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Pulmonary Rehabilitation in COPD: Current Practice and Future Directions

Michelle Casey, Amy Mulkerns,
Cliona O'Donnell and Tim McDonnell

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<http://dx.doi.org/10.5772/intechopen.71218>

Abstract

This chapter will review the rationale for and the need for pulmonary rehabilitation in patients with Chronic Obstructive Pulmonary Disease (COPD). Its clinical effectiveness will be considered, including the evidence supporting a role for rehabilitation in improving exercise tolerance in COPD as measured. While the influence of pulmonary rehabilitation on dyspnoea, exercise tolerance and quality-of-life is clear, evidence for the benefits of rehabilitation on reducing healthcare utilisation such as admission to hospital or attendance at out-of-hours services is limited. The chapter will provide guidance on the setting up of a pulmonary rehabilitation programme and clinical staff required and the suitability of patients to enter such programmes will be outlined. There will be discussion on the key components of a programme including education, nutritional advice and the management of dyspnoea. Exercise is the central component of pulmonary rehabilitation. Assessment of the patient and prescription of an exercise programme will be outlined as will assessing a patient's improvement. One key goal of pulmonary rehabilitation is ongoing lifestyle modification to encourage patients to undertake a more active lifestyle in the future. Ways of activating patients to do this will be discussed and the evidence for the use of telehealth in this area will be reviewed.

Keywords: pulmonary rehabilitation, COPD, exercise, physical activity

1. Introduction

COPD is a systemic disease associated with extra pulmonary effects such as osteopaenia, muscle wasting, cardiovascular disease and depression [1]. The symptoms of COPD make engagement in physical activity unpleasant. Air trapping and hyperinflation of the lungs

cause increased breathlessness due to the resultant inefficient breathing. The breathlessness itself provokes anxiety, which in turn leads to further breathlessness, exacerbations of COPD and episodes of panic. Due to this, activities that involve physical exertion are avoided, leading to muscle deconditioning and a further reduced capacity to engage in physical activity. Pulmonary rehabilitation improves symptoms, quality of life and health-care utilisation in patients with COPD [1, 2].

Pulmonary rehabilitation is defined as “an interdisciplinary programme of care for patients with chronic respiratory impairment that is individually tailored and designed to optimise each patient’s physical and social performance and autonomy. Programmes comprise individualised exercise programmes and education” [3]. Physical inactivity is a key predictor of mortality in COPD and consequently all major guidelines highlight the importance of exercise in the treatment and management of COPD. There is now high quality evidence for improved exercise capacity, health-related quality of life and decreased breathlessness, fatigue and health-care utilisation following pulmonary rehabilitation [1].

Pulmonary rehabilitation is focussed on an interdisciplinary and holistic approach to the management of COPD, emphasising behavioural change as a key component. It fits very well with the concept of integrated care, with its cornerstone being individually tailored exercise training. Patient assessment, education, psychosocial support and nutritional counselling are also included in the standard pulmonary rehabilitation programme. Overall, the focus of a pulmonary rehabilitation programme is to alleviate the physiological effects of the disease process and decrease the psychosocial effects of the illness on the individual.

2. Historical development

The effects of exercise in patients with chronic respiratory diseases have been a subject for study for some time. By the middle of the 20th century, accepted wisdom was that dyspnoea on exertion should be avoided [4]. Dr. Alvan Barach was the first to offer a contrary opinion in the 1950s, with his advice to “remember to cure the patient as well as the disease”. Thomas L. Petty was the first to establish an out-patient programme of pulmonary rehabilitation in the 1960s, despite the conventional wisdom of not exerting patients with respiratory limitations. This programme included individualised instruction, bronchial hygiene, breathing retraining, physical reconditioning and individualised pharmacologic therapy. Rehabilitation programmes were set up throughout the USA, and Petty noted improved exercise tolerance, reduced hospitalisations and a return to gainful employment in the majority of his patients [4]. Subsequently, in the 1980s a view became prevalent that as exercise conditioning did not improve lung function, pulmonary rehabilitation was unlikely to provide physiological benefit to patients. It was felt that if physiological benefit was not demonstrated, the programme design was not particularly important. Finally, in the 1990s, physiologic benefit was proven by using exercise at a higher intensity and the concept of pulmonary rehabilitation was reinvigorated [4, 5].

3. Rationale for pulmonary rehabilitation

Pulmonary rehabilitation is designed to reduce the symptoms of COPD, improve health related quality of life (HRQoL), improve and re-establish functional ability, enhance participation in everyday life and promote patient autonomy. The exercise component of pulmonary rehabilitation increases inspiratory volume and reduces dynamic hyperinflation, both of which reduce dyspnoea when a person is performing tasks. Exercise also increases muscle function, which delays fatigue and results in increased exercise tolerance. The educational component focuses on self-management and behaviour change. Providing information and knowledge, skills such as goal setting, problem solving and decision making, along with action plans to better recognise and manage their disease are all integral parts of the programme. Modifying nutritional intake and smoking patterns, medication adherence and utilising effective energy-saving strategies and breathing techniques are part of the education component [1].

The exercise capacity of patients with COPD is often impaired and limited by dyspnoea. The reasons for this are complex and multifactorial, including defective gas exchange, dynamic hyperinflation, peripheral muscle dysfunction, respiratory muscle dysfunction, the effects of physical deconditioning, the presence of co-morbidities and the natural age-related decline in exercise capacity [6]. Physical exercise in pulmonary rehabilitation is the best method of improving muscle function and skeletal muscle adaption in patients with COPD [5, 7–10]. The benefits pulmonary rehabilitation produces are explained by improvements in muscle function and the oxidative capacity and efficiency of skeletal muscles, despite the absence of any changes in lung function [11, 12]. Other related improvements include increased motivation, improved mood and improved cardiovascular functioning, which result in ongoing participation in exercise beyond the rehabilitation programme [13].

