Chapter

Pulmonary Rehabilitation in Chronic Obstructive Pulmonary Disease

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Abstract

With an ever-expanding understanding about chronic obstructive pulmonary disease (COPD), it has been realized that it is a respiratory disease with systemic manifestations. Systemic effects of COPD lead to cardiovascular co-morbidities, muscle wasting and osteoporosis that in turn lead to inactivity and physical deconditioning. This development has a direct impact on the health-related quality of life (HRQoL) of patients suffering from this respiratory disease. Pharmacological therapy leads to improvement in shortness of breath and has limited effect on the physical deconditioning. Latest research has shown an additive effect of pulmonary rehabilitation on improving the inactivity and overall HRQoL in COPD patients. Pulmonary rehabilitation (PR) is a comprehensive multimodality program that includes strength and endurance training, nutritional education and psychosocial support. This leads to a holistic approach to management of COPD which results in symptom improvement in patients and decreased utilization of heath care resources. There are several barriers to widespread adoption of pulmonary rehabilitation as a standard treatment. This includes availability, insurance coverage and patient compliance. With inclusion of pulmonary rehabilitation in respiratory society guidelines, there has been a renewed interest among both pulmonary specialist and community physicians. This chapter aims to provide exhaustive evidence based knowledge regarding pulmonary rehabilitation and its beneficial effect on COPD patients.

Keywords: rehabilitation, deconditioning, HRQoL, comprehensive, COPD, exercise, education

1. Introduction

Chronic obstructive pulmonary disease (COPD) is among the five leading causes of death in developed world [1]. Prevalence of COPD is constantly increasing. COPD has a high impact on patients' wellbeing, healthcare utilization, and mortality [2] and causes a substantial and increasing economic and social burden [3, 4]. Cigarette smoking is clearly the predominant cause but other environmental agents including biomass fuel and air pollution may play a role as well. Common symptoms of COPD patients are chronic and progressive dyspnea, cough, and sputum production. These symptoms can be disabling and lead to activity limitation and ultimately inability to work and take care of themselves [5]. This vicious circle of inactivity that begins with breathlessness is because of peripheral muscle dysfunction [6], and dynamic hyperinflation [7].

For several decades, treatment of COPD has been focused on smoking cessation, and pharmacological but with ever-increasing literature, intense exercise programs like pulmonary rehabilitation (PR) have become an integral part of management of COPD [8]. PR has been shown to be the most effective non-pharmacological intervention for improving health status in COPD patients and has become a standard of care for these patients [2]. PR and pharmacological therapy are not competitive but rather, must work closely together, if they are to result in a more successful outcome [9].

Despite increasing awareness on positive impact of rehabilitation in COPD, it remains underutilized in most countries. Lack of understanding on the benefits of a PR program, in addition to the incremental cost to the management, has hindered the widespread adoption of comprehensive PR for COPD patients [9]. This chapter aims at highlighting the impact of PR on patients with COPD, focusing on the clinical usefulness of PR. We also hope to stimulate primary care and pulmonary physicians to use PR more often.

2. Definition of pulmonary rehabilitation

Physical therapy has been incorporated into the treatment of pulmonary patients as far back as the First World War. Winifred Linton, a British nurse, first felt the need for physical therapy while treating traumatic respiratory complications during the war. Following the war, she entered physical therapy training and began to teach localized breathing exercises to other physical therapists (PTs) and surgeons at the Royal Brompton Hospital in London. A few physical therapists in the United States were instructed in airway clearance techniques and began to use and teach them to patients during the polio epidemic of the 1940s [10, 11]. Rehabilitation programs for patients with COPD have existed for more than three decades and were incorporated into ATS official statement in 1981 [12]. Comprehensive and multidisciplinary approach to the pulmonary rehabilitation programs have remained the key to its success over several years. It involves a team effort from physical therapist, respiratory therapist, nurses, physician and other support staff.

Pulmonary rehabilitation has been defined as a comprehensive program which is individual patient focused and includes exercise training, education, and behavior change. It has been found to help improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviors [13].

Pulmonary rehabilitation has demonstrated physiological, symptom reducing, psychosocial, and health economic benefits in multiple outcome areas for patients with chronic respiratory diseases [14]. PR is appropriate for most patients with COPD. Improved functional exercise capacity and health-related quality of life has been demonstrated across all grades of COPD severity, although the evidence is strong in patients with moderate to severe disease [15].

3. COPD as a systemic disease

Beside respiratory symptoms of dyspnea, COPD has been established to have extra-pulmonary manifestations. Some on them involve skeletal muscle dysfunction which results from physical inactivity and systemic inflammation in addition to hypoxemia, undernutrition, oxidative stress and systemic corticosteroid [16, 17].

