An Official American Thoracic Society/European Respiratory Society Statement: Key Concepts and Advances in Pulmonary Rehabilitation

EXECUTIVE SUMMARY


This official statement of the American Thoracic Society (ATS) and the European Respiratory Society (ERS) was approved by the ATS Board of Directors, June 2013, and by the ERS Scientific and Executive Committees in January 2013 and February 2013, respectively.

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BACKGROUND: Pulmonary rehabilitation is recognized as a core component of the management of individuals with chronic respiratory disease. Since the 2006 American Thoracic Society (ATS)/European Respiratory Society (ERS) Statement on Pulmonary Rehabilitation, there has been considerable growth in our knowledge of its efficacy and scope.

PURPOSE: The purpose of this Statement is to update the 2006 document, including a new definition of pulmonary rehabilitation and highlighting key concepts and major advances in the field.

METHODS: A multidisciplinary committee of experts representing the ATS Pulmonary Rehabilitation Assembly and the ERS Scientific Group 01.02, "Rehabilitation and Chronic Care," determined the overall scope of this update through group consensus. Focused literature reviews in key topic areas were conducted by committee members with relevant clinical and scientific expertise. The final content of this Statement was agreed on by all members.

RESULTS: An updated definition of pulmonary rehabilitation is proposed. New data are presented on the science and application of pulmonary rehabilitation, including its effectiveness in acutely ill individuals with chronic obstructive pulmonary disease, and in individuals with other chronic respiratory diseases. The importance of pulmonary rehabilitation in chronic disease management is highlighted. In addition, the role of health behavior change in optimizing and maintaining benefits is discussed.

CONCLUSIONS: The considerable growth in the science and application of pulmonary rehabilitation since 2006 adds further support for its efficacy in a wide range of individuals with chronic respiratory disease.

KEYWORDS: COPD; pulmonary rehabilitation; exacerbation; behavior; outcomes

OVERVIEW: Pulmonary rehabilitation has been clearly demonstrated to reduce dyspnea, increase exercise capacity, and improve quality of life in individuals with chronic obstructive pulmonary disease (COPD) (1). The Official ATS/ERS Statement, Key Concepts and Advances in Pulmonary Rehabilitation, available online at www.atsjournals.org, provides a detailed review of progress in the science and evolution in the concept of pulmonary rehabilitation.

since the 2006 Statement. It represents the consensus of 46 interna-
tional experts in the field of pulmonary rehabilitation. This printed
Executive Summary, by necessity, must focus on only those key
concepts and advances that have emerged over the past 6 years.

On the basis of current insights, the American Thoracic Society
(ATS) and the European Respiratory Society (ERS) have adopted
the following new definition of pulmonary rehabilitation: "Pulmo-
nary rehabilitation is a comprehensive intervention based on a thor-
ough patient assessment followed by patient-tailored therapies that
include, but are not limited to, exercise training, education, and
behavior change, designed to improve the physical and psycholog-
ical condition of people with chronic respiratory disease and to
promote the long-term adherence to health-enhancing behaviors."

Since the previous Statement, we now more fully understand
the complex nature of COPD, its multisystem manifestations, and
frequent comorbidities. Therefore, integrated care principles are
being adopted to optimize the management of these complex
patients (2). Pulmonary rehabilitation is now recognized as a core
component of this process (Figure 1) (3). Health behavior change
is vital to optimization and maintenance of benefits from any
intervention in chronic care, and pulmonary rehabilitation has
taken a lead in implementing strategies to achieve this goal.

Noteworthy advances in pulmonary rehabilitation that are
discussed in the online Statement and briefly outlined in this doc-
ument include the following:

- There is increased evidence for use and efficacy of a variety
  of forms of exercise training as part of pulmonary rehabil-
  itation; these include interval training, strength training,
  upper limb training, and transcutaneous neuromuscular
electrical stimulation.

- Pulmonary rehabilitation provided to individuals with chronic
  respiratory diseases other than COPD (i.e., interstitial lung
disease, bronchiectasis, cystic fibrosis, asthma, pulmonary
hypertension, lung cancer, lung volume reduction surgery,
and lung transplantation) has demonstrated improvements
in symptoms, exercise tolerance, and quality of life.

- Symptomatic individuals with COPD who have lesser
degrees of airflow limitation and who participate in pulmo-
nary rehabilitation derive similar improvements in symp-
toms, exercise tolerance, and quality of life as do those
with more severe disease.

- Pulmonary rehabilitation initiated shortly after a hospitalization
for a COPD exacerbation is clinically effective, safe, and asso-
ciated with a reduction in subsequent hospital admissions.

- Exercise rehabilitation commenced during acute or critical
illness reduces the extent of functional decline and hastens
recovery.

- Appropriately resourced home-based exercise training has
proven effective in reducing dyspnea and increasing exer-
cise performance in individuals with COPD.