Even those patients with severe chronic respiratory disease can often sustain the necessary training intensity and duration for skeletal muscle adaptation. Skeletal muscle adaptation following exercise training leads to gains in exercise capacity despite the absence of changes in lung function. In addition, the improved oxidative capacity and efficiency of the skeletal muscles leads to a reduced ventilator requirement for a given submaximal work rate. This could reduce dynamic hyperinflation, adding to the reduction in exertional dyspnoea [6]. Medical therapy should be optimised prior to exercise training beginning and a patient assessment is required prior to beginning an exercise programme.

4. The clinical effectiveness of pulmonary rehabilitation

4.1. Physiological

One of the first studies to show an improvement in exercise tolerance following exercise training in COPD was Casaburi et al. in 1991 [14]. They showed a statistically significant improvement in exercise tolerance and reduced blood lactate and ventilatory requirement

post exercise. These findings have been supported by others [5] and a Cochrane review in 2009 [2] showed a statistically significant improvement in exercise capacity in people who underwent a pulmonary rehabilitation programme. Results of a further Cochrane review in 2015 strongly supported the benefits of pulmonary rehabilitation [1]. They found clinically and statistically significant improvements in important domains of health-related quality of life, including dyspnoea, fatigue, emotional function and mastery, as well as the 6 minute walk test: a measure of functional exercise [1]. Also noted was a small but statistically significant improvement in physical activity levels. Physical activity has become more important in COPD management as it has been shown that inactivity is linked with reduced survival, poorer quality of life and increased healthcare utilisation [15].

4.2. Quality of life

The benefits of pulmonary rehabilitation on dyspnoea and health status have been supported by a Cochrane review [1]. The Chronic Respiratory Questionnaire was used in a number of studies and showed an improvement in dyspnoea that was statistically significant and clinically relevant. Improvement was also noted in the other CRQ domains of fatigue, emotional function and patient's sense of control. The St. Georges Respiratory Questionnaire Scores were also subject to a meta-analysis in the same Cochrane review and found to show significant improvement following pulmonary rehabilitation [16].

4.3. Reduction of healthcare utilisation

Several studies have investigated whether pulmonary rehabilitation leads to a decrease in the number of caregiver or physician visits, hospital days, and medication use [3, 6]. In general, some benefit is shown in this important area. Several randomised studies comparing pulmonary rehabilitation with usual care found a trend towards reduced hospital admissions and hospital days. Studies comparing healthcare use before and after pulmonary rehabilitation show that pulmonary rehabilitation significantly reduced emergency room visits and physician visits [3, 6].

4.4. Psychosocial

In a Cochrane review published in 2015, participants allocated to rehabilitation had significantly greater changes in HRQoL [17]. A Cochrane review in 2009 had previously shown moderate to large effects of rehabilitation on health-related quality of life and exercise capacity [2].

4.5. Self-efficacy

Self-efficacy refers to the level of belief someone has in their ability to complete a chosen task or goal. Overall, self-efficacy scores improve with pulmonary rehabilitation [1].

4.6. Survival

There is limited evidence for increased survival to date, however only one randomised controlled trial has looked at survival: the control group received education and the intervention group received rehabilitation and education. The study was unlikely to be powered to detect mortality [18]. A prospective observational study of 1218 patients showed no mortality benefit from pulmonary rehabilitation [19]; however, another study did show improved mortality in patients where exercise capacity and dyspnoea improved after rehabilitation only [9].

4.7. Nutrition

In an underweight population, some small weight gain was noted following exercise training; however, in general the effect of pulmonary rehabilitation on nutritional status does not appear to be significant. Nutritional outcomes at the start of a rehabilitation programme do not affect outcomes such as exercise capacity or health status [6].

5. Setting up a pulmonary rehabilitation Programme

5.1. Duration

There remains no consensus internationally on the optimum duration of a pulmonary rehabilitation programme. However, pulmonary rehabilitation programmes of 6–12 weeks are recommended and demonstrate a significant benefit in health status, dyspnoea and exercise in patients with chronic respiratory diseases limited by breathlessness. An attendance at a minimum of 12 exercise sessions is recommended to successfully complete the programme. Programmes of less than 6 weeks have been shown to provide some benefits in health status and exercise capacity in individuals with COPD; however, these programmes should be individualised and measures of benefit should be in place prior to the patient concluding the programme. The ongoing benefits of a pulmonary rehabilitation programme of longer than 3 months duration has been shown, including changes in daily physical activity levels, but the cost benefit of these remains unclear [3, 6, 20–22].

5.2. Frequency

The recommended frequency of exercise classes also differs internationally. The general consensus supports a minimum of two supervised exercise sessions per week, and either a third supervised session or formalised unsupervised session depending on the resources available. This is in contrast with the WHO recommendation of 5 sessions of 30 minutes exercise per week. However, to date the key improvement outcomes in pulmonary rehabilitation are based on at least two supervised sessions per week. Pulmonary rehabilitation

programmes should therefore encompass a minimum of twice weekly supervised exercise sessions, a third session of prescribed unsupervised exercise and encouragement of regular physical activity for 30 minutes five days per week in line with standard healthy living advice [3, 6, 20–22].

5.3. Staffing

There is no consensus on staffing levels for a pulmonary rehabilitation programme. The staffing of the programmes varies globally, with physical therapists coordinating programmes in Australia, South America and Europe, while respiratory therapists coordinate programmes in the United States. There is no one best staffing structure. Optimal staff-patient ratios also differ: the American Association of Cardiovascular and Pulmonary Rehabilitation recommends ratios of 1:4 for exercise training, 1:8 for educational sessions and 1:1 for complex patients; the British Thoracic Society recommends ratios of 1:8 for exercise training and 1:16 for educational sessions. These ratios are not evidence based and are designed based on experience and opinion [3, 6, 20–22].