Peripheral muscle dysfunction seen in COPD patients is a result of multitude of pathophysiological changes occurring in the skeletal muscles. Skeletal muscles in COPD patient have decreased oxidative capacity that can lead to early lactic

academia [18–20], decreased muscle fiber volume [21], redistribution of the muscle fiber type (from type 1 to type 2 fibers) [21–23], and abnormal muscle fiber capillarization [23]. These changes in the structure and functioning of the skeletal muscles can lead to higher concentration of lactate for a given work. This in turn can lead to increased ventilation, resulting in dynamic hyperinflation and overall increased ventilator burden. With muscle dysfunction there is a limitation in the activity and promotion of a sedentary lifestyle. A sedentary lifestyle inevitably leads to social isolation, depression and physical deconditioning. Exacerbations of COPD also promote the reduction of exercise performance, dyspnea, and the loss of Health-related quality of life (HRQoL) [24].

PR has no direct impact on lung mechanics or gas exchange [25]. Rather, it optimizes the function of other body systems so that the effect of lung dysfunction is minimized [26]. A comprehensive PR program can help COPD patients gradually improving muscle function by changing muscle biochemical structure. This leads to improved tolerance for higher work load in the patients [27]. PR additionally reduces the central perception of dyspnea and dynamic hyperinflation [28].

4. Clinical impact of pulmonary rehabilitation

A usual pulmonary rehabilitation program can range anywhere from 6 weeks to 12 weeks at various centers which incorporate aerobic exercise, education, muscle strengthening etc. Usually patients undergo supervised training 2–3 times a week, for 30–60 minutes in each session. This could include any regimen for endurance training, interval training, resistance/strength training, walking exercises, flexibility, inspiratory muscle training and/or neuromuscular electrical stimulation. The interventions are individualized to maximize personal functional gains.

There are several benefits of PR not limited to improvement in symptoms like dyspnea, exercise tolerance and overall health status in stable patients.

4.1 Symptom control

PR results in reduction in symptoms of dyspnea and leg discomfort. Patients notice improved limb muscle strength and endurance. Most patients also experience improved functional capacity with more independence in activities of daily living (ADLs) [29]. In a Cochrane review [30] including 23 randomized controlled trials, PR was found to relieve dyspnea, and fatigue, improved emotional function and patient's sense of control over their condition. All these improvements were large and statistically significant.

4.2 Physical activity and exercise tolerance

There has been increasing interest in physical activity, as inactivity has been linked with reduced survival, poorer quality of life and increased healthcare utilization [31]. In the same Cochrane review as above [30], patients were noted to have improved exercise capacity. Other studies from Griffith's et al. and Singh et al. have suggested similar findings [32, 33].

4.3 Healthcare burden

PR has also been found to reduce unscheduled healthcare visits, COPD exacerbation and hospitalization in some literature [34]. Rubi et al. reported reduction in COPD exacerbation, hospitalization and days of hospitalization in 82 consecutive

patients [35]. In fact, there is some literature to suggest reduced hospitalization in patients participating in PR programs immediately after acute exacerbation of COPD (AECOPD) beginning within 1 week of discharge [36].

4.4 Psychosocial

Anxiety and depression affect significantly in COPD patients leading to worse patient centered outcomes. Tselebis et al. conducted study in 101 consecutive patients and noted that psychological morbidity was improved with participation in PR program irrespective of severity of the disease (COPD) [37]. This was confirmed in a meta-analysis of six RCTs which indicated that pulmonary rehabilitation was more effective than standard care for the reduction of anxiety and depression [38].

HRQoL was noted to be significantly improved in patients with COPD participating in PR as well [34, 39]. The St. Georges Respiratory Questionnaire Scores were used in a meta-analysis, which showed significant improvement in HRQoL following pulmonary rehabilitation [40]. An early RCT compared pulmonary rehabilitation with education alone and demonstrated that self-efficacy improved in the intervention group [41].

4.5 Survival

COPD patients have been known to have improved mortality with cessation of smoking. There is some signal that an association exists between completion of PR and survival based on a retrospective analysis involving 1515 patients [42]. But a systematic review conducted of two randomized control trials showed significant survival benefit at 1 year in one trial but no significant benefit with another study at end of 3 years. Neither of the study was powered to really derive the desired outcome [43].

5. Indications of pulmonary rehabilitation

Patients with chronic lung condition who have symptomatic shortness of breath limiting their physical activity despite optimal medical management should be considered for pulmonary rehabilitation [44]. Patients with chronic diseases other than lung such as heart failure, musculoskeletal disease have the same benefit form pulmonary rehabilitation as patients with disabling lung conditions like chronic obstructive pulmonary disease, restrictive lung disease, and pulmonary hypertension. Pulmonary rehabilitation can markedly change the course of the disease if provided at an earlier stage of disease. This is due to improved exercise tolerance and physical activity, reduced exacerbations and improved self-efficacy and behavior change after pulmonary rehabilitation. [45]

One of the most important indicator for referral to pulmonary rehabilitation is based on the modified Medical Research Council Breathlessness (mMRC) score (see **Table 1**) [46]. The mMRC scale is a 0–4 grade scale used to establish levels of perceived respiratory disability. It allows patients to indicate the extent to which their breathlessness affects their mobility [45, 46].

