Pulmonary rehabilitation

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Educational aims

> 1. To provide insights into management goals of pulmonary rehabilitation.
> 2. To provide information about the structure and setting-up of pulmonary rehabilitation programmes.
> 3. To provide information to health providers about the outcome of non-pharmacological treatment programmes.

Summary

Pulmonary rehabilitation programmes in chronic respiratory diseases have clear effects on improvements in exercise tolerance, reduction of symptoms such as dyspnoea and of health-related quality of life. Further studies are needed in order to define the long-term benefits as well as the optimal programme structure to get the greatest effects. Cost-effectiveness studies are needed, as well as data on more optimal selection procedures, in order to select the best possible candidates for rehabilitation. Exercise training programmes have to integrate present knowledge of muscular adaptations in patients with chronic respiratory diseases as COPD. The shift from empiricism to science in performing pulmonary rehabilitation may result not only in a further improvement in quality of life, but perhaps also in life expectancy for patients with usually incurable and sometimes inexorably progressive pulmonary disease.

Introduction

"Rehabilitation involves holistic efforts to restore patients with debilitating and disabling disease to an optimally functioning state, and is a relatively recent concept in pulmonary medicine. In 1974, a committee of the American College of Chest Physicians defined pulmonary rehabilitation as "an art of medical practice wherein an individually tailored, multidisciplinary programme is formulated, which through accurate diagnosis, therapy, emotional support and education stabilises or reverses both physiopathological and psychopathological manifestations of pulmonary diseases, and attempts to return the patients to the highest possible functional capacity allowed by his handicap and overall life situation" [1]. More recent definitions were formulated by the National Institutes of Health (NIH) and by a task force of the European Respiratory Society (ERS). According to the NIH, pulmonary rehabilitation has to be defined as a multidimensional continuum of services directed to persons with pulmonary disease and their families, usually by an interdisciplinary team of specialists, with the goal of achieving and maintaining the individual's maximum level of independence and functioning in the community [2]. According to the ERS task force, pulmonary rehabilitation is a process which systematically uses scientifically based diagnostic management and evaluation options to achieve the optimal daily functioning and HRQL of individual patients suffering from impairment and disability due to chronic respiratory diseases, as measured by clinically and/or physiologically relevant outcome measures [3]. Although both definitions are primarily applied to patients with chronic obstructive pulmonary disease (COPD), they are clearly also applicable to other patients suffering from chronic respiratory diseases. The new official statement of the American Thoracic Society (ATS) on pulmonary rehabilitation, published in 1999, supports this approach by defining pulmonary rehabilitation as a multidisciplinary programme of care for patients with chronic respiratory impairment that is individually tailored and designed to optimise physical and social performance and autonomy [4]. These definitions refer to the philosophical concept of rehabilitation as the restoration of the individual to the fullest medical, mental, emotional, social and vocational potential of which the person is capable.

Selection of candidates for rehabilitation

Pulmonary rehabilitation should be considered for patients with COPD who have dyspnoea or other respiratory symptoms, reduced exercise tolerance, a restriction in activities because of their disease or impaired health status. There are no specific pulmonary function inclusion criteria that indicate the need for pulmonary rehabilitation, since symptoms and functional limitations (not the severity of the underlying physiology) direct the need for pulmonary rehabilitation. Often, referral to pulmonary rehabilitation is delayed until patients reach a stage of advanced lung disease. While these patients still stand to derive considerable benefit from pulmonary rehabilitation [5], referral at an earlier stage would allow for earlier preventative strategies, such as smoking cessation, nutritional therapy and a greater latitude in the exercise prescription. Current cigarette smokers are reasonable candidates for pulmonary rehabilitation, and probably obtain similar benefits to non-smokers or ex-smokers. Smoking cessation intervention is an obviously important component of the pulmonary rehabilitation process for smokers.

Outcome from pulmonary rehabilitation

From the beginning it has been clear that the goals of rehabilitation are multifactorial and include the following:

> 1. to decrease and control respiratory symptoms
> 2. to increase physical capacity
> 3. to improve quality of life
> 4. to reduce the psychological impact of physical impairment and disability
> 5. to decrease the number of acute exacerbations related to disease
> 6. to prolong life [6].