- Technologies are currently being adapted and tested to
support exercise training, education, exacerbation man-
agement, and physical activity in the context of pulmonary
rehabilitation.

- The scope of outcomes assessment has broadened, allow-
ng for the evaluation of COPD-related knowledge and
self-efficacy, lower and upper limb muscle function, bal-
ance, and physical activity.

- Symptoms of anxiety and depression are prevalent in indi-
viduals referred to pulmonary rehabilitation, may affect
outcomes, and can be ameliorated by this intervention.

In the future, we see the need to increase the applicability and
accessibility of pulmonary rehabilitation; to effect behavior

![Figure 1. A spectrum of support for chronic obstructive pulmonary dis-
hase. Reprinted by permission from Reference 3.](image-url)
change to optimize and maintain outcomes; and to refine this intervention so that it targets the unique needs of the complex patient.

INTRODUCTION
The Official ATS/ERS Statement, Key Concepts and Advances in Pulmonary Rehabilitation, available online at www.atsjournals.org, provides a detailed review of progress in the science and evolution in the concept of pulmonary rehabilitation since the 2006 Statement. This printed Executive Summary, by necessity, must focus on only those key concepts and advances that have emerged over the past 6 years.

METHODS
A multinational, multidisciplinary group of 46 clinical and research experts participated in an American Thoracic Society (ATS)/European Respiratory Society (ERS) Task Force with the charge to update the previous Statement (1). Task Force members were identified by the leadership of the ATS Pulmonary Rehabilitation Assembly and the ERS Scientific Group 01.02, “Rehabilitation and Chronic Care.” Members were vetted for potential conflicts of interest according to the policies and procedures of the ATS and ERS. This document represents the consensus of these Task Force members. Table 1 provides a summary of the methods used to accumulate the evidence.

DEFINITION AND CONCEPT
On the basis of our current insights, the ATS and ERS have adopted the following new definition of pulmonary rehabilitation: “Pulmonary rehabilitation is a comprehensive intervention based on a thorough patient assessment followed by patient-tailored therapies that include, but are not limited to, exercise training, education, and behavior change, designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviors.”

Pulmonary rehabilitation is implemented by a dedicated, interdisciplinary team, including physicians and other health care professionals; the latter may include physiotherapists, respiratory therapists, nurses, psychologists, behavioral specialists, exercise physiologists, nutritionists, occupational therapists, and social workers. The intervention should be individualized to the unique needs of the patient, based on initial and ongoing assessments, including disease severity, complexity, and comorbidities. Although pulmonary rehabilitation is a defined intervention, its components should be integrated throughout the clinical course of a patient’s disease. Pulmonary rehabilitation may be initiated at any stage of the disease, during periods of clinical stability or during or directly after an exacerbation. The goals of pulmonary rehabilitation include minimizing symptom burden, maximizing exercise performance, promoting autonomy, increasing participation in everyday activities, enhancing (health-related) quality of life, and effecting long-term health-enhancing behavior change.

This document places pulmonary rehabilitation within the concept of integrated care. The World Health Organization defines integrated care as “a concept bringing together inputs, delivery, management and organization of services related to diagnosis, treatment, care, rehabilitation and health promotion” (4). Integration of services improves access, quality, user satisfaction, and efficiency of medical care. As such, pulmonary rehabilitation provides an opportunity to coordinate care throughout the clinical course of an individual’s disease.

EXERCISE TRAINING
Endurance Training
Endurance exercise training is typically prescribed three to five times per week. A high level of intensity of continuous exercise (>60% maximal work rate) for 20 to 60 minutes per session maximizes physiologic benefits (i.e., exercise tolerance, muscle function, and bioenergetics) (5). Before starting an exercise training program, an exercise assessment is needed to individualize the exercise prescription, evaluate the potential need for supplemental oxygen, help rule out some cardiovascular comorbidities, and help ensure the safety of the intervention (6–11).

There has been increased awareness of the efficacy of leisure walking as a mode of exercise training in chronic obstructive pulmonary disease (COPD). For example, indoor ground walking increased endurance walking capacity more than cycle training and was similar to stationary cycle training in improving peak walking capacity, peak and endurance cycle capacity and quality of life (12). Moreover, a randomized, controlled trial of a 3-month outdoor Nordic walking exercise program (vs. control) in 60 patients with COPD resulted in significant improvements in exercise capacity and physical activity. These gains were sustained at 6 and 9 months after the initial intervention (13).

Interval Training
Interval training is a modification of endurance training where high-intensity exercise is interspersed regularly with periods of rest or lower intensity exercise. It results in lower symptom scores and fewer unintended breaks (14, 15) despite high absolute training loads, while reproducing the effects of endurance continuous training (14–16), even in cachectic individuals with severe COPD (17). Interval and continuous training modes generally have comparable improvements in exercise capacity, health-related quality of life, and skeletal muscle adaptations immediately after training (16, 18–25).