It has been strongly recommended that patients with an mMRC dyspnea score of 2–4 who are functionally limited by breathlessness should be referred for pulmonary rehabilitation. However, benefits of pulmonary rehabilitation have also been seen in patients with an mMRC dyspnea score of 1 who are functionally limited by breathlessness. Patients with COPD who have an mMRC score of 4 achieve similar benefits from the pulmonary rehabilitation as those with a lower breathlessness score [47].

Grade	Level of breathlessness with the activities
0	No shortness of breath except on strenuous exercise
1	Short of breath when walking on an incline
2	Walks slower than contemporaries on a level ground because of shortness of breath or has to stop due to breathlessness when walking up at own pace
3	Stops for breath when walking 100 m or after a few minutes on level ground
4	Too short of breath to leave the house, or short of breath when dressing and undressing

Table 1.
The modified Medical Research Council Breathlessness (mMRC) score.

Other frequent indications for referral to a pulmonary rehabilitation program include poor functional status, physical deconditioning, chronic fatigue, poor health-related quality of life and difficulty performing activities of daily living. Patients who are requiring increased use of medical resources due to frequent exacerbations, hospitalizations and emergency room visits also benefit from pulmonary rehabilitation.

Candidates for lung volume reduction surgery for severe emphysema or for lung transplantation are also good candidates for PR [48]. Patients with COPD have shown improvements following a pulmonary rehabilitation program irrespective of their age or gender [49–51].

Level of functional impairment [47, 52, 53] or disease severity does not affect the benefits seen in COPD patients with pulmonary rehabilitation program [54, 55]. A program of PR may be proposed in stable COPD as well as immediately after COPD exacerbation [56].

6. Contraindications of pulmonary rehabilitation

There are very few exclusion criteria for a referral to pulmonary rehabilitation, which includes patients with the following conditions [45, 46]:

- Unstable cardiovascular disease, uncontrolled diabetes and an ongoing orthopedic illness that will refrain patient from exercising.
- Inability to do exercise safely because of any other medical illness like severe arthritis, severe peripheral vascular disease.
- Untreated psychiatric illness and cognitive impairment which makes it hard for patients to follow directions are other reasons for not referring a patient to pulmonary rehabilitation.
- Lack of motivation is another exclusion criterion for pulmonary rehabilitation.

7. Nonadherence to pulmonary rehabilitation

Adherence to pulmonary rehabilitation program is critical to see the ongoing benefits from the program. However, non- adherence and high dropout rate of 20–30% is reported in the studies listing predictive factors of non-adherence to pulmonary rehabilitation. These factors include [52, 53, 57, 58]:

- Even though current smokers obtain the same benefits from pulmonary rehabilitation, smokers generally have poor adherence to pulmonary rehab than ex-smokers. Active smoking status is not an absolute contraindication for pulmonary rehabilitation. Patients are encouraged to undergo smoking cessation prior to pulmonary rehabilitation.

- Depression and social isolation.

- Lower quadriceps strength.

- COPD patients with higher mMRC score and frequent exacerbations.

- Long commute to pulmonary rehabilitation and lack of transport.

- Cost of pulmonary rehabilitation.

8. Pulmonary rehabilitation program

8.1 Pre-rehab assessment

Every patient referred for pulmonary rehabilitation should be thoroughly evaluated prior to initiation of the program. Majority of the patients have a regular pulmonary physician managing the lung disease. As a part of the management, pulmonary physicians refer the patient for pulmonary rehabilitation to supplement the pharmacological treatment. These patients when present to the pulmonary rehabilitation have already undergone an evaluation of symptoms and physical examination. Regardless, it is a good practice to perform a thorough evaluation of patient's medical problems, laboratory results, social habits and specific medications. This should be accompanied by a comprehensive physical examination with estimation of patient's functional capacity. In most of the pulmonary rehabilitation program, this assessment is performed by the physical therapists. If a pulmonologist is an integral part of the program, the physician can do this work up.

Prior to initiation of the pulmonary rehabilitation program, a careful appraisal of patient's pulmonary disease and current severity should be done. For COPD patients this will include the duration of their symptoms, current symptomatology, mMRC score [46], smoking history, pulmonary function testing, arterial blood gas analysis, inhaler therapy, oxygen supplementation and non-invasive ventilation prescription. It is imperative that a special attention should be paid to patient's co morbidities. This is essential as several other medical problems may have impact on patient's disease course and exercise capacity. These may include obesity, OSA, diabetes, cardiovascular co morbidities, hypertension, osteoarthritis, pulmonary hypertension, peripheral vascular disease and malignancy.