These goals are now considered as outcome parameters for optimal COPD management.

Relief of symptoms

Dyspnoea and fatigue are hallmark symptoms in most COPD patients. There is a considerable body of evidence that pulmonary rehabilitation improves exertional dyspnoea [7, 8] and dyspnoea associated with daily activities in COPD [9–16].

Improvement in exercise tolerance

Pulmonary rehabilitation improves exercise ability in COPD [9–14, 17–20]. Favourable outcomes include increased maximal exercise tolerance, peak oxygen uptake, endurance time during submaximal testing, functional walking distance, and peripheral and respiratory muscle strength (fig. 1).

Figure 1

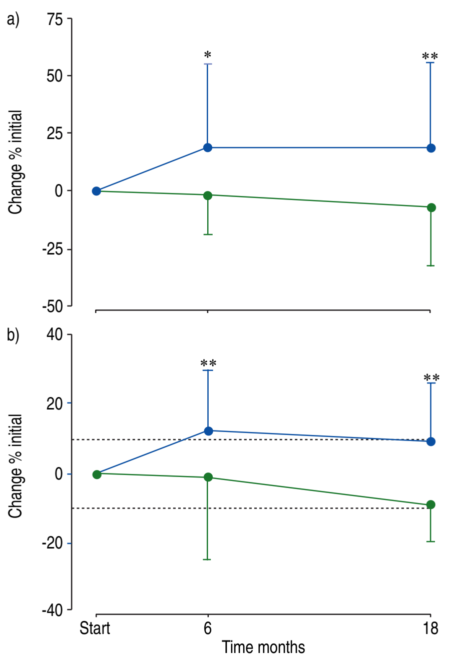


Figure 2

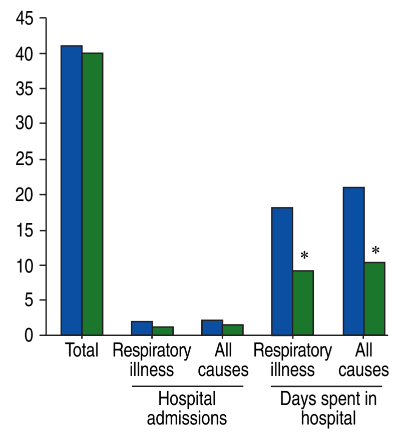


Figure 1
*a) Training effect for 6-min walking distance, expressed as mean±6SD per cent change compared with baseline. b) Mean±6SD training effect for the change in the dyspnoea dimension of the quality-of-life questionnaire is expressed as change (in points) compared with baseline. ······: minimal clinically-important difference. *: p<0.05; **: p<0.01 compared with controls. Reproduced with permission from [11].*

Figure 2
Use of secondary care in control (blue) and rehabilitation (green) patient groups admitted at least once during study period. Reproduced with permission from [22].

Improvement in health status

Pulmonary rehabilitation results in a significant improvement in disease-specific and general measures of health status [9, 12, 14, 15, 20]. These effects are relatively long lasting and not necessarily related to improvements in exercise ability.

Multiple domains of health status usually show improvement, such as dyspnoea, fatigue, emotional function and mastery components of the chronic respiratory disease questionnaire (CRQ) or symptoms, activity and impact components of the St George's Respiratory Questionnaire (SGRQ).

Improvement in health status following rehabilitation usually exceeds the thresholds for minimum clinically important differences established for respiratory-specific health status questionnaires [21].

Prevention of complications and exacerbations

There are conflicting reports on the effect of pulmonary rehabilitation on healthcare service utilisation. A randomised, controlled trial of pulmonary rehabilitation in California failed to show a beneficial effect on hospitalisations in COPD [10]. However, a study of out-patient pulmonary rehabilitation in Wales demonstrated that the rehabilitation group had a similar frequency of hospitalisations but a smaller number of hospital days than a control group in the year following the intervention (10.4 *versus* 21.0 days) [14]. The reduction in hospital days for both respiratory illness and all causes was noted. In a subsequent cost/utility analysis these authors demonstrated that out-patient rehabilitation produces cost per QALY (quality adjusted life years) ratios within bounds considered to be cost-effective and to result in financial benefits to the health service [22] (fig. 2).

