Exercise in chronic pulmonary disease: limitations and rehabilitation

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ABSTRACT

COOPER, C. B. Exercise in chronic pulmonary disease: limitations and rehabilitation. *Med. Sci. Sports Exerc.,* Vol. 33, No. 7, Suppl., pp. S643–S646, 2001. Chronic pulmonary disease is common in the community and increasing in prevalence. Although numerous etiologies exist, chronic obstructive pulmonary disease secondary to tobacco smoking, and asthma constitute the majority of cases. The important impact of these diseases on patients is disabling breathlessness and impairment of functional exercise capacity. The symptoms set up a vicious cycle leading to physical deconditioning and worsening exercise performance. The discipline of pulmonary rehabilitation has been conclusively shown to reverse this process, resulting in improved functional capacity and reduced breathlessness. Pulmonary rehabilitation, therefore, should be viewed as essential secondary preventative care for the majority of patients with chronic pulmonary disease. As such, early disease recognition and implementation of exercise reconditioning is important. In order to be maximally effective, pulmonary rehabilitation must recognize the complex underlying pathophysiology in chronic pulmonary disease and be customized to the individual patient. The chosen mode of exercise training should recognize that in order to be truly beneficial, any physiological responses need to translate readily into improvements in activities of daily living. Therefore, sessions in pulmonary rehabilitation should concentrate on exercises that have proven useful in this regard. Aerobic and resistance exercise prescriptions should be rigorous, scientifically based, and derived from an understanding of the basic principles of the human response to exercise prescription. Each of these exercise prescriptions should encompass the basic principles of intensity, frequency, duration, and progression suitably modified for the individual patient with chronic pulmonary disease.

Chronic pulmonary disease is common in the community and is increasing in prevalence (Table 1). Patients afflicted by these diseases typically complain of exercise limitation and disabling breathlessness or dyspnea. The pathophysiology is usually complex and must be understood in order to develop a rational approach to exercise reconditioning or rehabilitation. The purpose of this supplement is (a) to review the scientific basis of exercise limitation in chronic pulmonary disease, and (b) to develop logical strategies for aerobic and resistance exercise training on the basis of an understanding of the pathophysiology. Although there are general strategies for prescribing these modalities of exercise in this patient population, there is a lack of consensus regarding the detailed components of exercise prescription (3). We hope, therefore, that this supplement will provide useful guidance for exercise professionals who encounter these patients.

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PREVALENCE OF CHRONIC PULMONARY DISEASES

Among the chronic pulmonary diseases, chronic obstructive pulmonary disease (COPD) including chronic bronchitis and emphysema is the most prevalent, and is thought to affect 16.0 million people in the United States (15). COPD has consistently ranked as the fourth leading cause of death in the United States and accounts for approximately 100,000 deaths per year (16). In addition to mortality, COPD is a major cause of disability, with far reaching socioeconomic consequences (17). Asthma is estimated to affect 14.6 million people in the United States (15). Although distinctly different in pathogenesis, asthma is often difficult to distinguish clinically from smoking-related COPD. Indeed, the two conditions probably coexist in approximately 10% of COPD patients. Chronic restrictive pulmonary diseases are much less common. For example, there are varying estimates of the prevalence of idiopathic pulmonary fibrosis ranging from 2 to 26 persons per 100,000 (14), whereas the prevalence of other types of restrictive pulmonary disease such as chest wall deformity and respiratory muscle weakness are not precisely known. The common types of chronic pulmonary disease are listed in Table 1. Although diverse in etiology, several aspects of their pathophysiology are similar.

TABLE 1. Chronic pulmonary diseases with approximate prevalence in the USA according to the National Center for Health Statistics (15).

Type of Disease	Prevalence
Obstructive diseases	
Chronic bronchitis	14.2 million
Emphysema	1.8 million
Asthma	14.6 million
Bronchiectasis	[a]
Restrictive diseases	
Pulmonary fibrosis	0.05million
Chest wall deformity	[a]
Respiratory muscle weakness	[a]
Disordered control of breathing	
Sleep apnea	20.0 million
Obesity hypoventilation syndrome	[a]

[a] Exact prevalence unknown.

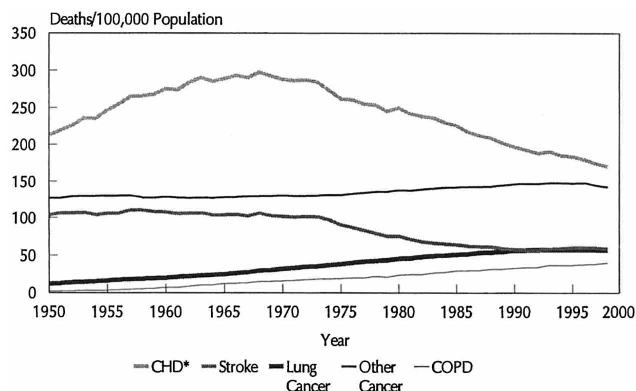

FIGURE 1—Fifty-year trends in crude death rates for selected smoking-related diseases in the United states. Since 1970, mortality from coronary artery disease and stroke has steadily declined, whereas mortality from COPD and lung cancer has significantly increased during the same time period. From National Institutes of Health (16) with permission.