A detailed pre rehab assessment enables the physical therapist to devise an individualized treatment plan for the patients. This strategy is particularly helpful for patients with advanced disease, low exercise tolerance, special healthcare needs such as high oxygen requirements, pacemaker or defibrillators, walkers and cane. Information gathered at the beginning of the program will help set realistic individualized goals and alert the provider regarding the possibility of adverse effects.

Physical examination at the beginning of the pulmonary rehabilitation program is centered on measurements of patient's functional status and capacity to handle additional physical stress. Most relevant for COPD patients will be an examination

of muscle wasting, joint mobility, postural deformities, and cardio-respiratory examination. Results of this examination allows physical therapist to gauge individual patient's tolerance and potential areas of improvement.

An important component of physical examination is nutritional assessment. This commonly includes measurement of weight, height and BMI. Both being underweight and overweight in a COPD patient can be detrimental. Excess weight can lead to extrinsic restriction on lung capacity as well as increased work of breathing. Weight loss and muscle wasting is a poor prognostic factor in COPD patients [59–61].

Pertinent respiratory examination in patients with COPD is directed at ability of the patients to clear their respiratory secretions, use of accessory muscles of respiration, breathing pattern, adventitious sounds on auscultation such as wheezing and crepitation. A knowledge of patients' respiratory status will help develop an educational plan regarding self-management, medication compliance and respiratory muscle training.

Reduced functional capacity due to physical deconditioning is widespread in COPD patients. This is multifactorial with poor nutritional status, systemic inflammation, cardiovascular comorbidities, postural deformities and osteoporosis [62] Interviewing the patient to ascertain their capacity to perform ADLs, sustained exercise and risk of falls is essential. Several questionnaires have also been used to objectively measure individual patient's baseline functionality. A few examples include: the Functional Independence Measure (FIM), the Assessment of Motor and Process Skills (AMPS), and a Functional Capacity Evaluation (FCE) [63].

Apart from questionnaire, various exercise tests can be used to gauge individual patient's functional capacity. These exercise tests can be done as field walking tests, on bicycle ergometer or on treadmill. In most hospital, simple walk testing can be cost effective and practical. Walk tests are considered more reflective of daily functionality of a COPD patient. Some of the commonly employed walk tests include the 6-minute walk test (6MWT) and the incremental shuttle walk testing. Standardized protocols have been established for performing the 6MWT. If done as per the set protocol, this walk test is highly reproducible and reliable test for both diagnostic and prognostic purposes. In this test, patient walk back and forth on a 30-m distance marked hallway at their own pace for 6 minutes. During the test, distance walked, vital signs, oxygen desaturation, development of dyspnea using a visual analog scale is measured [64]. The incremental shuttle walk test is performed on a 10 m marked course. It is a paced walk test to assess symptom limited maximal exercise capacity. Test is continued until patient develops symptoms of dyspnea or for 20 minutes, whichever occurs first. This is a valid and popular testing in various resource limited clinical settings [45].

If in addition to the functional limitation specific problems are identified by the physical therapists, various other tests may need to be performed. These tests address the muscle weakness, gait disturbances, and include balance testing and sit-to-stand tests [65].

8.2 Components of pulmonary rehabilitation

After an initial assessment, patient is enrolled into a pulmonary rehabilitation program. The basic aim of such a program in any COPD patient is to assist them in performing essential daily activities with independence. Independence comes from reduction in dyspnea and fatigue. COPD patient are inadvertently caught in a downward spiral where dyspnea is leading to inactivity, which in turn leads to physical deconditioning and decreased capacity to handle day-to-day stress. To save the patient from this downward spiral a pulmonary rehabilitation program focuses

on improving the cardiorespiratory endurance, muscle strength, body flexibility and respiratory muscle training. With an individualized patient's clinical analysis and examination, a specific therapy plan can be built for each patient. This plan is intended to establish patient specific goals and focus on areas of functional limitation, which need to improve to achieve those goals. As the COPD patients undergo pulmonary rehabilitation, improvement in their physical deconditioning and exercise capacity needs to be measured and documented. This is achieved by using a variety of parameters, such as quantity of exercise performed or improvement in perception of dyspnea, symptoms, heart rate during exertion. Any changes seen in these parameters will be suggestive of patient's improved capacity to handle the physical stress. As discussed earlier in the chapter walk tests and questionnaires can provide an objective measure of functional improvement for COPD patients undergoing pulmonary rehabilitation.

8.2.1 Endurance training

Physical exercise training in COPD patients can be delivered in two forms: Continuous high intensity aerobic endurance training or an interval training, which alternates high intensity aerobics with low intensity exercises [66]. Continuous high intensity regimen of endurance training can be administered with constant load or incremental load. It has been shown that high intensity aerobic training (70–80% of peak work rate), will result in maximal improvement in physical fitness by increasing oxygen consumption, delaying anaerobic threshold and decreasing heart rate for a given exercise rate [27, 62, 67–69].