Effect on mortality

Limited data from prospective studies do not support the conclusion that pulmonary rehabilitation affects long-term survival [10, 11]. These studies, however, are relatively small and probably were not sufficiently powered to detect this possible effect. Nutritional intervention, which is commonly incorporated into a comprehensive pulmonary rehabilitation programme, was associated with improved survival rates in a single clinical trial [23].

Effect on disease progression

Pulmonary rehabilitation has no significant effects on forced expiratory volume in one second (FEV_1) and presumably does not attenuate the decline of airflow limitation in COPD. However, using a broader concept of disease progression, which includes symptoms, exercise capacity, health status and healthcare utilisation, pulmonary rehabilitation would then be considered to have marked effectiveness.

Components of non-pharmacological treatment

Based on the historically defined approach of pulmonary rehabilitation, each patient enrolled in a rehabilitation programme has to be considered as a unique individual with specific physio- and psychopathological impairment caused by the underlying disease. Therefore, pulmonary rehabilitation incorporates many different therapeutic modalities applied as a comprehensive, multidisciplinary care programme, including pharmacological treatment. In order to improve quality of life or to promote self-management behaviour of chronically ill patients, it is also important to consider the different dimensions of the rehabilitation programme. In general, a distinction has to be made between:

> 1. the aim of the intervention
> 2. the level at which the intervention is focused
> 3. the directness of the intervention [24].

For pulmonary rehabilitation in general, these dimensions are described in table 1.

Based on this approach, interventions directed at improvement, for example quality of life, have to be focused on improvement of the general psychological, social, practical and physical well-being of the patient. Dependent upon the aim and the phase the patient is in, the interventions can involve physical exercise programmes as well as stress-management programmes, social skills training, or different kinds of counselling and support. The level of focusing of the intervention has to be decided depending on the aim of the intervention and the expected efficiency. Group training is highly appreciated by patients; psychological group interventions directed at patients and partners can increase efficiency in order to obtain management goals. Furthermore, interventions can be directed at changing or adaptation of the environment. These interventions are often specified by the term "social engineering", because these interventions are directed at modification of living-, work- or leisure-time situations, and healthy lifestyles of the patient from a social or patient perspective [25]. Finally, the directness of intervention has to be considered. As part of a comprehensive intervention, indirect interventions can be considered in order to improve social support for the patient or to train other professionals in intervention skills.

This theoretical approach of intervention programmes is still largely unattainable in most rehabilitation programmes, based on the limited resources still spent on non-pharmacological intervention strategies. In this approach, components of a rehabilitation programme are individualised based on a careful assessment of the patient, not limited to lung function testing, but addressing physical and emotional deficits, knowledge of the disease, cognitive and psychosocial functioning, as well as nutritional assessment. Furthermore, this assessment must be an ongoing process during the whole rehabilitation process. Education, exercise training, psychosocial support and nutritional intervention are now generally applied modalities in pulmonary rehabilitation.

Exercise training

Although exercise training is considered to be the cornerstone of a rehabilitation programme, the physiological benefits of exercise training remained unclear until the 1990s. Due to their ventilatory limitation, it was generally thought that COPD patients are unable to achieve a training intensity sufficiently high enough to train exercising muscles. Casaburi *et al*. [26], however, clearly showed that physiological training responses could be observed in these patients (fig. 3). At a given level of exercise, significant reductions in blood lactate, CO_2 production, minute ventilation, O_2 consumption and heart rate were observed. The ventilatory requirement for exercise dropped after an effective training programme, in proportion to the drop in blood lactate at a given work load. Based on these data and the results of other studies [27], it can be concluded that physiological adaptation to training may occur in COPD patients. A reduction in lactic acid production by the contracting muscles is probably

Table 1. Dimensions of pulmonary rehabilitation.