THERAPEUTIC OPTIONS IN CHRONIC PULMONARY DISEASE

Conventional wisdom has provided few effective therapeutic options for chronic pulmonary diseases, particularly in their advanced stages. New scientific approaches are needed with a focus on earlier intervention. Optimal medical management of chronic pulmonary diseases necessitates careful selection and adjustment of pharmacotherapies such as inhaled treatments in cases of COPD (10). Hypoxemia must be recognized, whether this occurs intermittently during exercise or chronically at rest, and corrected to whatever extent possible with supplemental oxygen. Supplemental oxygen increases exercise capacity (8), and long-term oxygen therapy improves life expectancy, at least in chronic hypoxemia caused by COPD (9). Lung transplantation is of value in limited numbers of highly selected patients (13). The same is likely to be proved true for lung volume reduction surgery in selected cases of emphysema (20). Importantly, these interventions including pharmacotherapy alone are insufficient to restore the patient toward more normal functional capacity and quality of life. To this end, a comprehensive strategy of multidisciplinary care is thought necessary and usually offered through pulmonary rehabilitation programs.

THE IMPORTANCE OF PREVENTATIVE CARE

Interesting facts emerge when we compare mortality statistics for various smoking-related diseases. Figure 1 shows 50-yr trends for crude death rates in the United States for selected smoking-related diseases, including COPD (16). Although mortality related to coronary artery disease and stroke declined by as much as 58% between 1966 and 1986, the mortality from COPD increased by 71% during the same time period and these trends continue up to the present date. Clearly, these findings are not related directly to smoking prevalence (i.e., primary prevention) but could be explained by the success of early diagnosis and rehabilitative strategies in the case of cardiovascular diseases (i.e., secondary prevention). Cardiac rehabilitation has successfully embraced the principles of secondary prevention since the 1960s, when bed rest and work restriction after myocardial infarction were abandoned in favor of early exercise rehabilitation and return to work. Early diagnosis, at least in the case of coronary artery disease, is vigorously pursued. Unfortunately, none of this is true for pulmonary rehabilitation, which is still viewed by many physicians and other health care providers as a treatment of last resort. Primary care providers will need to play a pivotal role in correcting the tendency for underdiagnosis and late specialist referral of COPD (19).

THE ROLE OF PULMONARY REHABILITATION

Pulmonary rehabilitation is increasingly prescribed for COPD, albeit often late in the disease process. A role for rehabilitation in the treatment of COPD is strongly endorsed (4), recognizing that these programs increase functional capacity, decrease symptoms, reduce utilization of health care resources and improve quality of life (4,11,12). Thus, pulmonary rehabilitation has been broadly defined as follows (5): “Pulmonary rehabilitation is a multi-disciplinary program of care for patients with chronic respiratory impairment that is individually tailored and designed to optimize physical and social performance and autonomy.”

Although pulmonary rehabilitation is practiced as a multidisciplinary therapy, evidence-based analysis identifies exercise training as the most effective component (18). Unfortunately, current recommendations lack specific details or consistency when it comes to prescribing both aerobic and resistance exercise. For example, the American Thoracic Society acknowledges the importance of higher intensity endurance training but recognizes the difficulties in using physiological parameters as a basis for the exercise prescription (5). The joint ACCP/AACVPR evidence-based guidelines merely recommend a “program of exercise training of the muscles of ambulation” but state that “exercise prescription guidelines cannot be defined with certainty” (18). With regard to strength training, the American Tho-

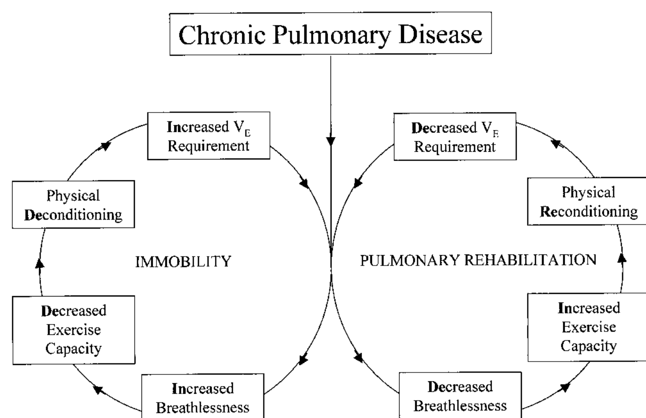

FIGURE 2—Diagram to illustrate the vicious cycle (on the left) of disabling breathlessness, physical inactivity, and deconditioning in chronic pulmonary disease. Pulmonary rehabilitation that includes exercise training offers a favorable cycle (on the right) of reconditioning, restoration of functional capacity, and improved quality of life.