It is recommended and accepted that for patients to gain optimum benefit from a pulmonary rehabilitation programme, a multidisciplinary approach should be taken [13, 23]. Availability of resources and staff will dictate the level of input the Multidisciplinary team will have but each member plays an important role in the rehabilitation programme:

- *Respiratory physician*: medical assessment; pharmacological management; referral; screening for oxygen and 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 for ambulatory oxygen requirements.
- *Respiratory nurse*: Disease specific education; development of action plans; inhaler technique training.
- *Dietician*: Nutritional assessment and advice.
- *Occupational therapist*: Assessment and modification of home environment; energy conservation advice.
- *Pharmacist*: advice and education on respiratory education and inhaler use.
- *Social worker*: information and access to support services.
- *Psychologist*: psychosocial assessment and treatment for conditions including panic, anxiety and depression.

5.4. Rolling or cohort programme

Deciding on whether to administer a rolling or a cohort programme is dependent on local considerations, as there is no high-quality evidence to suggest the benefit of one over the other. The characteristics of a rolling and a cohort programme are outlined in **Table 1** [3]:

	Rolling	Cohort
Nature of programme	Continual cycle of sessions, where patients join when there is a space available and leave after completing the programme of sessions	All patients start and finish the programme at the same time
Waiting list	Patients enter the programme when a space arises, permits fast track access, potentially allows better capacity	An accumulative number of patients wait to start the programme, the waiting list may be distorted
Rehabilitation delivered at different locations by the same team	Not possible as the programme always runs in the same venue	Suitable
Education programme	The order of the talk is individual and governed by the point of entry	Can 'flow' in a logical order
Group dynamics	A new patient may be the sole new participant which may be a beneficial or a challenge	Patients all start together which permits group leaning of lifestyle changes
Assessments	Must perform pre and post assessments in parallel to the course	Dedicated assessment slots can be programmed for all subjects pre and post rehabilitation
Duration of programme	Allows lengthening the programme or early graduation as required	Fixed length for each programme

Table 1. Characteristics of Rolling and Cohort programmes.

5.5. Selection criteria for pulmonary rehabilitation programmes

Any person with a chronic lung condition who continues to be limited by breathlessness despite optimal medical management should be considered for a pulmonary rehabilitation programme [22]. Improvements following a pulmonary rehabilitation programme have been shown in patients with COPD irrespective of their age or gender [24–26] level of functional impairment [27–29] or disease severity [30, 31]. By promoting self-efficacy and behaviour change, improving exercise tolerance and physical activity and reducing exacerbations, pulmonary rehabilitation at an earlier stage of disease has the potential to markedly change the course of the disease [6]. Frequent reasons for referral to a pulmonary rehabilitation programme include:

- Dyspnoea/fatigue and chronic respiratory symptoms.
- Impaired health-related quality of life.
- Decreased functional status.
- Difficulty performing activities of daily living.
- Increased use of medical resources (e.g., frequent exacerbations, hospitalizations, emergency room visits).
- One of the primary indicators for referral to pulmonary rehabilitation is based on the modified Medical Research Council Breathlessness (mMRC) score (see **Table 2**) [3]. This scale

measures perceived respiratory disability, and allows patients to indicate the extent to which their breathlessness impacts their mobility. It is a 0–4 grade scale used to establish levels of perceived breathlessness [3, 6].

There is very strong evidence that patients with an mMRC dyspnoea score of 2–4 who are functionally limited by breathlessness should be referred for pulmonary rehabilitation. However, patients with an mMRC dyspnoea score of 1 who are functionally limited by breathlessness should also be referred for pulmonary rehabilitation. Patients with COPD who have an mMRC score of 4 but who are able to attend an outpatient pulmonary rehabilitation programme achieve similar benefits from the programme as those with a lower breathlessness score [28].

5.6. Exclusion criteria

The exclusion criteria for enrolment into a pulmonary rehabilitation programme are minimal, and in some cases participation in the programme by a patient can be facilitated by the attendance and support of a carer or relative. However, general exclusion guidelines would include [3, 6]:

- Patients with unstable cardiovascular disease or mobility problems which make exercising safely impossible (for example, severe arthritis, severe peripheral vascular disease, severe orthopaedic conditions).
- Patients with significant psychiatric or cognitive impairment who are unable to follow simple instructions safely in a group setting.
- Any further excluding factors are based on the assessor’s own objective judgement or with a discussion with the referring physician, for example, a perceived lack of motivation to participate in the programme.

5.7. Referral process

Once a patient has been deemed suitable to attend a pulmonary rehabilitation programme by the healthcare professional, the referral should be used as an opportunity to educate the patient about the benefits of the programme, to explore their understanding of the programme

Grade	Degree of breathlessness related to activities
0	Not troubled by breathless except on strenuous exercise
1	Short of breath when hurrying or walking up a slight hill
2	Walks slower than contemporaries on level ground because of breathlessness or has to stop for breath when walking at own pace
3	Stops for breath after walking 100 metres or after a few minutes on level ground
4	Too breathless to leave the house, or breathless when dressing or undressing

Table 2. The modified Medical Research Council Breathlessness (mMRC) score.

and to address the patients' concerns [3]. The programme should be presented to the patient as a core treatment for the management of their condition as opposed to an optional adjunct. Patients should be referred to the programme under the care of a respiratory physician, who should be available to the staff co-ordinating the programme to discuss any medical problems which may arise during the programme and to ensure that potential participants have been medically assessed for suitability for the programme and that their pharmacological management has been optimised [22].