Aim of the intervention
- *Reduction and control of respiratory symptoms*
- *Improvement in physical functioning*
- *Improvement in quality of life*
- *Reduction of the number of acute exacerbations*
- *Promotion of self management behaviour*
- *Improvement of cognition and behaviour*
- *Reduction of psychological impact of physical impairment and disability*
- *Improvement of survival*

Level of focusing of the intervention
- *Individual*
- *Group*
- *Environment*

Directness of the intervention
- *Direct*
- *Indirect*
- *Supported by educational material*

Figure 3

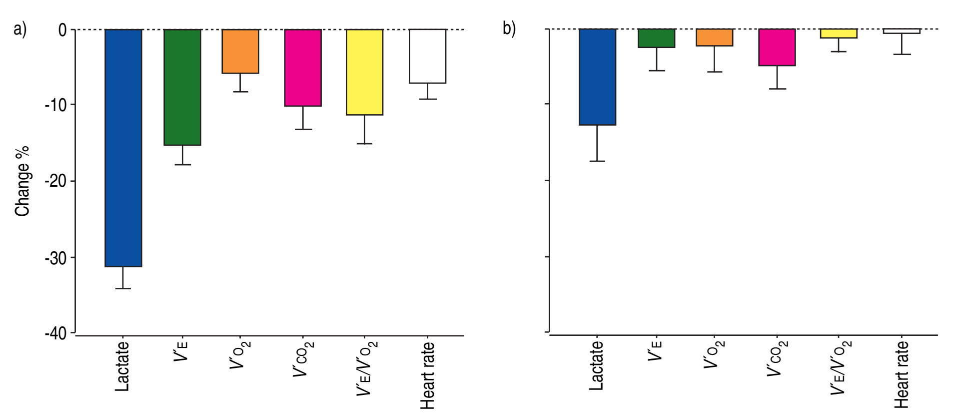


Figure 3
Physiological training responses in a) a high and b) a low work rate training group with COPD. V′E: minute ventilation; V′O2: oxygen consumption; V′CO2: carbon dioxide production. Reproduced with permission from [26].

Figure 4
Physiological endurance training effects in COPD. Reported values represent per cent changes of the baseline values that occurred after training. V′O2,max: maximum oxygen consumption; V′E: minute ventilation; V′CO2: carbon dioxide production; HR: heart rate; CS: citrate synthase; HADH: 3-hydroxyacyl-CoA dehydrogenase. Significant changes are indicated by an asterisk. Reproduced with permission from [28].

the main mechanism underlying this adaptive process. Indeed, early lactic acid production during exercise is reported in COPD patients, probably related to a decreased oxidative capacity and altered muscle substrate metabolism. MALTAIS *et al.* [28] showed a decreased capacity of the Krebs cycle enzyme citrate synthase in the muscle vastus lateralis in COPD (fig. 4) while ENGELEN [29] demonstrated a relationship between decreased muscular glutamate status and early lactic acid production. Subsequently, an improvement in citrate synthase was shown [28] after a 3-month endurance training programme, related to the reduction in exercise-induced lactic acidosis in these patients.

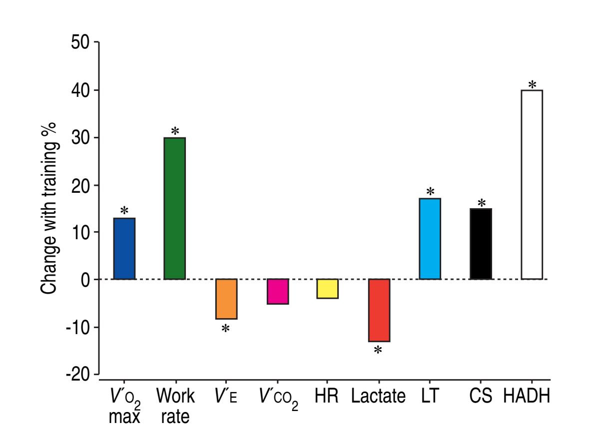
Beneficial effects of training in patients with COPD are also reported on skeletal muscle bioenergetics assessed by nuclear magnetic resonance-spectroscopy. The half-time of phosphocreatine recovery fell significantly after an 8-week endurance training programme and, at a given submaximal work-rate, improved bioenergetics was reflected in a decreased inorganic phosphate-to-phosphocreatine ratio and an increased intracellular pH. In summary, these data indicate that physiological changes provoked by endurance training are observed at the level of skeletal muscle adaptations during submaximal exercise [30].

