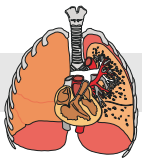

Pulmonary Rehabilitation

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Pulmonary rehabilitation is increasingly recognized as an important component of the comprehensive management of patients with symptomatic lung disease. A somewhat nihilistic approach became widespread when multiple studies evaluating this therapeutic tool in patients with severe lung disease failed to show any improvement in conventional pulmonary function tests. Fortunately, the perseverance of many investigators from multiple disciplines has provided firm proof that pulmonary rehabilitation offers the best treatment option for patients with symptomatic lung disease. This article reviews the fundamental concepts of pulmonary rehabilitation, its different components, and its effect on several outcomes. This review focuses on data obtained from studies of patients with chronic obstructive pulmonary disease because this entity affects the majority of patients who are candidates for this therapeutic modality, but many of the principles are also applicable to patients with other advanced symptomatic respiratory diseases.

Definition, objectives, goals

Definition

The Council of Rehabilitation defines rehabilitation as attempts to restore the individual to the fullest medical, mental, emotional, social and vocational potential of which he or she is capable. The most important concept in the definition is that any program must attempt to treat each enrolled patient as an "individual." The variation that arises from the need to individualize therapy from one patient to another is one of the factors that makes the objective evaluation of each group of patients enrolled in a rehabilitation program difficult.

Pulmonary rehabilitation has recently been redefined by the American Thoracic Society [1] as: "A multidisciplinary program of care for patients with chronic respiratory impairment that is individually tailored and designed to optimize physical and social performance and autonomy."

This definition is similar to others proposed over the years [2,3]. It is clear from these reviews that because pulmonary rehabilitation is multidisciplinary and utilizes different therapeutic components, it is difficult to attribute improved global outcomes to the effect of individual elements of a program. However, certain concepts are based on significant evidence [3]. Independent of the study design used, conventional pulmonary function tests do not change after pulmonary rehabilitation [4–8]. Nevertheless, well-controlled studies [Table 1] have shown significant improvement in different outcomes, including increased exercise capacity, improved health-related quality of life, decreased dyspnea, and fewer hospital admissions [7–16].

Objectives and goals

From the definition it follows that pulmonary rehabilitation has two major objectives: a) to control, alleviate, and as much as possible reverse the symptoms and pathophysiologic processes leading to respiratory impairment; and b) to improve the quality of, and attempt to prolong, the patient's life.

In the broadest sense, pulmonary rehabilitation implies providing good, comprehensive respiratory care to patients with pulmonary disease. In practical terms, comprehensive care may be best provided by a multidisciplinary approach through a structured "rehabilitation program." The practical goals are shown in Table 2.

Patient selection

Any patient symptomatic of respiratory disease is a candidate for rehabilitation. It is preferable to choose patients with moderate to moderately severe disease in order to prevent the disabling effects

Table 1. Outcomes of pulmonary rehabilitation in patients with COPD

Reference	Outcome	Effect	Grade of evidence
[7–27]	Exercise, endurance	Large and significant increase	A
[8,9,11,14,16,27]	Exercise, work capacity (Watt or VO_2)	Modest increase	A
[24,25]	Biochemical muscle enzyme changes	Controversial	\b
[7,17]	Dyspnea	Large and significant improvement	A
[9,11,13,16,17]	Quality of life	Improvement	A
[15]	Health-related cost	Improvement	B

Evidence is graded according to these guidelines.
Grade A: Evidence obtained from well-controlled randomized studies.
Grade B: Evidence obtained from well-designed controlled trials, small numbers.
Grade C: Evidence obtained from multiple time series.

Table 2. Practical goals of a pulmonary rehabilitation program

Reduce work of breathing
Improve pulmonary function
Normalize arterial blood gases
Alleviate dyspnea
Increase efficiency of energy utilization
Correct nutrition
Improve exercise performance and activities of daily living
Restore a positive outlook in patients
Improve emotional state
Decrease health-related costs
Improve survival

of end-stage respiratory failure. This is an important issue because it seems intuitive that patients with minimal functional limitations may benefit little from programs designed to improve function. On the other hand, patients who are too far advanced along the course of their illness could be considered unlikely to benefit from rehabilitation [16]. This concept is debatable, as shown by the fact that patients with the most severe degree of lung disease, such as those waiting for lung transplantation and lung volume reduction surgery, have shown significant functional improvement and increased exercise endurance after pulmonary rehabilitation [17].