5.8. Pulmonary rehabilitation post exacerbations of COPD

Exacerbations of COPD result in increased mortality and healthcare use, worsening symptoms and health-related quality of life, as well as impaired exercise capacity, reduced skeletal muscle function of the lower limbs and reduced physical activity levels [3, 6]. Studies have therefore been conducted to explore the merits and the safety of 'early' pulmonary rehabilitation both during a hospital admission and within 1 month of hospital discharge for an acute exacerbation of COPD. It is now known that early pulmonary rehabilitation post exacerbation [2]:

- Is not associated with any adverse events or increased mortality
- Reduces risk of hospital readmissions
- Improves health related quality of life
- Improves exercise capacity

It is therefore recommended unequivocally that patients with COPD who are hospitalised for an acute exacerbation should be referred for pulmonary rehabilitation at discharge, and should be enrolled into the pulmonary rehabilitation programme within 1 month of leaving the hospital.

6. Patient assessment

The initial assessment for the programme is an opportunity to outline a detailed description of the programme to the patient, to assess for co-morbidities, risk factors and contraindications for the programme, and to consider any appropriate onward referrals to maximise the benefit the patient will receive from the programme [3]. The essential information required for pulmonary rehabilitation includes:

- Known communication/language barriers.
- Current activity levels.
- Respiratory diagnosis: spirometry for those with COPD.
- Height, weight, BP and oxygen saturations at rest are desirable.
- Modified Medical Research Council breathlessness score.

- Smoking status (for those who continue to smoke, document details of previous attempts to quit; recent quitters may require support and/or counselling).
- Therapies: current list of medication.
- Use of oxygen: long-term oxygen therapy, short-burst oxygen therapy, ambulatory; oxygen saturations, use of domiciliary Positive Pressure Ventilation.
- Significant and relevant comorbidities (which may affect their ability to participate in the exercise programme or education sessions, including adequacy of literacy and vision).
- Transport needs: if applicable to that rehabilitation provider.
- Health care utilisation: including number of hospital admissions and length of stay in the previous 12 months.

6.1. Specific situations at assessment

When deciding on a patient's suitability for pulmonary rehabilitation, there are certain groups of patient characteristics which need further consideration during assessment for the programme including [3]:

6.1.1. *Smoking status*

There is currently no evidence that smokers benefit any less from pulmonary rehabilitation than non-smokers, and the rehabilitation programme can be an ideal opportunity to support and facilitate these patients in smoking cessation. Smokers should be offered smoking cessation advice and should be referred to smoking cessation programmes.

6.1.2. *Chronic respiratory failure*

Patients with chronic respiratory failure ($\text{PaO}_2 < 8 \text{ kPa}$, $\text{PO}_2 > 6 \text{ kPa}$ or both) gain much benefit from pulmonary rehabilitation and should not be excluded from the programme for this reason alone. The use of oxygen and non-invasive ventilation for these patients during the programme should be discussed with the referring physician, and the safety of the patient with consideration to the skill mix of the staff in the programme and the programme setting should also be considered when accepting these patients onto the programme.

6.1.3. *Cardiovascular disease*

From a safety perspective, patients with unstable cardiovascular disease (e.g. unstable angina, unstable arrhythmias) should not commence a pulmonary rehabilitation programme until their cardiac condition is stabilised. However, patients with stable cardiovascular disease as well as a chronic respiratory disease do benefit from the programme, and should be referred if pulmonary rehabilitation is indicated. Patients with aortic aneurysms $< 5.5 \text{ cm}$ can participate safely in moderate intensity aerobic exercise training as long as their blood pressure is monitored and controlled.

6.1.4. Anxiety and depression

Patients with symptoms of anxiety and depression also benefit from the pulmonary rehabilitation programme, and should not be excluded from referral to the programme. The pulmonary rehabilitation programme allows an opportunity to detect these conditions and to consider onward referral for optimal management.

6.1.5. Obese subjects

Pulmonary rehabilitation may be an ideal setting in which to address the needs of obese patients with associated respiratory symptoms, including exercise training, nutritional education, psychological support and onward referral to specialists as required. Obese patients should not be excluded from the pulmonary rehabilitation programme; however, assessments for other cardiac and pulmonary comorbidities may need to be considered prior to commencing the pulmonary rehabilitation programme. Weight limits of equipment should be considered, low impact exercises may be more appropriate and specialised equipment may be required to accommodate these patients [6].

6.1.6. Co-morbidities

COPD is commonly associated with other medical co-morbidities, which may result from the common risk factors for COPD such as smoking as well as systemic inflammation. These can further impact on the patient's management, and can include cardiovascular disease (arrhythmias, congestive heart failure, hypertension, and coronary disease), metabolic conditions (diabetes mellitus, osteoarthritis, and hyperlipidaemia), infections, lung cancer, obstructive sleep apnoea, cognitive dysfunction, depression or anxiety. These co-morbidities must be considered in the assessment and management of COPD patients enrolled in a pulmonary rehabilitation programme, as early intervention may influence the course and prognosis of the disease and can have a beneficial effect on both COPD and the relevant co-morbidity. Pulmonary rehabilitation is very important for patients with COPD and co-morbidities as physical activity is well documented to not only benefit COPD but also many other chronic conditions including obesity, diabetes, cardiovascular disease, musculoskeletal disease and peripheral vascular disease [32–36].

The presence of co-morbidities does not preclude pulmonary rehabilitation in patients with COPD but they should be considered thoroughly when monitoring and prescribing exercise to allow these individuals to exercise safely. For patients with cardiac conditions, the need for pre-rehabilitation investigations (for example, echocardiography or stress testing) should be discussed with the referring physician to define safe exercise parameters. Anaemia, orthopaedic and neurological issues require further consideration of a safe exercise plan and the need for specialised equipment. The patient may also require further onward referrals (for example, dual energy X-ray absorptiometry (DEXA) scan, psychological review, and nutritional review) based on observations during the exercise programme.