In patients with advanced COPD and persistent dyspnea a high intensity endurance training is difficult to sustain. These patients can be provided with interval endurance training. In this approach, high intensity aerobic training in short bouts (30–180 s) is alternated with low intensity exercises (leading to a subjective experience of exertion between 4 and 6 on the modified Borg scale) or rest [70–74].

Even though there may be less appreciable gains in aerobic parameters, this training approach has proven to be effective in improving exercise endurance in COPD patients [42, 75]. Interval endurance training leads to lesser degree of pulmonary hyperinflation allowing patients to exercise longer without excessive dyspnea. COPD patients may more easily adapt a lower intensity exercise regimen in their daily life. The choice of regimen is ultimately based on both therapist and patient preference.

Endurance training is delivered using various modalities including walking (treadmill or supported ground walking with walker or wheelchair), cycling, rowing, and swimming or modified aerobic dancing. It is recommended to provide this training 3–5 times per week at an intensity aimed at a Borg Dyspnea score of 4–6 (moderate level of exercise) [26, 44, 48, 67, 69, 76–79]. Exercise sessions can last from 30 to 120 minutes, with at least 30 minutes of continuous aerobic activity, based on each patient's capacity [26, 46, 79, 80]. General recommendation for the frequency of pulmonary rehabilitation is two supervised exercise sessions a week with third unsupervised session based on the available resources [44, 81, 82]. A minimum of 12 exercise sessions or 4 weeks of rehabilitation program is essential to achieve any improvement in physical fitness. Program length can be increased up to 72 weeks if patient is inclined and insurance coverage is favorable [48, 83, 84]. While shorter (6–8 weeks) pulmonary rehabilitation programs are more cost effective and widespread, longer duration programs have shown sustained beneficial effects. This is mostly due to fact that longer duration programs not only lead to physiological changes but also behavioral changes [85].

More specific for COPD patients it is recommended to check oxyhemoglobin saturation both prior to the start of the exercise and at peak work rate. This will not only help to ascertain the need for oxygen supplementation but also guide both therapist and the patient to know appropriate level to use with different intensity of work. Similarly, a careful attention on patient's bronchodilator therapy, both long acting and short acting, is essential during the program. Patients may require administration of short acting bronchodilator at the beginning of the exercises or during the workout. For a successful outcome of endurance training it is important that patient gets trained on similar oxygen delivery device that they use at home and are on optimal management of COPD. A stable respiratory function will allow the patients to tolerate higher intensity workout for longer duration.

8.2.2 Strength training

Apart from improvement in endurance, COPD patients benefit from increase in their muscle strength [26, 83, 86, 87] . Increased muscle strength provides the patients with an ability to handle the ADLs better, improves their gait and reduce fall risk, thereby making them more independent [88]. A recent meta-analysis investigating different methods of PR in COPD showed greater improvement in HRQoL by adding strength training than endurance training alone [89]. Physiologically improving muscle strength in COPD patients can lead to increase in physical endurance, 6-minute walk distance and maximum oxygen consumption [90, 91]. Strength training is most beneficial if directed at muscles involved in functional living. This involves training muscles in upper and lower extremities as well as the trunk.

It has been well proven that exercise training of the lower extremities leads to significant improvement in ambulatory stamina in COPD patients [42, 67, 92–94]. This is because lower extremities suffer most from disease-related muscular dystrophy in COPD patients. Additionally increasing lower extremity strength can reduce falls and maintain bone mineral density in COPD patients [45]. General recommendation to improve lower extremity strength is to provide resistance training with 2–4 sets of 10–15 repetitions of each exercise, for 2–3 days per week. Selection of weight for this type of resistance training workout is individualized based on patient's capacity. Increment in the weight is done gradually once patient is able to accomplish all sets of exercise with a prescribed weight [45]. Lower extremity training can be achieved using walking, bicycling with incremental loads, stair climbing, swimming, weight machines or elastic bands. Choice is driven by available resources at the training site.

Patients suffering from COPD who have hyperinflation and flattened diaphragm have limitation in using their upper extremities to perform ADLs. Elevation of arms can result in increased ventilatory and metabolic demands in COPD patients with low respiratory reserves. This is thought to be because some of the upper extremity muscles also serve as accessory muscles of respiration [95–97]. Majority of the published literature on pulmonary rehabilitation suggests beneficial effect of upper extremity training in COPD patients. Some of the observed benefits of this training include improved upper extremity strength, which is task specific, decreased ventilatory demands and more independence in performing ADLs. Despite these observed benefits, optimal prescription of upper extremity training remains unclear.

Physical therapists have to be mindful that in training the upper extremities, COPD patients may have elevated ventilatory work, asynchronous breathing and more dyspnea for the level of work. It is prudent to start with low resistance and frequent repetitions before gradually increasing the weight [81]. Upper extremity

and trunk muscle strength training is achieved by using light weights (dumbbells, elastic bands), weight machines for stronger patients, rowing machines etc. Several of these instruments can also provide aerobic exercise training thereby improving both strength and endurance in the upper extremities.