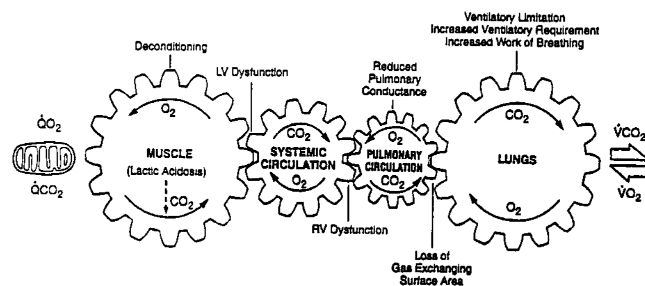

FIGURE 3—Diagram to illustrate the interrelationships between pulmonary, cardiovascular, and musculoskeletal function during exercise in chronic pulmonary disease. The diagram facilitates an understanding of the complex pathophysiological mechanisms that limit exercise performance in these patients. From Cooper, C. B. Determining the role of exercise in chronic pulmonary disease. *Med. Sci. Sports Exerc.* 27:147–157, 1995, with permission.

racic Society highlights the paucity of literature and makes no specific recommendation (5). On the other hand, the joint ACCP/AACVPR evidence-based guidelines do not even mention strength training (18). Unfortunately, such a lack of clear guidelines leads to a free-for-all approach, and a national survey of 283 pulmonary rehabilitation programs in 1995 identified considerable differences in program content (7). This survey mentions cycle and treadmill training but not strength training, and the overwhelming majority of programs judged exercise intensity by dyspnea. Lack of consistency in the approach to aerobic and resistance training in chronic pulmonary disease is likely to result in suboptimal outcomes in many cases.

Chronic pulmonary diseases can be viewed as a vicious cycle of disabling symptoms that lead to physical inactivity, deconditioning, and worsening symptoms of exercise limitation (Fig. 2). By contrast, pulmonary rehabilitation can be viewed as the strategy to break this vicious cycle, as shown in Figure 2. Successful rehabilitation requires optimal medical management, particularly pharmacotherapy, oxygen supplementation when needed, and psychosocial support. These measures should serve to enhance exercise participation so that the optimal benefits of exercise reconditioning might then be realized. As such, they need to form part of a stepwise approach to the management of chronic pulmonary disease and be regarded as an absolute prerequisite to exercise training. The next step necessary to obtain the best possible results from physical training is a structured approach to both aerobic and resistance exercise prescription. Furthermore, in order to be effective and safe, such an approach must recognize the limitations imposed by the pathophysiology of the disease.

COMPLEXITY OF PULMONARY PATHOPHYSIOLOGY

When comparing cardiac and pulmonary rehabilitation, certain basic differences are apparent as well as the fact that, for the most part, the approach to exercise reconditioning is essentially the same (1,2). Cardiac rehabilitation has more obvious, immediate, and potentially life-threatening risks. However, pulmonary rehabilitation is perhaps more complex than cardiac rehabilitation because of three factors: (a) the older age range of the patients and generally poorer physical condition at baseline; (b) the coexistence of pulmonary and cardiovascular diseases in many pulmonary patients; and (c) the highly complex nature of the pathophysiology in chronic pulmonary disease. Figure 3 illustrates the interdependence of the pulmonary, cardiovascular, and musculoskeletal systems during exercise and allows consideration of potential limitations. Chronic pulmonary disease imposes certain obvious problems in terms of pulmonary ventilation and gas exchange. However, an appreciation of the intricacies of breathing pattern and the complex relationship between pulmonary mechanics and dyspnea is also important. Pulmonary patients have cardiovascular limitations, particularly in the presence of chronic hypoxemia. Furthermore, significant problems exist with skeletal muscle function as highlighted by recent research (6).