The optimal mode of exercise training still remains a matter of debate. In general, exercise training can be divided into two types: aerobic or endurance training, and strength training. The majority of the studies of exercise training in COPD have focused on endurance training. In healthy subjects, recommendations are available about duration, intensity and frequency for aerobic training [31, 32].

Aerobic training

Aerobic training calls for rhythmical, dynamic activity of large muscles, performed three to four times a week for 20–30 min per session at an intensity of at least 50% of maximal oxygen consumption. Such a programme of aerobic training is capable of inducing structural and physiological adaptations that provide the trained individual with improved endurance for high-intensity activity. Most of the rehabilitation programmes include exercise sessions of at least 30 min, three to five times a week. Although no ideal duration has been established, duration in many programmes is between 8 and 12 weeks. In order to assess the optimal duration of a pulmonary rehabilitation programme, one randomised controlled trial investigated a 7-week twice weekly out-patient-based programme with a comparable but

Figure 4



shortened 4-week programme. The 7-week course of pulmonary rehabilitation provided greater benefits in terms of improvement in health status [33].

Limited information is also available on physiological outcomes of different types of exercise testing. Most studies have investigated the physiological response of continuous training at a given workload in order to stress oxidative metabolism. Otherwise, interval training has been evaluated since by alternating high and lower training loads, as it more closely resembles daily activity patterns, especially in severe COPD patients. Furthermore, interval training may also stress glycolytic metabolism. One comparative study indeed showed that continuous training resulted in a significant increase in oxygen consumption, and a decrease in minute ventilation and ventilatory equivalent for carbon dioxide at peak exercise capacity, while no changes in these measures were observed after interval training [34] (fig. 5). A significant reduction in lactic acid production was observed after both training modalities but this was most pronounced in the continuous training group. Remarkably, in the interval training group a decrease in leg pain was reported as well as a significant increase in peak workload.

The optimal training intensity for COPD patients is still a matter of debate. In healthy subjects, training is normally targeted at the base of maximal heart rate (60–90% predicted) or the percentage of maximal oxygen uptake (50–80% predicted) [31]. However, principles of exercise intensity derived from healthy subjects may not be applicable for pulmonary patients who are limited by breathing capacity and dyspnoea. Some investigators have reported that patients with COPD can tolerate high-intensity training. These patients could even be trained at an intensity that represents a higher percentage of maximum exercise tolerance than recommended for healthy subjects, because they can sustain ventilation at a high percentage of their maximum breathing capacity [35, 36]. In some studies, it was even concluded that high-intensity training is superior to low-intensity training [36]. Others, in contrast, concluded that most patients with COPD are unable to achieve high-intensity training, defined as a training intensity of 80% of baseline maximal power output [37]. Furthermore, these authors demonstrated that the intensity of training achieved is not influenced by the initial baseline maximal oxygen consumption, age or the degree of airflow limitation.