Resistance/Strength Training
Resistance/strength training, in which local muscle groups are trained by repetitive lifting of relatively heavy loads (26–28), is frequently provided to individuals who have reduced skeletal

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TABLE 1. METHODS CHECKLIST

<table>
<thead>
<tr>
<th>Method</th>
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<th>No</th>
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<tr>
<td>Panel assembly</td>
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<tr>
<td>Included experts from relevant clinical and nonclinical</td>
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<td>disciplines</td>
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<tr>
<td>Included individual who represents views of patients in</td>
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<td>society at large</td>
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<td>Included methodologist with documented expertise</td>
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<td>Performed in collaboration with librarian</td>
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<tr>
<td>Searched multiple electronic databases</td>
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<tr>
<td>Reviewed reference lists of retrieved articles</td>
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<tr>
<td>Evidence synthesis</td>
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<td>X</td>
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<tr>
<td>Applied prespecified inclusion and exclusion criteria</td>
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<td>X</td>
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<tr>
<td>Evaluated included studies for sources of bias</td>
<td></td>
<td></td>
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<tr>
<td>Explicitly summarized benefits and harms</td>
<td></td>
<td>X</td>
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<tr>
<td>Used PRISMA to report systematic review</td>
<td></td>
<td>X</td>
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<tr>
<td>Used GRADE to describe quality evidence</td>
<td></td>
<td>X</td>
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<tr>
<td>Generation of recommendations</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Used GRADE to rate the strength of recommendations</td>
<td></td>
<td>X</td>
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Definition of abbreviations: GRADE = Grading of Recommendations Assessment, Development and Evaluation; PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
muscle mass and/or strength (29–31). Resistance training provides greater increases in muscle mass and strength (27, 31–33), and induces less dyspnea (34) than endurance training, thereby making it attractive for individuals with severe dyspnea (35) and/or with a COPD exacerbation (36). The combination of endurance and strength training provides complementary benefits when treating peripheral muscle dysfunction in patients with chronic respiratory disease (33, 37).

Upper Limb Training
A systematic review demonstrated that upper limb resistance and endurance training improves upper limb function in COPD (38). Moreover, upper limb training improved functional task completion and fatigue scores (39), but did not show benefits in dyspnea during activities in daily life or in quality of life (40).

Neuromuscular Electrical Stimulation
Transcutaneous neuromuscular electrical stimulation (NMES) of leg muscles is a technique in which involuntary muscle contraction is elicited, and selected muscles can thereby be trained (41, 42). Muscle contraction induced by electrical stimulation does not lead to dyspnea; poses minimal cardiovascular demand (43, 44); and bypasses the cognitive, motivational, and psychological aspects involved in conventional exercise that may hinder or prevent effective exercise training.

NMES is safe, generally well tolerated, improves leg muscle strength and exercise capacity, and reduces dyspnea in stable outpatients with severe COPD and poor baseline exercise tolerance (41). NMES can be continued during COPD exacerbations (45–47). The duration of these benefits has not been studied.

Inspiratory Muscle Training
Systematic reviews have concluded that inspiratory muscle training (IMT), given as an adjunct to whole-body exercise training in individuals with COPD, leads to benefits in inspiratory muscle strength and endurance, but not on dyspnea or maximal exercise capacity (48, 49).

Maximizing the Effects of Exercise Training
Optimizing the use of maintenance bronchodilator therapy within the context of a pulmonary rehabilitation program for individuals with COPD augments the benefits of exercise training (50, 51), potentially allowing individuals to exercise at higher intensities. Anabolic drug supplementation to enhance the effects of exercise training has not received sufficient study for its routine use in pulmonary rehabilitation (52).

The evidence to date is equivocal on the widespread use of oxygen supplementation during exercise training for all individuals with COPD (53) apart from those already receiving long-term oxygen therapy. Individualized oxygen titration trials may identify individuals with COPD who respond to oxygen supplementation during exercise testing (54).

Studies testing the potential benefits of helium–oxygen mixtures as adjuncts to exercise training in COPD have had varied results, and its application as an adjunct to pulmonary rehabilitation remains to be established (55–57).

A systematic review evaluating the effects of noninvasive positive-pressure ventilation (NPPV) as an adjunct to pulmonary rehabilitation in individuals with COPD concluded that NPPV (either given nocturnally or during exercise) augments the benefits of an exercise program (58). The presumed mechanism is through allowing increased work rate to be performed via unloading the respiratory muscles. The benefit appears to be most marked in individuals with severe COPD, and higher positive pressures may lead to greater improvements.