Physical therapists may provide training of upper and lower extremities on alternate days to improve patient tolerance. Progressive improvement in muscle strength is documented using standardized lifting tests, incremental resistive load tolerated by the patient and increased capacity in performing ADLs efficiently [86].

8.2.3 Flexibility training

Many COPD patients suffer from modification in the structure of their chest wall due to hyperinflation, hypertrophy of the accessory respiratory muscles and physical inactivity. This further leads to changes in the posture and reduced mobility. To prevent this from happening, COPD patients undergo flexibility training as a part of the pulmonary rehabilitation program.

Flexibility exercises lead to improved mobility by increasing joint range of motion, reducing joint stiffness, better posture and increment in vital capacity [45]. Gentle stretching exercises with full body movements, coordinated with breathing techniques are appropriate for COPD patients [65, 98, 99].

This kind of workout teaches the patient the influence of body movements on respiration. Since these exercises are done at a slower pace without any resistive loads, they can be used during warm up or cool down periods of the program. Limited research has been done on adequate duration and intensity of stretching exercises. General recommendation are to perform stretching of major muscle groups in the upper and lower extremities 2–3 days per week at the minimum [100]. Benefits of this training can be measured by documenting reduction in subjective perception of stiffness, reduced incidence of back pain and joint injuries.

8.3 Education

8.3.1 Disease education

To provide a holistic care, every pulmonary rehabilitation program should incorporate patient education. It has been well proven that COPD patients who are well aware about the nature of their disease, its management and long-term implications are able to cope with both the disease and treatment better [101]. Education about the disease empowers the COPD patients to better recognize their symptoms, make lifestyle changes and get involved in the management of the disease. This leads to increased motivation to participate in pulmonary rehabilitation and adhere to the exercise regimen.

At the beginning of the rehabilitation program, individual educational needs of each patient are identified. This is continuously reassessed while the patients are undergoing the rehabilitation program. Instead of a didactic teaching, a patient centered and self-management teaching approach focusing on lifelong behavioral changes are adopted these days [45]. Specifically for COPD patients, a collaborative self-management plan which helps them in an identification of symptoms of onset of an exacerbation, make treatment modification and to communicate early with a healthcare provider, is highly beneficial in the long run [102]. Patient education runs alongside the exercise training. It is meant to supplement the knowledge gaps and instill confidence in the principles of ongoing training. Various topics regarding disease and its management are covered with utilization of the expertise of various specialists.

Exacerbation of COPD is an additional burden on patient's already weakened functional capacity. It leads to hospitalization, further inactivity, deterioration of lung capacity and mortality. It may also disrupt any advances the patient may have made in improving their exercise capacity and muscle strength [45, 46]. There is an emerging data suggesting that there is benefit in instituting and/or continuing with pulmonary rehabilitation during hospital admission or within a month of hospital discharge. An early initiation of pulmonary rehabilitation reduces risk of re-hospitalization and improves overall symptoms without any adverse effects [103].

8.3.2 Occupational therapy

A pulmonary rehabilitation program incorporating occupational therapy is important in COPD patients [104, 105]. Occupational therapy assists COPD patients with development of specific strategies to perform ADLs with least expenditure of energy [106]. With conservation of energy expenditure, there is an improvement in subjective perception of breathlessness, increased efficiency in performing daily basic activities, elevated sense of control and better social engagement [104–107]. Occupational therapy skills even though simple in principle, require a learning process, which is achieved through a multidisciplinary rehabilitation program. There is an ever-increasing evidence that improvement in occupation performance of COPD patients lead to a holistic improvement in their health [108]. Occupational therapist can also instruct COPD patient to use wheeled walking aids, which can result in increased functional autonomy, ventilatory capacity and waling efficiency [109–112]. Since this therapy has a major impact on social networking of COPD patients, it serves well to involve patient's family and friends [113].

8.3.3 Nutritional education

Body composition in COPD patients may change as the disease severity progresses. While obesity predominates in the milder stages of the disease, patients with advanced disease and emphysema tend to be underweight and have generalized muscle wasting [114, 115]. Factors other than the lung disease itself, which can lead to this shift, includes inactivity, systemic inflammation, osteoporosis and glucocorticoids use. Studies have shown an increase in mortality in COPD patients who are underweight, independent of their disease severity [116, 117]. These patients with decreased fat free mass have higher limitation to exercise tolerance and thereby reported a decreased HRQoL status in comparison to COPD patients with normal weight [118–121]. Various studies have shown a survival benefit with weight gain as low as 2 kg or by increase in one body mass index unit [116, 117]. This is why nutritional education are particularly essential in rehabilitation of COPD patients.