Endurance and strength training

Only limited data are available on the

Figure 5

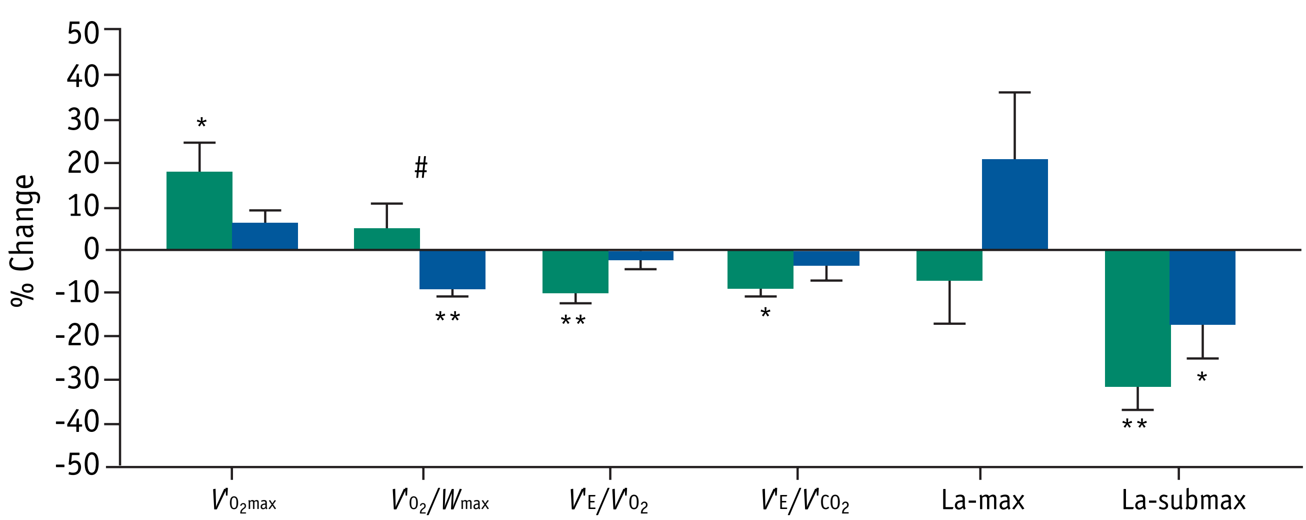


Figure 5
*Difference in metabolic response pattern after interval (green) and continuous (blue) training. V'_{O_2},max: maximum oxygen consumption; Wmax: maximum work rate; V'_E: minute ventilation; V'_{O_2}: oxygen consumption; V'_{CO_2}: carbon dioxide production; la-max: maximum lactate concentration; la-submax: submaximum lactate concentration. *: p<0.05; **: p<0.01, within the group; #: p<0.05, between interval and continuous training. Reproduced with permission from [34].*

effects of strength training in patients with pulmonary disease. Strength training involves the performance of explosive tasks, such as weightlifting, over a short period of time. SIMPSON *et al.* [38] reported a 73% increase in cycling endurance time at 80% of maximal power output following 8 weeks of weightlifting training of the upper and lower extremity muscles. Otherwise, no significant changes in maximal cycling exercise capacity or walking distance were observed. Others confirmed that weight training can improve treadmill walking endurance of patients with mild COPD and that this improvement in treadmill endurance correlated with improvements in upper and lower limb isokinetic sustained muscle strength following training [39]. The outcome of a combination of strength training and endurance training also needs further evaluation. In one study, a combination of aerobic endurance training and strength training resulted in a significant increase in quadriceps strength, thigh muscle cross-sectional area and pectoralis major muscle strength, but no specific influence on peak work rate, walking distance or health status was seen [40].

Education

Patient education is generally used as an "umbrella" term for various forms of goal-directed and systematically applied communication processes, directed at improvement of cognition, understanding and motivation, as well as on improvement of action- and decision-making possibilities of a patient to improve the coping with and recovery of the disease [41]. Ideally, patient education is a "planned learning experience using a combination of methods such as teaching, counselling and behaviour modification techniques in order to influence patient knowledge and health behaviour" [42]. Promotion of self-management behaviour in COPD can be directed to improve adherence to medical advice with respect to medication and healthy lifestyle, aim at stabilisation or retardation of progression, or at avoidance of undesirable consequences and complications. Medical advice to chronically ill patients can also be directed at various aspects of cognition and behaviour [43].

An optimal education programme for patients with COPD can be formulated as follows:

- the programme should be conducted by experts specially trained in techniques to change behaviour or irrational cognitions
- information should be provided in a structured way
- although a group programme is preferable from a health economical perspective, a combination of an individualised programme and a group programme may be most effective
- both participation of the social environment and attention for the problems of the partners should have a high priority to maintain newly acquired skills and cognitions in the home-situation
- both medical and psychosocial parameters should be emphasised
- the responsibility of the patient for his own health must be emphasised
- in order to promote the patient's self-activity and to support the maintenance of behavioural changes in the home situation, additional materials should be made available to be used at home
- follow-up sessions are necessary to support the patient and his or her partner in the home situation
- specific patient education interventions should be implemented in a multi-disciplinary programme to improve physical and psychological functioning
- short- and long-term effects have to be evaluated by valid measurements.

Psychosocial and behavioural intervention

Stabilisation or reversal of disease-related psychopathology was one of the initially defined goals of pulmonary rehabilitation. Personality traits and intra-psychic conflicts, as well as acute psychological states such as panic, anxiety or depression, are widely recognised problem categories in patients with COPD. Specific psychosocial intervention strategies are usually required in order to modify these problems. Future research is needed to assess the outcome of more specific psychosocial intervention strategies, as well as to delineate the contribution of psychosocial intervention itself over and above pulmonary rehabilitation programmes.