Patients with mild disease may not justify the intense effort needed to maintain a viable program. Other factors that may hinder the ultimate success of rehabilitation for an individual are: presence of disabling diseases such as severe heart failure or arthritis, very low educational level, occupation, lack of support and, above all, motivation [2,4]. Although it is customary not to consider patients with cancer as candidates for rehabilitation, we have included selected patients with limited exercise performance who are otherwise candidates for surgery. This is particularly important in view of new reports of simultaneous resection of lung nodules in patients with severe COPD who until now were deemed inoperable because of very severe airflow obstruction. Likewise, the inclusion of pulmonary rehabilitation in the preoperative conditioning of patients undergoing lung transplant or lung volume reduction surgery [17] has expanded the list of indications for rehabilitation.

Program organization

The program needs a coordinator who will organize the different components into a functioning unit. The coordinator develops the educational program to include respiratory anatomy and physiology with simplified explanations of disease process and their therapy. The program should have resources available to teach and supervise respiratory therapy techniques (oxygen, inhalers, nebulizers, etc.), physical therapy (breathing techniques, chest physical therapy, postural drainage), exercise conditioning (upper and lower extremity), and activities of daily living (work simplification, energy conservation). Also desirable are services to evaluate and advise on nutritional needs, psychological evaluation and vocational counseling [18,19].

COPD = chronic obstructive pulmonary disease

The decision whether to have an inpatient or an outpatient program depends on the methods of reimbursement, patient population, available personnel, and hospital policy. The ideal system is one that provides an in-hospital arm for patients who may benefit from the program while recovering from acute exacerbations, and an outpatient arm (including home therapy) that could complete the program started in the hospital.

Therapeutic modalities that improve patients' performance

Exercise conditioning

Exercise conditioning is based on three physiologic principles [18,19]: a) specificity of training, which attributes improvement only to the exercise practiced; b) intensity of training, which establishes that only a load higher than baseline will induce a training effect; and c) reversal of the training effect, which holds that once discontinued, the training effect will disappear. The first two have been extensively applied in the rehabilitation of patients with severe COPD. Extrapolation from the effect on normal subjects and in populations such as patients selected for lung transplant gives support to the inclusion of exercise in the rehabilitation of patients with diseases other than COPD.

- *Lower extremity exercise*

Several recent controlled trials prove that pulmonary rehabilitation is better than regular treatment in the symptomatic COPD patient. The first study, reported by Goldstein et al. [10], involved 89 patients randomized to either inpatient rehabilitation for 8 weeks, which was then followed by 16 weeks of outpatient treatment, or to conventional care as provided by their physician. At the end of the study, the patients in the rehabilitation group (n=45) significantly improved their exercise endurance, submaximal cycle time, compared to controls (n=44). This was associated with a decrease in dyspnea, improvement in emotional function, and mastery. Wijkstra and co-workers [12] reported the results of 12 weeks of rehabilitation in 28 COPD patients as compared to 15 patients who received no treatment and served as controls. This study is unique in that the rehabilitation was conducted at home, with the program supervised by non-specialists. After rehabilitation the treated patients showed a greater increase in walked distance, maximal work in watts, oxygen uptake (VO_2), and a decrease in lactate production and perception of dyspnea when compared to controls. These two studies, one inpatient and one at home, demonstrate that rehabilitation is clearly effective.

Exercise training is the most important component of a pulmonary rehabilitation program. Casaburi [20] reviewed 36 uncontrolled studies that evaluated the effect of exercise training on exercise performance in over 900 COPD patients. Exercise training improved exercise endurance in all these patients. This has been confirmed by controlled trials showing that a rehabilitation program that includes lower extremity exercise is better than other forms of therapy such as optimization of medication, education, breathing retraining, and group therapy [7–16].