6.2. Exercise testing

Prior to commencing the rehabilitation programme, an exercise assessment is essential to [6]:

- Ensure the patient is safe to participate
- Rule out cardiovascular morbidities
- Assess baseline capacity
- Individualise exercise prescription
- Assess for the need for supplementary oxygen
- Define the factors contributing to exercise limitation
- Evaluate the effectiveness of the intervention

Exercise tests can include field walking tests, or laboratory cycle ergometer or treadmill tests. Field walking tests are most commonly used, and are considered more reflective of daily living; they are low cost and are convenient in most settings. These include the 6-minute walk test (6MWT) and the incremental shuttle walk test (ISWT). The 6MWT is a valid, reliable and reproducible self-paced walk test once the established, recommended and standardised protocol is used. Performed over a minimum of 30 metres, patients are asked to walk as far as possible in 6 minutes along a flat corridor [37]. The ISWT is a symptom limited maximal exercise capacity, externally paced walk test performed over a 10-metre course. It is also valid and reliable. The walk speed continues until the participant can no longer continue, with a maximum duration of 20 minutes. The endurance shuttle walks test (ESWT) is a constant walking speed test performed at a set speed based on the ISWT [6].

The choice of test is usually decided based on objectives, time, cost and availability.

7. Exercise training in pulmonary rehabilitation

Lower limb weakness is commonly seen in patients with COPD, and is a poor prognostic indicator [12]. The exercise component of pulmonary rehabilitation therefore should primarily be delivered reflecting aerobic exercise and on lower limb endurance and resistance training. The general principles of exercise in COPD are no different than in exercising a healthy population: it must reflect the individuals own capacity, progress as improvement occurs and exceed normal loads encountered in daily life to improve aerobic capacity and muscle strength.

7.1. Aerobic/endurance training

A target intensity of 60% peak work rate, aiming for an accumulative time of 30–60 minutes of aerobic training per session is recommended, with 30 minutes of continuous aerobic

activity [3]. However, both interval and continuous training have been shown to be effective in patients with COPD, and should be selected based on both therapist and patient preference. Endurance exercise, most commonly delivered in the form of walking (treadmill or ground walking) or cycling, three to five times per week at a Borg dyspnoea or fatigue score of 4–6 (moderate to severe) is the recommended target training intensity [6].

7.2. Resistance training of the lower limbs

Resistance training of all major muscle groups, but particularly the quadriceps, should also be incorporated, not only for the improvements that are well documented for COPD symptoms, but also to reduce falls and to improve or maintain bone mineral density [6]. Resistance training should aim for 2–4 sets of 10–15 repetitions of each exercise, on 2–3 days of the week. The selected weight should be individualised for each patient, aiming for a prescribed weight of 60–70% of 1 repetition maximum for each individual patient. The weight should only have progressed once all sets can be completed with the selected weight [6]. Based on local resources, weight machines, elastic bands or free weights are all acceptable forms of resistance training.

7.3. Resistance training of the upper limbs

While it is suggested that upper limb training can improve upper limb function in patients with COPD, the optimal prescription of this training remains unclear, as do the improvements gained in broader outcomes for COPD patients. However, upper limb training may be incorporated based on individual needs to improve functional living. It could be assumed that starting loads and progression may follow the same prescription as for lower limb training [20].

7.4. Flexibility training

While minimal research has been done on flexibility training as part of the pulmonary rehabilitation programme or the optimal duration and intensity of stretching exercises, flexibility of the major upper and lower limb muscle groups on 2–3 days a week can be recommended [38]. Also, improved thoracic mobility and posture may improve vital capacity in COPD patients, and should be assessed and addressed in all COPD patients [6].

7.5. Generic vs. individualised exercise programmes

Generic exercise training is recommended for the pulmonary rehabilitation classes: all patients in the class should do all the same exercises as opposed to an individualised exercise programme for each patient. However, the prescription of exercise should be individualised to each patient to ensure the correct intensity for that patient. Goal setting should be addressed with each patient on the initial assessment to address any hurdles to exercise and to further address each patient's specific needs [3].

8. Education in pulmonary rehabilitation

Education on COPD and its management to both patient and family is an integral component of pulmonary rehabilitation programmes. Several studies show that patients instructed about the nature of their disease and the implications of therapy can better understand, recognise, and treat the symptoms of their disease [39]. The educational component acts as a support to lifestyle and behavioural change, and assists in the development of self-management skills. Patients are empowered to actively participate in their own healthcare, which can promote adherence to therapy and self-efficacy (i.e., the confidence in successfully managing one's health). The educational needs of each patient should be individualised and identified at the initial assessment and reassessed over the course of the programme. The style of teaching used in pulmonary rehabilitation is changing from traditional didactic lectures to a collaborative self-management approach, which may be more effective [6]. Education should run in conjunction with an exercise programme and should cover relevant topics associated with chronic lung disease. Different aspects should be delivered by different healthcare professionals involved in the programme, with the relevant expertise in that area.

Self-management includes core generic strategies, such as goal setting, problem solving, decision making, adherence to medication, maintaining regular exercise, nutritional advice, breathing techniques, bronchial hygiene and smoking cessation [40, 41]. Behavioural change strategies including the prevention, early recognition and treatment of exacerbations and advanced care directives are additional core educational issues incorporated in collaborative self-management programmes. The development of a patient-specific, collaborative self-management plan for COPD exacerbations including the recognition of symptoms, a personalised action plan and communication with a healthcare provider has been shown to be beneficial [41, 42].

8.1. Breathing strategies

Breathing strategies encompasses a range of breathing techniques, including active expiration, pursed lip breathing, diaphragmatic breathing, adapting certain body positions and co-ordinating paced breathing with activities. The aim of these techniques is to improve regional ventilation, gas exchange, respiratory muscle function, dyspnoea, exercise tolerance and quality of life [43].