Every pulmonary rehabilitation program should include nutritional screening with measurement of BMI at the least. A more comprehensive program may also include fat free mass estimate using skinfold anthropometry or bioimpedance analysis. Estimation of osteoporosis can be done using dual energy X-ray absorptiometry (DEXA) scanning. Improvement of nutritional status requires a multi-pronged approach with utilization of both physiologic and pharmacological interventions. Endurance and strength training as described previously in this chapter can improve muscle mass as well as bone strength. Nutritional interventions include adding nutritional supplementation to patient's diet with emphasis on adequate protein intake to maintain or restore lean body mass. Patients who are unable to eat large meals due to dyspnea can switch to frequent small meals. It has been shown that a 6-month intervention involving dietary counseling, nutritional supplementation and positive reinforcement led to a significant weight gain in advanced COPD patients [60].

8.4 Psychosocial support

Many COPD patients who are referred to pulmonary rehabilitation suffer from depression and anxiety [45, 122]. Recent studies have estimated prevalence of depressed mood in about 45% and anxiety in 32% of patients with moderate to advanced COPD [123–125]. Dyspnea on exertion leads to fear and anxiety anytime a COPD patient has to exercise. This severely limits their social interaction and eventually leads to depression. COPD patients can suffer from hopelessness, sense of isolation and lack of motivation. It is essential to assess the presence of depressed mood during initial evaluation in a pulmonary rehabilitation program. Family and caregiver involvement is advisable to assess the social support system for the patient.

Identifying the mood disorders and deficit in the social support is an integral part of the program [114]. Patients in need can be provided with psychological and social support, which works to elevate mood, positive thinking and adaptive behavior towards disease and its management. This also improves the compliance with the pulmonary rehabilitation program. Psychological support can be provided by the physical therapist but often require a psychologist or a psychiatrist involvement.

9. Location of the training

Various models of PR have been adopted worldwide. An outpatient or hospital based-outpatient setting is the most widely used model to deliver PR to COPD patient in the developed countries [126]. Current body of evidence regarding effectiveness of PR in COPD patients is based on this model. In recent years an alternative model where the site of delivery of PR is at home has been studied. Home based PR setting provides the benefit of exercise training in a familiar setting to a larger patient population. Specifically for patients with severe COPD dependent on long term oxygen therapy, this model of PR has been shown to be both safe and effective [127, 128]. While home based PR model offers convenience, it lacks the group dynamics which an outpatient model can offer. Group therapy leads to socialization, mood elevation and positive reinforcement. Additionally a home based program does not have a multidisciplinary and comprehensive structure of a hospital based outpatient setting. At the present time, choice of location of PR is dependent on patient preference, disease severity and regional availability of resources.

10. Adjuncts to exercise training

10.1 Neuromuscular electrical training

Several COPD patients with advanced lung disease who are bed bound or wheelchair bound are unable to participate in a conventional pulmonary rehabilitation program. To help these patients, a new modality of transcutaneous neuromuscular electrical stimulation (NMES) has been devised recently [129–131]. This technology involves application of low amplitude electric current via electrodes transcutaneously to the targeted muscle groups by depolarizing motor neurons. Low intensity electric current (10–100 mA) is delivered at stimulation frequencies between 8 and 120 Hz for duration of 250–400 ms. Although no large RCTs are available, a recent meta-analysis did report improvement in quadriceps strength and exercise capacity with NMES. Unfortunately, no significant improvement in HRQoL in moderate to

severe COPD was seen [132]. Apart from debilitated COPD patients, this technology has been recommended for use during COPD exacerbation, as it has low impact on ventilation, heart rate and dyspnea [133, 134].

10.2 Respiratory muscle training

A pulmonary rehabilitation programs for COPD patients usually includes respiratory muscle training. The goal of this training is to improve the abnormal breathing pattern, which may result due to increased work of breathing, chest wall changes and poor breathing habits in COPD patients [135–138]. The most commonly applied approach is through the endurance and strength training. [26]. Exercise training can lead to increase in minute ventilation, which leads to an increase in work of breathing. Constant controlled aerobic exercises of upper and lower extremities can lead to a recurrent stimulation to respiratory muscles. This helps the COPD patients to modify their breathing patterns on a day-to-day basis as well as be better prepared for an exacerbation.

Apart from exercise training, specific breathing exercises such as diaphragmatic breathing, paced breathing with exercises and pursed lip breathing has been proven to be beneficial in COPD patients. Diaphragm, which is the main inspiratory muscle, is flattened and ineffective in patients with hyperinflated lungs. This puts these patients at a mechanical disadvantage to adequately maintain and increase their minute ventilation. COPD patients who undergo the training to improve the coordination of their diaphragmatic muscle tend to fare better overall [139].

Many patients with emphysema self-discover the method of purse lip breathing for faster recovery from shortness of breath post exercise. Other patients can be instructed regarding this method. It helps patients to increase alveolar ventilation, tidal volume and CO_2 removal. It also leads to slow expiratory flow and decreased respiratory rate [140]. Using the same principle, respiratory muscles can be trained by using resistive breathing devices. This can be particularly useful in patients who continue to have dyspnea despite optimal medical management.