Nutritional modulation

Body compositional studies have shown that weight loss is accompanied by significant loss of fat-free mass (FFM) and that it is specifically the loss of FFM or other measures of muscle mass that are related to impaired skeletal muscle strength and exercise capacity [44]. Depletion of FFM is reported as a common problem in patients referred for pulmonary

Educational questions

1.
Pulmonary rehabilitation results in changes in gas exchange. One of the physiological effects after training is an increase in the V'_E/V'_{O_2} ratio. True or false?

2.
Pulmonary rehabilitation results in marked changes in enzymatic activity of skeletal muscles. One of these effects is an increase in citrate synthetase activity. True or false?

3.
Pulmonary rehabilitation results in marked effects in walking capacity. In general, these effects persist for short periods (<6 months). True or false?

Answers on page 42.

rehabilitation [45]. Nutritional support combined with an anabolic stimulus such as exercise has been advocated for these depleted patients [46]. Studies have demonstrated that the combined treatment of nutritional support and exercise increases body weight and results in a significant improvement of FFM and respiratory muscle strength [47]. In depleted patients, increases in body weight and FFM are reported by this combined intervention, and these body compositional changes were associated with improvements in ventilatory muscle function, hand grip strength, peak work capacity and health status [48]. Further characterisation and unravelling the pathophysiological mechanisms involved in tissue wasting may enlarge future perspectives for nutritional intervention.

Long-term outcomes of pulmonary rehabilitation

While several studies address the short-term outcomes of pulmonary rehabilitation, the long-term outcomes of pulmonary rehabilitation are studied by only a few. Ries *et al*. [10] reported that benefits in exercise performance, dyspnoea, exercise-associated symptoms of breathlessness, and muscle fatigue and self-efficacy, obtained after an 8-week comprehensive rehabilitation programme, could be partially maintained for 1 yr with monthly reinforcement, but that the obtained benefits decreased after that time. Continued participation in a supervised training programme over an additional 12 weeks was also required for maintenance of the benefit in walking endurance up to 1 yr in another study [18]. Wijkstra *et al*. [49] demonstrated that incorporation of a session of physiotherapy once weekly or a session of physiotherapy once a month has no significant effects on walking distance, assessed over a period of 18 months. A recent randomised controlled trial comparing pulmonary rehabilitation to standard medical care demonstrated that patients with moderate-to-severe COPD achieved improvements in exercise tolerance and dyspnoea lasting up to 2 yrs following a 12-week out-patient programme [50].

Some studies have analysed the long-term outcome of rehabilitation on quality of life. Ketelaars *et al.* [51] evaluated the long-term effect of rehabilitation on HRQL. She reported that patients with moderate HRQL scores upon admission had the greatest decline after 9 months of follow-up, despite having made substantial gains in HRQL by the end of the initial rehabilitation programme. Otherwise, patients with poorer baseline HRQL scores showed very little improvement during the rehabilitation programme and remained severely impaired in HRQL long term. These authors suggested that differentiated aftercare programmes may be indicated in order to maintain initial gains in HRQL. Wijkstra *et al.* [49] reported that especially rehabilitation at home for 3 months followed by once monthly physiotherapy sessions improves HRQL. Foglio *et al.* [52] evaluated the long-term outcome of pulmonary rehabilitation in a group of asthmatics as well as COPD patients. Regardless of diagnosis, they found that patients with chronic airflow limitation who underwent a rehabilitation programme maintained an improved HRQL 1 yr post-discharge, despite a partial loss of the improvement in exercise tolerance [52]. They confirmed the data of Ketelaars *et al*. [51] that not all patients may show a clinically significant improvement in HRQL and extended these results to asthmatics.

At present, it can be concluded that further information is needed about the optimal means and settings to maintain short-term effects of pulmonary rehabilitation on exercise tolerance and HRQL.

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Suggested answers

1.
False. Pulmonary rehabilitation contributes to a reduction in this ratio.

2.
True.

3.
False. Effects on walking distance persist for 12–18 months.

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