The breathing strategies are tailored to the individual, with patients adopting the technique most effective in reducing symptoms [44].

8.2. Bronchial hygiene techniques

Excessive airway secretions secondary to mucus hypersecretion and impaired mucociliary clearance are distinctive features for some patients. Chest physiotherapy is used to aid removal of airway secretions, which involves teaching on importance of daily clearance and training in drainage techniques [45].

8.3. Smoking cessation

In approximately 90% of cases of COPD, cigarette smoking is the direct cause. The single most important intervention to retard the progression of air-flow limitation and improve survival is smoking cessation. For many patients smoking cessation may be difficult due to strong physiologic and psychological dependence. Long-term quit success rates of up to 25% can be achieved when sufficient reserves and time are dedicated to smoking cessation programmes [46]. The rehabilitation programme provides a forum for education and continued reinforcement, on risks of continued smoking, advice on nicotine replacement therapy and other pharmacotherapy, along with referral to smoking cessation programmes.

8.4. Advance care planning

The process of advance care planning is often inadequate in chronic respiratory diseases [47]. Anxiety and fear of death is well described in individuals with advanced COPD along with reluctance to discuss it with their treating physician [48]. The pulmonary rehabilitation programme has been identified as an appropriate setting for discussion on advance care planning and end of life care [49].

The idea is to allow both patient and family a unique opportunity to communicate goals of treatment and preferences regarding the use of life-sustaining treatments, such as cardiopulmonary resuscitation, mechanical ventilation, dialysis and feeding tubes, with the health care provider. Ideally, the discussion will facilitate better understanding of certain topics, such as the disease itself and prognosis, process of dying and end-of life care, advance directive documents (e.g. designating a health care proxy or enduring power of attorney).

8.5. Psychosocial support

Severe COPD is associated with increased risk for anxiety and depression, which can affect motivation levels and result in decreased participation in social activities [6, 46]. Episodes of dyspnoea often trigger fear and anxiety in patients with COPD and result in further anxiety in anticipation of repeat episodes [50]. Depression, feelings of hopelessness and an inability to cope are common in patients with COPD, with an approximate prevalence rate of 45% in patients with moderate to severe disease [51, 52]. Patients with depression have the tendency to withdraw from social interactions which can worsen feelings of isolation and loneliness. Sexual activity can be affected by depression and also the physical restrictions imposed by COPD itself, sexuality should be raised and discussed when necessary and appropriate counselling initiated.

Screening for anxiety and depression should be included at the initial assessment in a pulmonary rehabilitation programme. If possible interviewing and involving the caregiver is beneficial. Promotion of an adequate patient support system is an important component of pulmonary rehabilitation [53]. Psychological and social support provided within the pulmonary rehabilitation setting can facilitate adjustment the physiological impact of the disease by

encouraging adaptive thoughts and behaviours. These aid patients in diminishing negative emotions, provides a socially supportive environment and may improve compliance with rehabilitation. Multidisciplinary team members with the appropriate expertise to address these issues are most useful and referral to appropriate professional care may be necessary.

8.6. Nutrition

Nutrition counselling and education on weight management are particularly important in lung disease. Up to 20–30% of normal weight individuals with COPD show a shift in body composition to muscle wasting and relative increased fat mass, independent of spirometric severity [53]. Typically, underweight status and weight loss are more prevalent in advanced disease and emphysematous phenotype [54], while obesity is more prevalent in mild disease [53]. Patients with COPD are at risk of obesity and muscle wastage due to limitations in physical activity and adverse effects of glucocorticoids given for exacerbations. For patients with COPD there is an association between underweight status and lean muscle loss and increased mortality, again independent of FEV1 [55, 56], in addition underweight patients report a lower HRQoL status than normal weight patients with COPD [57].

Changes in body weight or BMI do not accurately reflect all the changes in body composition that occur in patients with COPD. Body weight is made up of fat mass and fat free mass (FFM), fat free mass consists of water and body cell mass (organ, muscles, bone). Muscle mass constitutes a major part of fat free mass. The loss of FFM is characteristic of chronic lung diseases such as COPD and in severe COPD low FFM and mid-thigh cross sectional area have been shown to be a better predictor of prognosis than BMI [58]. Patients with COPD and low FFM have a lower exercise tolerance and impaired respiratory muscle strength than patients with maintained FFM [59–61]. FFM can be estimated using skinfold anthrometry, bioimpedance analysis or dual energy X-ray absorptiometry (DEXA).

A comprehensive pulmonary rehabilitation programme should at a minimum include a simple nutritional screening, such as calculating patient's body mass index or BMI. The aetiology of weight loss and muscle wasting in COPD is complex and a number of different physiologic and pharmacologic interventions have been used to stop or even reverse the process. This includes simple nutritional supplementation with an emphasis on adequate protein intake in order to stimulate protein synthesis to maintain or restore FFM. The increased energy requirements during activity in pulmonary rehabilitation must also be met in both underweight and normal weight individuals. Nutritional supplementation alone has not been successful in achieving significant weight gain. However, a 6 month intervention of dietary counselling along with nutritional supplementation resulted in significant weight gain and maintenance of FFM compared with control group [62].

9. Post rehabilitation assessment

9.1. Patient-centred outcomes

Patient-centred outcomes are used as outcome measures in pulmonary rehabilitation to measure the change or impact the pulmonary rehabilitation programme has had on the patient's

symptoms and quality of life [6]. Outcomes used during the programme should be valid, reliable and sensitive to change and have descriptions of relevant change, such as the minimally clinically important difference, which indicate a meaningful change of the condition for better or for worse.

Outcome measures used are generally generic or disease specific, and should assess quality of life (health related quality of life, symptoms and functional impairment), depression and anxiety, functional status and breathlessness.