PULMONARY REHABILITATION IN CONDITIONS OTHER THAN COPD
Individuals with chronic respiratory diseases other than COPD also experience exercise and activity limitation, dyspnea and fatigue, and impaired quality of life (59–92). Although the evidence-base supporting pulmonary rehabilitation in non-COPD disorders remains smaller than for COPD, randomized controlled trials and uncontrolled trials have shown its benefits in chronic respiratory diseases, such as interstitial lung disease, bronchiectasis, cystic fibrosis, asthma, pulmonary hypertension, lung cancer, lung volume reduction surgery, and lung transplantation (Table 2).

BEHAVIOR CHANGE AND COLLABORATIVE SELF-MANAGEMENT
The educational component of pulmonary rehabilitation that promotes adaptive behaviors such as self-efficacy (i.e., the confidence in successfully managing one’s health) stands next to exercise training as an essential component of this comprehensive intervention. A traditional didactic approach alone is likely to be insufficient to achieve optimal benefits (93).

Collaborative self-management strategies promote self-efficacy through increasing the patients’ knowledge and skills required to participate with health care professionals in optimally managing their illness and comorbidities (94). This multifaceted approach can be implemented through pulmonary rehabilitation (95, 96).

Self-management includes core generic strategies, such as goal setting, problem solving, decision-making, and taking action on the basis of a predefined action plan. These strategies should apply to any individual with any chronic respiratory disease. Action plans for the early recognition and treatment of COPD exacerbations have been shown to reduce health care use, improve time to recovery, and reduce costs (97–101). Action plans are integral to pulmonary rehabilitation, but can also be used independently, using a case manager.

Advance care planning is the process of communication among individuals and their caregivers that includes, but is not limited to, options for end-of-life care and the completion of advance directives (81, 102–105). Advance care planning can be effective in changing outcomes for individuals and their loved ones and can provide support for the implementation of advance directives (106–109). Pulmonary rehabilitation can provide the forum to discuss these issues.

BODY COMPOSITION ABNORMALITIES
Since the previous Statement, some data have indicated that a program of exercise and standardized nutritional supplements in individuals with mild to moderate COPD and low fat-free mass index (FFMI) may have clinical and health service use benefits compared with usual care (110). At the other end of the disease severity spectrum, a randomized controlled trial of 3 months of home rehabilitation (including health education, oral nutritional supplements, exercise, and oral testosterone) evaluated exercise performance, body composition, and survival in 122 underweight individuals with chronic respiratory failure (111). Improvements were seen in body mass index, FFMI, peak cycling work rate, and quadriceps muscle function. However, no significant improvement in the primary outcome, 6-minute walk distance (6MWD), was noted and there was no overall survival benefit up to 15 months (111). Creatine supplementation has not been found to enhance outcomes in patients with COPD participating in pulmonary rehabilitation (112, 113).
<table>
<thead>
<tr>
<th>Population</th>
<th>Evidence for PR</th>
<th>Outcomes of PR</th>
<th>Special Considerations</th>
<th>Specific Assessment Tools</th>
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<tbody>
<tr>
<td>Interstitial lung disease</td>
<td>Two RCTs of exercise training (272, 273); one observational pulmonary rehabilitation study (274); one systematic review (275)</td>
<td>Improved 6-min walk distance, dyspnea, and quality of life. Magnitude of benefits smaller than that seen in COPD (275, 276). Benefits not maintained at 6 mo (275, 276).</td>
<td>Exercise-induced desaturation and pulmonary hypertension are common. Supplemental oxygen should be available and appropriate monitoring of oxyhemoglobin saturation during exercise is indicated.</td>
<td>An IPF-specific version of the St. George’s Respiratory Questionnaire is available, with fewer items than the standard version (277)</td>
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<tr>
<td>Bronchiectasis</td>
<td>One RCT of exercise ± inspiratory muscle training (278); one large retrospective study of standard PR (279)</td>
<td>Improvement in incremental shuttle walk test distance and endurance exercise time. Benefits maintained after 3 mo only in group that did inspiratory muscle training in addition to whole body exercise training (278). Benefits of equivalent magnitude to those seen in COPD (279).</td>
<td>Role of airway clearance techniques not yet established. Importance of inspiratory muscle training muscle training unclear—associated with better maintenance of benefit in RCT (278)</td>
<td>Consider measuring impact of cough, e.g., Leicester Cough Questionnaire (280)</td>
</tr>
<tr>
<td>Cystic fibrosis</td>
<td>Six RCTs of aerobic training (281–283), anaerobic training (283, 284), combined training (285), or partially supervised sports (286); one systematic review (287)</td>
<td>Improvements in exercise capacity, strength, and quality of life; slower rate of decline in lung function; effects not consistent across trials</td>
<td>Walking exercise decreases sputum mechanical impedance (288), indicating a potential role for exercise in maintaining bronchial hygiene. No specific recommendations regarding pulmonary rehabilitation are included in CF infection control guidelines (289); however, it is noted that people with CF should maintain a distance of at least 3 ft from all others with CF when in the outpatient clinic setting. Local infection control policies may preclude participation in group exercise programs. Preexercise use of bronchodilators and gradual warm-up are indicated to minimize exercise-induced bronchospasm. Cardiopulmonary exercise testing may be used to evaluate for exercise-induced bronchospasm (295).</td>
<td>CF-specific quality of life questionnaires are available—Cystic Fibrosis Quality of Life Questionnaire (290) and Cystic Fibrosis Questionnaire (291)</td>
</tr>
<tr>
<td>Asthma</td>
<td>One systematic review (292); two RCTs of exercise training (293, 294)</td>
<td>Improved physical fitness asthma symptoms, anxiety, depression, and quality of life (292–294)</td>
<td>Preexercise use of bronchodilators and gradual warm-up are indicated to minimize exercise-induced bronchospasm. Cardiopulmonary exercise testing may be used to evaluate for exercise-induced bronchospasm (295).</td>
<td>Consider measures of asthma symptoms and asthma-specific quality of life measures, e.g., Asthma Quality of Life Questionnaire (296)</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
<td>One RCT (297); two prospective case series (87, 298)</td>
<td>Improved exercise endurance, WHO functional class, quality of life, peak VO₂ (87, 297, 298), increased peak workload (298), and increased peripheral muscle function (87)</td>
<td>Care must be taken to maintain S₉O₂ &gt; 88% during exercise and supplemental O₂ should be available. BP and pulse should be monitored closely. Telemetry may be needed for patients with known arrhythmias. Avoid falls for patients receiving anticoagulant medication. Light or moderate aerobic, and light resistive, training are recommended forms of exercise (299). High-intensity exercise, activities that involve Valsalva-like maneuvers or concurrent arm/leg exercises are generally not recommended. Close collaboration between PR providers and pulmonary hypertension specialists is needed to ensure safe exercise training. Exercise should be discontinued if the patient develops lightheadedness, chest pain, palpitations, or syncope.</td>
<td>Cambridge Pulmonary Hypertension Outcome Review (CAMPHOR) (300) WHO Functional Class (301) SF-36 (302) Assessment of Quality of Life instrument (AQoL) (303)</td>
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(Continued)
**TABLE 2. (CONTINUED)**