All these studies hold in common an increase in exercise endurance, a modest but significant improvement in work or oxygen

uptake, and a decrease in the perception of dyspnea. Perhaps the most complete of these repots is the study by Ries and colleagues [8]. They randomized 119 patients to education (n=62) and education with exercise training (n=57). After 6 months the trained patients significantly increased their exercise endurance time and peak oxygen uptake, and reported an improvement in perception of dyspnea and self-efficacy for walking, when compared to controls. In a unique report, O'Hara et al. [21] enrolled 14 patients with COPD in a home program that included weight lifting. After training, weight lifters had reduced their minute ventilation and increased their ergometry endurance by 16%, when compared with controls. This study suggests that strength training may achieve results similar to those of specific endurance training, and could be an alternative form of training.

It has been suggested that with exercise, patients with COPD become desensitized to the dyspnea induced by the ventilatory load. This was supported by studies such as the one by Belman and Kendregan [22], who randomized patients to upper or lower extremity exercise and obtained muscle biopsies of the trained limbs before and after training. In spite of a significant increase in exercise endurance, there were no changes in the oxidative enzyme content of the trained muscle. In contrast, Maltais et al. [23] documented evidence for a true training effect. In this study the muscle biopsies of trained patients but not those of the controls manifested significant increases in all enzymes responsible for oxidative muscle function. That these biochemical changes are associated with important physiologic outcomes was supported by a reduction in exercise lactic acidosis and minute ventilation after training.

The importance of exercise training is highlighted by several studies documenting important improvement in physiologic outcomes, such as increase in submaximal exercise endurance and capacity, respiratory muscle strength, improved breathing pattern and decreased lactic acid production at isowork exercise [24–26] in patients undergoing relatively high intensity exercise training. However, the importance of high intensity endurance training as the only mode of training has been challenged by other studies that have shown clinically significant improvement in other outcomes such as dyspnea and quality of life using strength training [27,28] or lower intensity endurance training [29]. Overall, it is safe to state that some training is required and that the intensity should be the highest possible, taking into account the patient's tolerability and specific goals.

All symptomatic patients who are willing and capable of some exercise are candidates for rehabilitation. ZuWallack et al. [30] evaluated 50 severe COPD patients before and after exercise training. They observed an inverse relationship between the baseline 12 minute walk distance and the oxygen uptake on one hand, and improvement on the other. The results in patients selected for lung transplantation show that rehabilitation improves performance to a degree not achieved with any other form of therapy. The data therefore support exercise as a crucial component in the rehabilitation of patients with very severe lung disease. This is demonstrated in Figure 1. There was a significant improvement in 6 minute walking distance in patients with severe COPD (mean forced expiratory volume at 1 sec of 0.82 L) who underwent preoperative pulmonary rehabilitation before lung volume reduction surgery at our institution.

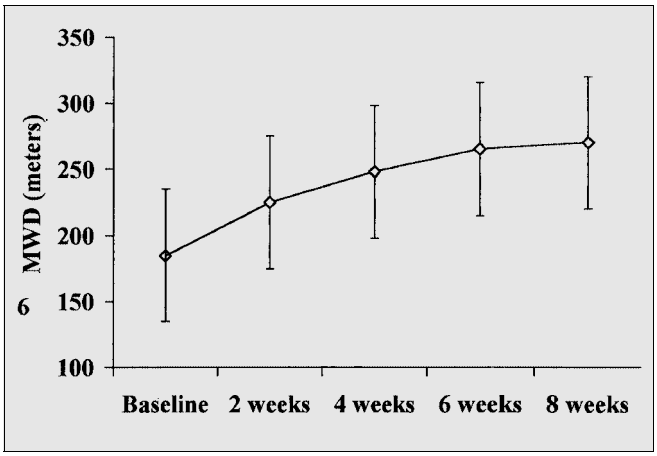

Figure 1. Timed (6 minutes) walking distance in 16 patients with advanced lung disease (COPD) before and after 24 sessions of preoperative pulmonary rehabilitation for lung volume reduction surgery at St. Elizabeth's Medical Center.

- *Upper extremity exercise*

Most of our knowledge about exercise conditioning is derived from programs emphasizing leg training. This is unfortunate, because the performance of many everyday tasks requires not only the hands but also the concerted action of other muscle groups that are also used in upper torso and arm positioning. Some of these serve a dual function (respiratory and postural), and arm exercise will decrease their capacity to participate in ventilation [31]. These observations suggest that if the arms are trained to perform more work, or if the ventilatory requirement for the same work is decreased, as we have shown, this could improve the capacity to perform activities of daily living.