Exacerbation history should also be documented as an outcome measure. The same exercise test used in the pre-rehabilitation assessment (6MWT or ISWT) should also be reassessed on completion of the programme to assess for improvements in exercise capacity. Quality of life measures are used to assess symptoms, physiological functioning, functional impairment and health related quality of life [55, 63, 64]. At least one of these questionnaires is advised and may include, for example, the Chronic Respiratory Disease Questionnaire [65, 66], the St. Georges Respiratory Questionnaire [16], or the COPD Assessment Test [67]. As outlined previously, up to 40% of COPD patients have symptoms of depression and anxiety [68]. All patients should be assessed both before and after the rehabilitation programme using, for example, the Hospital Anxiety and Depression Scale [68, 69], and an onward referral to a mental health professional considered if symptoms persist significantly on completion of the programme.

Patients who are attending pulmonary rehabilitation should have the outcome of their treatment in terms of dyspnoea, health status and exercise capacity measured. Objective measurements of a patient's baseline function and post-rehabilitation function, and reassessments in the months following completion of the rehabilitation programme allows the co-ordinator to assess the benefit obtained by the individual during the programme, to provide quality assurance for the rehabilitation services and to facilitate ongoing referrals if required. Other measures of outcome, such as muscle strength, nutritional status, physical activity levels and self-efficacy measures) may also be beneficial.

10. Unanswered questions in pulmonary rehabilitation

10.1. Where is the ideal location to carry out rehabilitation?

The ideal location to carry out rehabilitation is currently unclear. The settings for pulmonary rehabilitation programmes vary; most of the research to date has involved outpatient programmes; however pulmonary rehabilitation programmes may also be conducted in an inpatient hospital or home setting. In a recent international survey involving 400 centres in 40 countries, 85% of pulmonary rehabilitation programmes in Europe and North America were using an outpatient model [70]. Outpatient settings include hospital outpatient departments, community facilities and physiotherapy clinics.

Inpatient rehabilitation is offered in hospitals and can provide specialised rehabilitation care for individuals in a stable pulmonary state or after an exacerbation. In certain cases it can be initiated during inpatient acute care including the intensive care unit where ventilator limitations may limit aerobic exercise, but resistive muscle training can be well tolerated and is associated with improved 6-minute walk distance and muscle strength [6, 71]. Potential

disadvantages with inpatient rehabilitation include higher costs and lack of coverage by health insurance in certain countries.

Home based rehabilitation is an alternative model, which involves transferring the site of exercise training to the home. This could make the course more convenient and broaden the availability of the service. There is increasing evidence comparing home- and hospital-based programmes, including a recent large randomised equivalence study of home vs. outpatient rehabilitation. This demonstrated that important outcomes such as functional exercise capacity and health related quality of life were equivalent between both groups [72]. Fernandez and colleagues demonstrated that a home-based programme was safe and effective in a group of 50 patients with severe COPD on long-term supplemental oxygen [73]. There has been little uptake in clinical practice, with less than 5% of centres worldwide providing home based rehabilitation [70]. This is likely a result of limitations in some of the current studies, with many being underpowered or failing to provide all of the essential components of pulmonary rehabilitation.

The American Thoracic Society (ATS)/European Respiratory Society (ERS) Policy Statement on Pulmonary Rehabilitation identified the need to increase accessibility of pulmonary rehabilitation as a key priority, which includes investigating novel PR programme models that are more accessible and acceptable to patients [74]. Thus, when choosing a rehabilitation setting characteristics of both a particular healthcare system or setting and the patient as an individual need to be considered. Factors such as transportation, availability of various programme settings as described above and in certain countries, payment considerations and health insurance need also to be considered. In relation to patient specific factors, the severity of their disease is important, as is the haemodynamic stability of a patient often in the context of recent exacerbation, co-morbidities and extent of disability if any. These factors can influence the most appropriate setting and level of supervision a patient needs enrolling in a pulmonary rehabilitation programme.

10.2. What are the barriers to the uptake of pulmonary rehabilitation?

One key goal of pulmonary rehabilitation is ongoing lifestyle modification to encourage patients to undertake a more active lifestyle in the future. Despite the extensive evidence for its benefits, pulmonary rehabilitation is delivered to fewer than 10% with those with COPD who would benefit [52]. Accessibility is a major factor particularly in rural settings where programmes are not available or appropriate infrastructure to provide them does not exist. However, it has also been shown in metropolitan areas that up to 50% of those who are referred will never attend and of those who do present, up to a third will not complete the programme [75].

A systematic review in 2011 was carried out to identify barriers to uptake and factors affecting pulmonary rehabilitation adherence. The factors that influence whether people choose to attend their initial appointment can be different to the factors that influence programme completion [75]. A number of barriers to enrolment following referral were identified, including:

- Disruption to established routine, varying from concerns over missing social activities to work commitments or carer demands such as caring for other family members.
- Travel, transport and location, including distance to travel, available transportation or inability to travel independently.
- Influence of the referring physician – some patients declined to attend following referral by a doctor they did not know or if they perceived that their doctor did not think the rehabilitation programme would benefit them.
- Lack of perceived benefit, as some studies report patients perceiving their disease to be too severe to gain improvement or that the programme lacks guaranteed benefits.
- Inconvenient timing of the programme – patient preference on timing of rehabilitation sessions can vary between morning and afternoon, and given the limited capacity and availability not everyone's preference can be accommodated.

The definition of programme non-adherence varies in the literature from declining to participate in the programme to attending at least one session. A non-adherence rate ranging from 10 to 32% has been described and varies considerably from study to study [75]. Factors associated with non-adherence include illness and co-morbidities, travel, transportation, lack of perceived benefits, smoking, depressive symptoms and lack of support [27, 76]. Cigarette smoking at enrolment was the sole independent risk factor for non-completion of pulmonary rehabilitation, in the systematic review described above [75]. This highlights the importance of the educational component and facilitating behaviour change including programmes for strategies for smoking cessation.