<table>
<thead>
<tr>
<th>Population</th>
<th>Evidence for PR</th>
<th>Outcomes of PR</th>
<th>Special Considerations</th>
<th>Specific Assessment Tools</th>
</tr>
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<tbody>
<tr>
<td>Lung cancer</td>
<td>Preoperative PR: Small, uncontrolled observational studies (304, 305)</td>
<td>Improved exercise tolerance (304, 305), possible change in status from noncandidate for surgical resection to operative candidate</td>
<td>Short duration (e.g., 2–4 wk), up to 5 times per week, needed to avoid delay in potential curative surgery</td>
<td>Functional Assessment of Cancer Therapy-Lung Cancer (FACT-L) (313, 314)</td>
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<td>Postoperative PR: Small uncontrolled trials (306–308); two RCTs comparing aerobic training, resistive training, or both in postsurgical lung cancer patients are ongoing (309, 310); one systematic review (311)</td>
<td>Increased walking endurance, increased peak exercise capacity, reduced dyspnea and fatigue (306–308). Variable impact on quality of life (311)</td>
<td></td>
<td>Trial Outcome Index (314, 315)</td>
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<tr>
<td>Lung volume reduction surgery</td>
<td>Medical treatment: Case series of patients with nonresectable stage III or IV cancer (312)</td>
<td>Improved symptoms and maintenance of muscle strength (312)</td>
<td></td>
<td>Functional Assessment of Cancer Therapy Fatigue Scale (316, 317)</td>
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<td>Prospective observational study (318): Analysis of data from the National Emphysema Treatment Trial; a small case series (efficacy of home-based PR before LVRS) (319)</td>
<td>Pre-LVRS PR and exercise training: Improved exercise capacity (peak workload, peak VO₂, walking endurance), muscle strength, dyspnea, and quality of life (318, 319)</td>
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<tr>
<td>Lung transplantation</td>
<td>Pretransplant PR: One RCT comparing interval versus continuous training (324); small uncontrolled trials evaluating benefits of pretransplant PR, including Nordic walking (325–328)</td>
<td>Pretransplant PR: Improved exercise tolerance and well-being (325–327) Post-transplant PR: Increased muscle strength, walking endurance, maximal exercise capacity, and quality of life (83, 329–331)</td>
<td>Oxygen saturation should be monitored. Explanations of the surgical procedure, postoperative care including chest tubes, lung expansion, secretion clearance techniques, and importance of early postoperative mobilization should be included in the educational component of PR. Exercise prescription must be tailored to patients with severe end-stage lung disease and to specific considerations pertaining to the disease for which the transplant is being considered. Patients may require lower intensity or interval training. Hemodynamic parameters and oxygenation should be monitored closely; O₂ should be available. Educational component should cover surgical techniques, risks, benefits of the surgery, postoperative care (controlled cough, incentive spirometry, chest tubes, wound care, secretion clearance techniques, importance of early mobilization, risk and benefits of immunosuppressive agents)</td>
<td>Quality of Well-Being Score (320, 321)</td>
</tr>
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<td></td>
<td>Post-transplant PR: Two RCTs; a few cohort studies; one systematic review assessing PR after lung transplantation (83, 329–331)</td>
<td></td>
<td>Usual outcome assessments for COPD, such as CRQ (322) and SGRQ (323), are appropriate. Consider generic tools such as SF-36 (302) to allow comparison with population normative values postoperatively. SF-36 and other assessment tools appropriate for the individual disease state</td>
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**Definition of abbreviations:** BP = blood pressure; CF = cystic fibrosis; COPD = chronic obstructive pulmonary disease; CRQ = Chronic Respiratory Questionnaire; IPF = interstitial pulmonary fibrosis; LVRS = lung volume reduction surgery; PR = pulmonary rehabilitation; RCT = randomized controlled trial; SaO₂ = oxygen saturation; SF-36 = Short Form-36; SGRQ = St. George’s Respiratory Questionnaire; VO₂ = aerobic capacity; WHO = World Health Organization.