Arm training results in improved performance, which is for the most part task-specific. Ries and colleagues [32] studied the effect of two forms of arm exercise – gravity resistance and modified proprioceptive neuromuscular facilitation – and compared them with no arm exercise in 45 patients with COPD. The 20 patients who completed the program improved performance on the tests that were specific for the training. The patients also reported a decrease in fatigue for all tests performed. Martinez et al. [33] showed that unsupported arm training (against gravity) decreases oxygen uptake at the same workload when compared to arm-cranking training. They concluded that unsupported arm exercise may be more effective for training patients in activities that resemble those of daily living.

Physical modalities of ventilatory therapy

These modalities comprise two categories: a) controlled breathing techniques (diaphragmatic breathing exercise, pursed lip breathing, and bending forward), and b) chest physical therapy (postural drainage, chest percussion and vibration position). The former are aimed at decreasing dyspnea, and the latter should enhance

drainage of secretions. The benefits of these modalities include less dyspnea, a decrement in anxiety and panic attacks, and improvement in sense of well-being. These modalities require careful instruction by specialists familiar with the techniques. They should be initiated as soon as possible and repeated often with close supervision until the patient shows thorough understanding of the technique. It is often necessary to involve family members since some of these modalities require the help of another person (e.g., chest percussion).

- *Breathing training*

Breathing training is aimed at controlling the respiratory rate and breathing pattern, thus decreasing air trapping. It also attempts to decrease the work of breathing and improve the position and function of the respiratory muscles [18]. The easiest of these maneuvers is pursed lip breathing. Patients inhale through the nose and exhale for 4 to 6 seconds through lips pursed in a whistling, kissing position. The exact mechanism whereby this decreases dyspnea is unknown. It does not seem to change functional residual capacity or oxygen uptake, but it does decrease respiratory frequency with increase in tidal volume [18]. The bending forward posture has been shown to result in a decrease in dyspnea in some patients with severe COPD, both at rest and during exercise. These changes can also be seen in the supine or Trendelenburg position. The best explanation for the improvement is the improved diaphragmatic function, as the increased gastric pressure in these positions places the diaphragm in a better contracting position.

Diaphragmatic breathing is a technique aimed at changing the breathing pattern from one where the ribcage muscles are the predominant pressure generators, to a more normal one where the pressures are generated by the diaphragm. It is usually practiced for at least 20 minutes two or three times daily. The patient should start the training in the supine position and, once familiar with the technique, perform it in the upright posture. He or she is instructed to breathe in, trying to outwardly displace his/her hand that is placed on the abdomen. He then exhales with pursed lips, while encouraged to use his abdominal muscles in an attempt to return the diaphragm to a more lengthened resting position. Although most patients report improvement in dyspnea and clinical perception, there are minimal if any changes in oxygen uptake and resting lung volume. Similar to pursed lip breathing, there is usually a fall in respiratory rate and minute ventilation and increased tidal volume.

- *Chest physical therapy*

The goal of these techniques is removing airways secretions, thereby decreasing airflow resistance and bronchopulmonary infection. These techniques include postural drainage, chest percussion, vibration, and directed cough. Postural drainage uses gravity to help drain the individual lung segments. Chest percussion should be performed with care in patients with osteoporosis or bone problems.

Cough is also an effective technique for removing excess mucus from the larger airways. Unfortunately, patients with COPD have impaired cough mechanisms, maximum expiratory flow is reduced, ciliary beat is impaired and the mucus itself has altered viscoelastic properties. Since cough spasms may lead to dyspnea, fatigue and worsened obstruction, directed cough may be helpful by modulating the beneficial effect and preventing the untoward ones. With controlled coughing, patients are instructed to inhale deeply, hold their breath for a few seconds and then cough two or three times with the mouth open. They are also instructed to compress their upper abdomen to assist in the cough. It seems clear that pulmonary function does not improve with any of these techniques. On the other hand, programs that include a combination of postural drainage, percussion, vibration and cough, do increase the clearance of inhaled radio-tracers and increase sputum volume and weight. The single most important criterion for chest physical therapy is the presence of sputum production.