Additionally COPD patients specifically with chronic bronchitis occasionally have ineffectual cough leading to difficulty in respiratory secretion clearance. Instructions on special coughing techniques (huffing, autogenic drainage) combined with oscillating expiratory breathing devices (Acapella, In-exsufflator) can prove effective [141]. Patients can be instructed to perform daily chest physiotherapy to assist in respiratory secretion clearance through postural drainage techniques [142]. A meta-analysis of 32 studies focusing on respiratory muscle training showed that it leads to improvement in respiratory muscle strength, exercise capacity and perception of exertional dyspnea [143].

11. Maintenance of the training

The beneficial effects of a comprehensive pulmonary rehabilitation program are not sustained beyond 12 months [32, 42, 144, 145]. On the other hand, repeating a pulmonary rehabilitation programs has not been found to be an effective treatment option [146]. Considering this, it is challenging to maintain the changes made in physical activity and lifestyle due to a pulmonary rehabilitation. Although there is a lack of data on maintenance programs, some centers do provide these in the hope to achieve prolonged benefits gathered in a successful rehabilitation program. There are no set guidelines to establish an optimal strategy for providing maintenance pulmonary rehabilitation. Additionally other factors such as lack of transportation

to the PR center, disruption of daily life routine, absence of family support, perception regarding gains from the PR program, have impact on patient's participation in the post PR programs. A recent multicenter RCT studying the long term (3 year) maintenance program after PR in severe COPD patients, showed a sustained beneficial effect on BODE index and 6MWD at 24 months. Although, the effect vanished beyond 2 years as at end of study only 66% of COPD patients were still adherent with the maintenance program [147].

Various methods adopted to provide therapy beyond a comprehensive program include weekly telephone contacts, home exercise training with or without weekly-supervised outpatient sessions and recurrent PR program [146, 148–151]. A recent meta-analysis analyzing post-PR exercise program in COPD patients suggested that such a program even though effective in maintaining a good exercise capacity with the 6 months of PR, loses its benefit beyond 1 year and has no impact on HRQoL [152]. The patient population and the interventions used were variable and results of this study need to be interpreted cautiously.

Since the structure of the most effective maintenance program remains elusive, it is important at this time to encourage the COPD patients to continue with healthy lifestyle changes. This can be achieved by a concerted effort of the PR staff, family members, and patients' healthcare team. Those COPD patients who continue with the exercise routine and lifestyle changes they had learnt in the PR program tend to accumulate gains in physical endurance and psychological functioning [153].

12. Future directions

Pulmonary rehabilitation has a major role in the management of patients with chronic lung conditions especially COPD. The need for more convenient and efficient programs using new technology would be beneficial for patients. Tele-rehabilitation to deliver rehabilitation services over telemedicine using internet or phone can provides services to patients who live in remote areas without access to transportation. Tele-rehabilitation allows video conferencing between a central control unit and a patient at home. This will also deliver health services to patients with disability who cannot travel long distances for rehabilitation programs. Both mobile phones and video conferencing have used in few studies deliver rehabilitation services. The studies have demonstrated good compliance, decrease in exacerbations and hospitalizations, improved exercise capacity and quality of life [154, 155]. Benefits of telemonitoring in COPD patients have been described in a systemic review that showed decrease in hospitalizations and emergency room visits using telephone support for telerehabilitation [156].

13. Conclusions

A comprehensive multimodality pulmonary rehabilitation program is becoming an essential part of the management of COPD patients. It is not only cost effective but also scientifically proven to improve patients' symptoms and functionality. With a gradual increase in daily activity, COPD patients are able to achieve higher HRQoL compared to pharmacotherapy alone. Despite these proven benefits, widespread utilization of PR remains poor. Multiple factors, including; physician unfamiliarity of benefits of PR, patient compliance with the exercise regimen and insurance coverage contribute to this gap. With the increasing prevalence of COPD worldwide, a safe and effective option like PR needs to be actively promoted and utilized.

Apart from standardized exercise regimens and strength training, the emphasis of an effective PR program is on behavioral modification. This result in long lasting, positive changes on the disease course. In addition, empowering the COPD patients by educating them about disease, smoking cessation and nutrition is a crucial step in the right direction. Development of home based or telerehabilitation services may assist in reducing the disparity in access to PR for many more COPD patients.

Conflict of interest

Authors declare no conflicts of interest.

Appendix

COPD	chronic obstructive pulmonary disease
AECOPD	acute exacerbation of chronic obstructive pulmonary disease
PR	pulmonary rehabilitation
HRQoL	health-related quality of life
RCT	randomized controlled trial
NMES	neuromuscular electrical stimulation
ADLs	activities of daily living
mMRC	modified Medical Research Council
6MWT	6 minute walk test
FIM	functional independence measure
AMPS	assessment of motor and process skills
FCE	functional capacity evaluation
DEXA	dual energy X-ray absorptiometry
BODE index	body mass index, airflow obstruction, dyspnea and exercise capacity

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