An increasing number of individuals with obesity-related dyspnea and respiratory disturbances as well as those with chronic respiratory diseases and coexisting obesity are being referred for pulmonary rehabilitation (114). Despite less severe airflow obstruction and comparable constant work rate cycling endurance time, obese individuals with COPD have lower 6MWD compared with overweight and normal weight individuals (115). Although obesity may have a negative impact on exercise tolerance in individuals with COPD (115), it does not diminish the magnitude of gains made in pulmonary rehabilitation (115–118).

**PHYSICAL ACTIVITY**

Individuals with chronic respiratory disease are physically inactive (119–123). This inactivity is associated with poor outcomes, including higher mortality risk (124–127) and increased risk of readmission after a hospitalization for a COPD exacerbation (124, 127–130).

Pulmonary rehabilitation, with its goals of increasing exercise tolerance and improving self-efficacy, has the potential to promote increased levels of physical activity. However, studies evaluating the effectiveness of pulmonary rehabilitation on physical activity have had inconsistent results, with some showing benefit and others showing no effect (131–143). No study characteristics seem to consistently explain these differences. This disparity highlights the fact that there is, to date, little knowledge on how to transfer the gains in exercise capacity into increased physical activity in daily life. This is compounded by the fact that the optimal method for measuring physical activity is not known (144, 145).

**TIMING OF PULMONARY REHABILITATION**

**Earlier in the Course of the Disease**

Most randomized trials of pulmonary rehabilitation have involved individuals with COPD with a mean FEV₁ less than
50% of the predicted value (95, 146). Because physical inactivity and the systemic effects of COPD often occur earlier in the disease process (29, 35, 147–151), pulmonary rehabilitation for individuals with less severe disease may be beneficial and may impact long-term disease outcomes. In support of this, a community-based pulmonary rehabilitation program in individuals with mild to moderate COPD who had baseline exercise impairment was effective in improving exercise performance and in maintaining this benefit for 24 months (152). A 10-week pulmonary rehabilitation program in individuals with Global Initiative for Chronic Obstructive Lung Disease (GOLD) stages II to IV led to improvements in functional capacity and beneficial morphologic adaptations in leg muscle fibers (23). These improvements were similar across GOLD stages.

**During the Periexacerbation Period**

Since the previous Statement, considerable evidence has been published supporting exercise-based pulmonary rehabilitation during and immediately after hospitalization for COPD exacerbations. Although ventilatory limitation may preclude endurance training in this setting, resistance training of the leg muscles during exacerbations is well tolerated and safe, can lead to improvements in muscle strength, and may confer gains in exercise tolerance (36). NMES is an alternative training method that can prevent muscle function decline and hasten recovery of mobility for hospitalized individuals, including those in critical care settings (41, 153–155).

Pulmonary rehabilitation initiated early (e.g., within 3 wk) after hospital discharge for a COPD exacerbation is feasible, safe, and effective, and leads to gains in exercise tolerance, symptoms, and quality of life (156–165), and reductions in subsequent health care use (160, 163–165). A 2011 Cochrane review of randomized controlled trials comparing outcomes of pulmonary rehabilitation versus usual care after a hospitalization for a COPD exacerbation showed at least a 42% reduction in readmissions over 25 weeks (163). However, a trial involving 60 patients with COPD did not show a reduction in health care use at 1 year (166), although patients were probably not medically optimized. Pulmonary rehabilitation started during or shortly after a hospitalization for COPD may also favorably influence survival (163). More data would be needed before a firm conclusion can be made.