10.3. How can the benefits of pulmonary rehabilitation be maintained?

Given the nature of COPD as a progressive chronic disease, it frequently results in a progressive loss of function over time. It is therefore reasonable that any benefits obtained from an initial programme are likely to regress over time [3]. The benefits of an initial pulmonary rehabilitation programme have been shown to persist to some degree for at least 12 months, with quality of life maintained better than the increased exercise capacity. Developing strategies to extend the effects of the rehabilitation programme is extremely important. The benefits of ongoing supervised maintenance exercise programmes beyond the completion of the initial cycle remains uncertain [6].

A repeat programme in those whose condition has deteriorated more than 1 year since completing the programme should be considered, and an earlier repeat programme may be warranted in those patients with a profound physiological decline within the initial 12 months of completing the programme. The benefits of a repeat programme of a patient who failed to benefit from the original programme are questionable. Ongoing exercise upon completing the programme should be encouraged in all patients, and opportunities for exercise upon completion of the programme should be provided to all patients.

Implementation of a home exercise programme at least twice a week at an early stage during the rehabilitation programme encourages the participant to exercise independently during the programme, but also improves adherence to regular exercise once the programme has been completed. Written material with an individualised description and prescription of each exercise, resembling those undertaken in the supervised classes should be provided to each participant. The programme coordinator should monitor the patients home exercise diary throughout the programme, and any barriers to exercise that the patient is experiencing should be addressed. Precautions and advice on exercise should also be addressed [20].

On completion of the programme, patients should be provided with a written, individualised, structured plan for ongoing exercise maintenance to encourage ongoing exercise. It should include aerobic and strength exercises, and information on local exercise amenities. Patients should be asked to reflect on the effect the programme has had on their daily physical activity and on their symptoms. Strategies to maintain their improvements and adherence to an ongoing exercise programme should be discussed. Regular assessments following completion of the initial programme can assist in maintaining the gains achieved during the programme [22].

10.4. Is there a role for new technology?

Pulmonary rehabilitation has rapidly established itself as a cornerstone in the comprehensive management of patients with COPD. As previously stated, a recent joint policy statement by the ATS and ERS has identified improved access and delivery of pulmonary rehabilitation to suitable patients as a priority in need of further research and development. As popularity and lack of capacity increase demand, other settings for effective rehabilitation will need to be found. These new settings would ideally maintain the quality and effectiveness of conventional programmes but be more convenient to patients [6].

New technology may play a part in improving services by telemonitoring or provision of remote rehabilitation to inaccessible regions. Telemedicine is the use of telecommunication and information technology to provide clinical health care from a distance. Telerehabilitation is the delivery of rehabilitation services over telecommunication networks and the internet, allowing point-to-point video conferencing between a central control unit and a patient at home. This is a promising way of delivering health services to individuals who may live in isolated areas without adequate access to transportation or have a level of disability which limits their ability to travel. A study carried out in 2008 used mobile phone based systems to remotely monitor an endurance exercise programme at home [77]. This programme provided a music component with an appropriate tempo to facilitate the correct intensity of training; adherence could also be monitored and appropriate feedback and support delivered. The study demonstrated good compliance and significant improvement, and was also associated with fewer exacerbations and hospitalisations [78].

There has also been evidence to support the delivery of a pulmonary rehabilitation programme from a large expert centre to smaller regional centres via videoconferencing [78]. In a

controlled trial, there were equivalent outcomes for exercise capacity and quality of life. One other small trial in individuals with moderate to severe COPD, who had completed at least 12 sessions of outpatient pulmonary rehabilitation, found that telemonitoring by health care professionals reduced primary care contacts for respiratory issues compared with usual care [79]. Neither demonstrated any differences between groups and hospital admissions, days in hospital or contact with COPD nurse specialists in the community.

Education, psychosocial support and counselling are components of a pulmonary rehabilitation programme which are critical to its success. A study in 2006 demonstrated that the combination of exercise counselling, stimulation of lifestyle change or adaption and the use of a pedometer is feasible and may improve outcome and maintenance of rehabilitation results [80]. Results of a systematic review comparing home telemonitoring with usual care showed that home telehealth (home telemonitoring and telephone support) decreased rates of hospitalisation and emergency department visits, whereas findings for hospital days varied between studies. There is a great deal of variability between studies in terms of interventions and approach [81].

11. Conclusion

Pulmonary rehabilitation is one of the most cost-effective therapies for individuals with chronic respiratory disease. Despite this, many programmes are not funded adequately due to a lack of knowledge and awareness of the benefits of pulmonary rehabilitation. Healthcare professionals in clinical practice are often not familiar with the benefits, science and process of pulmonary rehabilitation, and therefore do not offer it to suitable patients. The need for standardised formal training in pulmonary rehabilitation is clear. Interestingly, even when referred, uptake of pulmonary rehabilitation by suitable patients remains poor. This may be due to a perception of pulmonary rehabilitation as being difficult or frightening. Therefore, equally important is patient education regarding the proven benefits of pulmonary rehabilitation and the processes by which those benefits are attained. Given that pulmonary rehabilitation is an evidence-based, widely-accepted gold standard treatment for many respiratory patients, the disparity in access and availability results in unacceptable inequality of healthcare [82].

Author details

Michelle Casey[†], Amy Mulkerns[†], Cliona O'Donnell[†] and Tim McDonnell*

*Address all correspondence to: timothymcdonnell@icloud.com

Department of Respiratory Medicine, St. Michaels Hospital and St. Vincent's University Hospital, Dublin, Ireland

[†]These authors contributed equally

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