Ventilatory muscle training

Respiratory muscles can be specifically trained to improve their strength or endurance. Since reduced inspiratory muscle strength is evident in patients with COPD, considerable effort has been made to define the role of respiratory muscle training in these patients [3]. Strength training has limited clinical significance. Controlled trials of endurance training have shown an increase in the endurance time that the ventilatory muscles can tolerate a known load. Some have shown a significant increase in strength and a decrease in dyspnea during inspiratory load and during exercise [34–37]. In the studies that evaluated systemic exercise performance, there was an increase in walking distance and cardiopulmonary exercise endurance. The extensive data available indicate that ventilatory muscle training with resistive breathing results in improved ventilatory muscle strength and endurance, and has a beneficial effect on overall exercise performance [36]. It is not clear whether this effort results in changes in important clinical outcomes such as health status or functional dyspnea, although the results in some recent small studies are encouraging [36,37].

Respiratory muscle resting

When the respiratory muscles have to work against a large enough load, they may fatigue. This has been shown experimentally both in normal volunteers and in patients with COPD. Clinically, it seems that respiratory muscle fatigue plays an important role in the acute failure of patients with COPD. It seems logical that non-invasive ventilation may be helpful in cases of acute or chronic respiratory failure with impending respiratory muscle fatigue. A randomized trial has confirmed this assumption [38]. This trial showed that non-invasive positive pressure ventilation improved several outcomes, including rate of intubation, length in the intensive care unit and total hospital stay, dyspnea and mortality. Currently there is uniform agreement that non-invasive positive pressure ventilation was effective in reversing acute respiratory failure. The best patients were those with elevated $PaCO_2$, who were able to cooperate with the caregivers and did not suffer from other serious conditions (sepsis, severe pneumonia, etc.). Because positive pressure non-invasive ventilation is potentially dangerous, patients considered for this therapy should be closely monitored and treated by individuals familiar with these ventilatory techniques.

The possibility that the respiratory muscles of patients with stable severe COPD were functioning close to the fatigue threshold led numerous investigators to explore the role of resting the muscles with the use of non-invasive negative and positive pressure ventilation. All but one of the controlled trials [39,40] using both forms of ventilation did not demonstrate any benefit in most of the outcomes studied. Therefore, the routine use of non-invasive ventilation in stable COPD is not justified.

Nutritional evaluation

Many patients with emphysema appear thin and emaciated. It has recently been shown that in fact they may be protein-calorie malnourished. Most authorities agree that an attempt should be made to correct deficiencies that may be present [18]. Correction of factors such as anemia (to improve oxygen-carrying capacity) and electrolyte imbalances (sodium, potassium, phosphorous and magnesium) could result in improved cardiopulmonary performance. Similarly, simple measures such as encouraging the patient to take small amounts of food at more frequent intervals result in less abdominal distension and decreased dyspnea after meals. We also recommend evaluating oxygen saturation during meals. If present this can be alleviated by supplementing oxygen at meal time.

Psychological support

Most patients with advanced lung disease have minor psychological problems, mainly reactive depression and anxiety [18]. These problems are likely to subside as the patient becomes involved in a rehabilitation program that improves activity performance. Being able to exercise under the supervision of specialists frequently results in a desensitization of the symptoms, and decreased dyspnea and fear. It has been shown that 15–20 rehabilitation sessions that include education, exercise, modalities of physical therapy, breathing techniques and relaxation are more effective in reducing anxiety than a similar number of psychotherapy sessions. Occasionally, however, patients will require psychiatric evaluation and treatment.

Conclusions

Pulmonary rehabilitation has gradually become the gold standard treatment for patients with severe lung disease, especially COPD. Although most of the data on rehabilitation were obtained from studies of patients with COPD, the basic principles and tools are applicable to patients with many other exercise-limiting chronic diseases of the respiratory system. New therapeutic strategies such as lung volume reduction surgery and lung transplantation require that the recipients of such treatment be well conditioned preoperatively. Thus, pulmonary rehabilitation is becoming a crucial component of the overall treating strategy for many patients previously deemed untreatable. Pulmonary rehabilitation should therefore be made available to all patients with symptomatic respiratory disease.

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