CONTENT OF THIS SUPPLEMENT

The articles that follow will address the complex pathophysiology in chronic pulmonary diseases and then present logical strategies for aerobic and resistance exercise prescription derived from firmly established principles of exercise training and from an understanding of how these need to be adapted in the face of pathophysiological limitations. This supplement is intended to serve as a guide to exercise management within the broader context of pulmonary rehabilitation. We recognize that the clear majority of patients

TABLE 2. Typical patient mix in a pulmonary rehabilitation program.[a]

Patients	%
COPD, emphysema, bronchiectasis	70
Restrictive pulmonary disease	18
Asthma	5
Lung transplant patients	5
Neuromuscular disease	2

[a] UCLA Pulmonary Fitness and Rehabilitation Program, 1995.

entering pulmonary rehabilitation programs have COPD (Table 2). Consequently, most studies of pulmonary rehabilitation have focused on COPD and most of our understanding of the pathophysiology is derived from these patients. The following articles are obviously weighted with references to COPD patients, and the guidelines that we derive will perhaps be most readily applicable to COPD patients. As such, these guidelines will be directly applicable to approximately 70% of patients undergoing pulmonary rehabilitation. Whenever possible, we have endeavored to extend our conclusions and recommendations to all patients with chronic pulmonary diseases.

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REFERENCES

1. American Association of Cardiovascular and Pulmonary Rehabilitation. In: *Guidelines for Cardiac Rehabilitation Programs*, 3rd Ed. Champaign, IL: Human Kinetics, 1999, pp. 1–12.
2. American Association of Cardiovascular and Pulmonary Rehabilitation. In: *Guidelines for Pulmonary Rehabilitation Programs*, 2nd Ed. Champaign, IL: Human Kinetics, 1998, pp. 7–25.
3. American College of Sports Medicine. In: *ACSM's Guidelines for Exercise Testing, and Prescription*, 5th Ed. Philadelphia: Williams & Wilkins, 1995, pp. 194–205.
4. American Thoracic Society Statement. Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease. *Am. J. Respir. Crit. Care Med.* 160:1666–1682, 1995.
5. American Thoracic Society Statement. Pulmonary rehabilitation—1999. *Am. J. Respir. Crit. Care Med.* 159:1666–1682, 1999.
6. American Thoracic Society/European Respiratory Society Statement. Skeletal muscle dysfunction in chronic obstructive pulmonary disease. *Am. J. Respir. Crit. Care Med.* 159:S1–S40, 1999.
7. Bickford, L. S., J. E. Hodgkin, and S. L. McInturff. National Pulmonary Rehabilitation Survey. Update. *J. Cardiopulm. Rehabil.* 15:406–411, 1995.
8. Cooper, C. B. Long-term oxygen therapy. In: *Principles and Practice of Pulmonary Rehabilitation.* R. Casaburi and T. L. Petty (Eds.). Philadelphia: WB Saunders Company, 1993, pp. 183–203.
9. Cooper, C. B., J. Waterhouse, and P. Howard. A twelve year clinical study of patients with hypoxic cor pulmonale given long term oxygen therapy. *Thorax* 42:105–110, 1987.
10. Fergusson, G. T., and R. M. Cherniack. Management in chronic obstructive pulmonary disease. *N. Engl. J. Med.* 328:1017–1022, 1995.
11. Griffiths, T. L., M. L. Burr, I. A. Campbell, et al. Results at 1 year of outpatient multidisciplinary pulmonary rehabilitation: a randomized controlled trial. *Lancet* 355:362–368, 2000.
12. Lacasse, Y., E. Wong, G. H. Guyatt, D. King, D. J. Cook, and R. S. Goldstein. Meta-analysis of respiratory rehabilitation in chronic obstructive pulmonary disease. *Lancet* 348:1115–1119, 1996.
13. Levine, S. M., A. Anzueto, J. I. Peters, et al. Medium term functional results of single-lung transplantation for endstage obstructive lung disease. *Am. J. Respir. Crit. Care Med.* 150:398–402, 1994.
14. Markovitz, G. H., and C. B Cooper. Exercise in interstitial lung disease. *Curr. Opin. Pulm. Med.* 4:272–280, 1998.
15. National Center for Health Statistics. *Current Estimates from the National Health Interview Survey, United States, 1996.* Series 10, No. 200. Bethesda, MD: Centers for Disease Control, Department of Health and Human Services, 1999.
16. National Institutes of Health, NHLBI. *Morbidity & Mortality: 2000 Chart Book on Cardiovascular, Lung and Blood Diseases.* Bethesda, MD: National Institutes of Health, Department of Health and Human Services, 2000.
17. Ries, A. L. Scientific basis of pulmonary rehabilitation. *J. Cardiopulm. Rehabil.* 10:418–441, 1990.
18. Ries, A. L., and the ACCP/AACVPR Pulmonary Rehabilitation Guidelines Panel. Pulmonary rehabilitation: joint ACCP/AACVPR evidence-based guidelines. *J. Cardiopulm. Rehabil.* 17:371–405, 1997.
19. The National COPD Awareness Panel. Keys to the early detection and management of COPD. *J. Respir. Dis.* 21:481–488, 2000.
20. The National Emphysema Treatment Trial Group. Rationale and design of the National Emphysema Treatment Trial: a prospective randomized trial of lung volume reduction surgery. *Chest* 116:1750–1761, 1999.