The provision of exercise rehabilitation during periods of critical illness prevents functional decline and hastens recovery (153, 154, 167–169). This is feasible even for individuals receiving mechanical ventilation.

**MAINTENANCE OF BENEFITS FROM PULMONARY REHABILITATION**

The benefits of pulmonary rehabilitation tend to diminish over 6–12 months, with quality of life being better maintained than exercise capacity (143, 170–172). Developing methods to extend the benefits of pulmonary rehabilitation is an important goal, although maintenance strategies thus far have been largely disappointing.

A small, controlled trial suggested that training effects obtained from an outpatient rehabilitation program can be maintained by home-based exercise training (accompanied by monthly phone calls) in patients with moderate COPD (173). However, periodic phone calls alone to individuals after a pulmonary rehabilitation program have had inconsistent results (138, 171).

Several randomized controlled trials have examined the effects of maintenance strategies (138, 171, 174). The evidence for supervised maintenance exercise remains equivocal, with one study finding no additional benefits of weekly sessions over routine follow-up (171) and another reporting that weekly sessions resulted in improved exercise capacity but not in health-related quality of life (175). Reducing the frequency of supervised sessions to every 2–4 weeks demonstrated no significant benefits for either outcome measure (175, 176). Repeating pulmonary rehabilitation appears to have comparable results to those of the initial program (177, 178). The precise format and timing of maintenance strategies have yet to be established (157).

**PATIENT-CENTERED OUTCOMES**

Since the previous Statement, studies have shown that pulmonary rehabilitation reduces symptoms of depression and anxiety (179), especially in individuals with high symptom scores at baseline (180).

In the area of new outcome tools, a new quality of life instrument, the COPD Assessment Test (181), has been shown to be responsive to pulmonary rehabilitation (182–184). Newer questionnaires to assess the information needs of individuals include the Lung Information Needs Questionnaire and the Bristol COPD Knowledge Questionnaire (185, 186). Both have been shown to demonstrate knowledge gains after pulmonary rehabilitation (93, 186, 187). The COPD Self-Efficacy Scale and the Pulmonary Rehabilitation Adapted Index of Self-Efficacy (PRAISE) tool have been shown to be responsive measures of self-efficacy in individuals attending pulmonary rehabilitation (188–190). The usefulness and applicability of these newer measures in pulmonary rehabilitation assessment remain to be determined. Importantly, in participants with chronic respiratory disorders other than COPD, alternative outcome assessments may be needed to understand the impact of the disease and document the benefits of pulmonary rehabilitation (Table 2).

Resistance training of lower and upper limbs is now a routine component of pulmonary rehabilitation that includes the assessment of skeletal muscle function before and after pulmonary rehabilitation (191).

Balance is generally impaired in individuals with COPD (192, 193), resulting in frequent falls (194). Pulmonary rehabilitation resulted in minor improvements in balance and had no effect on balance confidence in people with COPD (195), whereas a 12-week supervised Sun-style tai chi training program did improve balance compared with a usual care control group (196).

Elevated arterial stiffness and cardiac autonomic dysfunction occur in individuals with COPD and are related to quality of life, exercise performance, and physical inactivity (197–200). First studies show small but significant decreases in aortic and brachial pulse-wave velocity in individuals with COPD after pulmonary rehabilitation (200, 201). Effects of pulmonary rehabilitation on heart rate variability are equivocal (202–204).

The term “minimal important difference” (MID) has been defined as the smallest difference in a measurable clinical parameter that indicates a meaningful change in the condition, for better or for worse, as perceived by the patient, clinician, or investigator (205). MIDs for the shuttle field tests of exercise performance have been identified. After pulmonary rehabilitation, the MID has been determined to be 47.5 m for the incremental shuttle walk test and approximately 186 seconds for the endurance shuttle walk test (206, 207). The MID for 6MWD for COPD interventions was previously considered to be 54 m (208), although more recent studies support lower values in the range of 25 to 35 m (209–211). Comparable values were derived for individuals with pulmonary arterial hypertension or idiopathic pulmonary fibrosis (212, 213).
PROGRAM ORGANIZATION

Although all pulmonary rehabilitation programs share essential features, the available resources, program setting, structure, personnel, and duration vary considerably among different health care systems (214, 215).

Patient Selection

Pulmonary rehabilitation can be beneficial for any individual with chronic respiratory disease with persistent symptoms and/or functional status limitation despite otherwise optimal therapy (216). There is evidence that this intervention is effective irrespective of age, disease severity, or disease stability (23, 163, 217–221). Contraindications to pulmonary rehabilitation are few, but include any condition that precludes safe exercise training or would substantially interfere with the pulmonary rehabilitative process.

