suggesting that a chronic disease self-management program can improve health status while reducing utilization and costs: a randomized trial. *Med. Care* 1999; **37**: 5–14.
179 Bourbeau J, Julien M, Maltais F *et al*. Reduction of hospital utilization in patients with chronic obstructive pulmonary disease. A disease-specific self-management intervention. *Arch. Intern. Med.* 2003; **163**: 585–91.
180 Harris D, Hayter M, Allender S. Improving the uptake of pulmonary rehabilitation in patients with COPD: qualitative study of experience and attitudes. *Br. J. Gen. Pract.* 2008; **58**: 702–10.