Comorbidities

COPD is commonly associated with comorbidities (222–235), which often have significant impact on symptoms, functional status, and outcomes (236–238). The presence of comorbidities needs to be considered in the context of enrolling individuals for and monitoring individuals within pulmonary rehabilitation programs, to ensure safety and enhance outcomes. The impact of comorbidities on attendance, completion, and outcomes of pulmonary rehabilitation is as yet unknown (117, 118, 239, 240).

Rehabilitation Setting

Pulmonary rehabilitation can be provided in inpatient and outpatient settings, and exercise training can also be provided in the individual’s home. Since the previous Statement, one large randomized trial compared appropriately resourced home-based with hospital-based exercise training in COPD (241). There were comparable improvements in the primary outcome, dyspnea, as measured by the Chronic Respiratory Questionnaire. Smaller randomized controlled trials have demonstrated similar improvements in home- and center-based exercise training (242, 243). Home exercise training (vs. usual care) in 50 oxygen-dependent individuals showed increased exercise performance and decreased dyspnea (244). Albores and colleagues tested the effectiveness of a 12-week home exercise program based on a user-friendly, computer system (five or more days per week) in 25 clinically stable patients with COPD (245). Significant improvements in exercise performance, arm-lift and sit-to-stand repetitions, and health status scores were noted.

Technology-assisted Pulmonary Rehabilitation

Telehealth is a promising way of delivering health services to individuals, particularly for those living in isolated areas or without access to transportation. However, to date, there is limited evidence of the benefit of these technologies in pulmonary rehabilitation. New technologies that may be applicable to pulmonary rehabilitation in the future include cell phone–based, monitored, home exercise training programs (246), videoconferencing (247), telemonitoring (248), and activity counseling delivered via telehealth (249, 250).

Program Duration, Structure, and Staffing

Since the previous Statement, there remains no consensus on the optimal duration of pulmonary rehabilitation (251). However, longer programs are thought to produce greater gains and maintenance of benefits, with a minimum of 8 weeks required to achieve a substantial effect on exercise performance and quality of life (251–254).

Program Enrollment and Adherence

A sizeable percentage of individuals referred for pulmonary rehabilitation do not enroll or fail to complete the program. Major barriers to enrollment include disruption to the patient’s routine, distance and transportation problems, influence of the patient’s health care provider, lack of perceived benefit from the program, and inconvenient timing of the program (255). The major issues for noncompletion include illness and comorbidities, travel, transportation, lack of perceived benefits, smoking, depressive symptoms, lack of support, deprivation, and perceived impairment (256–258). Moreover, the provider’s support for enrollment can influence patient attendance and adherence. Addressing these major barriers may increase enrollment and graduation rates. For example, Graves and colleagues reported positive effects of a “group opt-in session” on the uptake and graduation rates for a pulmonary rehabilitation program for patients with COPD in an observational study using historical controls (259).

HEALTH CARE USE

Several studies comparing health care use before and after pulmonary rehabilitation found significant reductions in the number of hospital admissions, hospital days, and emergency room visits (260–265). Randomized controlled trials comparing pulmonary rehabilitation with usual care found a significant reduction in hospitalizations (266) or a trend in the same direction (160, 267, 268). A 2011 Cochrane review showed a positive impact of pulmonary rehabilitation on readmissions after COPD exacerbations (163). There are four full economic evaluations of pulmonary rehabilitation that included both program costs and total costs of health care use during and after rehabilitation (171, 269–271), with varying results because of differences in country, setting, target group, and comparator treatment.

MOVING FORWARD

The science and application of pulmonary rehabilitation have grown considerably since the previous Statement. This Task Force identifies the following major areas that need to be addressed further in the coming years:

1. Increasing the scope of pulmonary rehabilitation: This includes further defining its efficacy in patients with diseases other than COPD, in those hospitalized for exacerbations, and in those with critical illness. Furthermore, it is important to explore the disease-modifying potential of pulmonary rehabilitation in those with milder chronic respiratory disease.

2. Increasing the accessibility to pulmonary rehabilitation: This includes developing robust models for alternative forms of delivery, defining the role of telehealth and other new technologies, advocating for funding to ensure viability of existing pulmonary rehabilitation programs, fostering the creation of new programs, increasing clinician and patient awareness of the benefits of pulmonary rehabilitation, and identifying and overcoming barriers to participation.

3. Optimizing pulmonary rehabilitation components to influence meaningful and sustainable behavior change: This includes further developing collaborative self-management
strategies and ways to translate gains in exercise capacity into increased physical activity.

4. Further understanding and addressing the heterogeneity and multisystem complexity of COPD and other forms of chronic respiratory disease. This includes defining phenotypes and using this information in optimizing the impact of the pulmonary rehabilitation.

This official statement was prepared by an ad hoc subcommittee of the ATS Assembly on Pulmonary Rehabilitation and the ERS Scientific Group 01.02 “Rehabilitation and Chronic Care.”

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