

## Educational Aims

- To illustrate the common mechanisms limiting exercise tolerance in patients with chronic lung and heart disease
- To highlight the impact of lung and heart disease on daily physical activity levels
- To outline the effects of cardiopulmonary rehabilitation on functional capacity in patients with chronic lung and heart disease
- To discuss an innovative tele-rehabilitation intervention using information and communications technologies to improve functional capacity in patients with chronic lung and heart disease



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# Physiological basis of cardiopulmonary rehabilitation in patients with lung or heart disease



## Summary

Shortness of breath associated with cardiorespiratory abnormalities and peripheral muscle discomfort are the major factors that limit exercise capacity in patients with chronic obstructive pulmonary disease (COPD) and those with congestive heart failure (CHF). Both of these symptoms negatively impact on patients' daily physical activity levels. In turn, poor daily physical activity is commonly associated with increased rates of morbidity and mortality. Cardiopulmonary rehabilitation programmes partially reverse muscle weakness and dysfunction and increase functional capacity in both COPD and CHF. However, benefits gained from participation in cardiopulmonary rehabilitation programmes are regressing soon after the completion of these programmes. Moreover, several barriers limit access and uptake of cardiopulmonary rehabilitation programmes by eligible patients. A potential solution to the underutilisation of cardiopulmonary rehabilitation is the implementation of tele-rehabilitation interventions at home using information and communications technologies. Thus, tele-rehabilitation may be useful to encourage and educate patients with COPD or CHF on how best to maintain and/or further enhance daily physical activity levels.

**Conflict of interest**  
None declared.

## Introduction

Although exercise capacity is limited in patients with chronic obstructive pulmonary disease (COPD) and those with congestive heart failure

(CHF), there is clear evidence that the systemic consequences of these disease entities negatively impact on daily physical activity levels [1–9].

Along these lines, it is well documented that in patients with COPD, daily physical



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activity levels are significantly reduced compared with those in healthy individuals even during the early course of the disease [10]. Specifically, time spent in walking is on average 47% less, whilst intensity of daily activities adopted by COPD patients is on average 25% lower compared with those recorded in age-matched healthy individuals [2]. Reduced levels of daily physical activity in patients with COPD are associated with a faster rate of disease progression and increased rates of hospital admissions and mortality [11, 12].

Similarly, in patients with CHF, daily physical activity levels are significantly lower compared with daily activity recommendations set by the World Health Organization (WHO). A reduced level of daily activity has been shown to constitute a more powerful index to predict mortality compared with laboratory-based exercise testing variables, such as peak oxygen uptake and exercise endurance time [6, 13, 14].

Consequently, relative inactive patients with COPD or CHF experience more intense symptoms when they engage in activities of daily living. Due to the unpleasant nature of dyspnoea and leg discomfort, these patients tend to avoid such activities, eventually becoming less active [15, 16]. This vicious circle can be distressing to patients and leads to a profound reduction in health-related quality of life. Along these lines, exercise training aiming at improving exercise capacity induces a reduction in exercise-induced symptoms, thereby increasing exercise tolerance [17, 18]. Whether improved exercise capacity readily translates into improved daily physical activity is still an issue of intense investigation and debate [19].

The present article describes the physiological rationale of cardiopulmonary rehabilitation programmes for patients with COPD or CHF, whilst it focuses on a novel interventional approach aiming at enhancing daily physical levels with the use of tele-rehabilitation strategies.

## Common underlying mechanism of exercise limitation

Despite the fact that the primary system of impairment is different in patients with COPD and those with CHF (*i.e.* ventilatory

and gas exchange limitations in COPD, central haemodynamic abnormalities in CHF), leg discomfort is very often the predominant complaint reported during exercise in both disease entities.

The origin of leg discomfort is due to a number of histological and metabolic alterations manifested in peripheral muscles of these patients, namely 1) peripheral muscle atrophy across all fibre types, 2) shift from type I oxidative to type II glycolytic muscle fibres, 3) decrease in aerobic enzyme activity and mitochondrial volume density and 4) decrease in muscle capillary density [20–23]. The above alternations reduce muscle oxidative potential, regional muscle blood flow and muscle oxygen delivery to the peripheral muscles, thereby accelerating the occurrence of peripheral muscle fatigue during exercise [20–23]. As far as dyspnoea symptoms are concerned, previous findings show that in both disease entities exercise-induced metabolic acidosis increase respiratory drive thereby intensifying dyspnoea sensations [24–27].

Regular exercise training can partly reverse the aforementioned peripheral muscle abnormalities [28–30]. Indeed, there is strong evidence that in patients with COPD or CHF, participation in cardiopulmonary rehabilitation programmes induces significant peripheral muscle adaptations that mitigate the intensity of locomotor muscle discomfort and dyspnoea sensations during exercise [31, 32] (table 1).

**Table 1** Similar benefits of cardiopulmonary rehabilitation in COPD and CHF

Improves functional capacity
Lessens the intensity of breathing and locomotor muscle discomfort
Improves health-related quality of life
Increases musculoskeletal blood flow
Increases oxidative and metabolic muscle capacity
Attenuates and/or reverses skeletal muscle atrophy
Improves autonomic activation
Increase in endothelial function
Improves muscle performance

## Cardiopulmonary rehabilitation programmes

Physical exercise training is the cornerstone of any cardiopulmonary rehabilitation programme (table 2). Exercise training sessions may combine aerobic and resistance muscle training sessions. Aerobic exercise training can be either continuous or interval. In addition resistance training consists of arm, leg and trunk exercises (fig. 1) [17, 18, 33].

In view of the fact that intensity of the exercise training stimulus is a critical determinant of the magnitude of physiological adaptations that occur in response to training, high intensity continuous exercise training may not be feasible for those COPD or CHF patients who are unable to sustain high intensities for long periods of time due to symptom limitations [34].

Accordingly, it has been documented that when exercising loads are applied intermittently (*i.e.* alternating periods of high intensity exercise by resting periods or periods of lower-intensity exercise), COPD as well as CHF patients can tolerate high work rates (100% of peak work rate) with lower metabolic and cardiorespiratory demands (table 3) [34, 35]. Indeed, when COPD patients exercised for short period of time (*e.g.* 30 s) alternated with equal periods of rest intervals, patients were able to complete the total amount of work with lower symptoms of dyspnoea and leg discomfort compared with moderate constant-load exercise training [36]. Delayed occurrence of lactic acidosis observed during interval exercise appears to be beneficial by reducing respiratory drive, thereby lowering dyspnoea sensations and the occurrence of peripheral muscle fatigue [36]. Thus, interval exercise is more affordable by patients with advanced



**Figure 1**

*View of the Pulmonary Rehabilitation Unit at Athens University Medical School – First Department of Respiratory Medicine, Sotiria Hospital, showing necessary apparatus to administer hospital-based cardiopulmonary rehabilitation programmes.*

disease. In addition, the magnitude of training improvements in functional capacity, morphological and typological muscle adaptations is not different to that obtained following conventional constant-load training [36]. In patients with CHF, interval exercise training has been shown to induce superior effects to those of constant-load exercise in terms of improving aerobic capacity, aortic dilatation capacity and augmented systolic pressure in parallel with improvement in left ventricular diastolic function and endothelial function, thereby lessening the ventilatory requirement and thus the intensity of perceived dyspnoea [35].

There are studies reporting that cardiopulmonary rehabilitation programmes have positive effects on daily physical activity levels in patients with COPD or CHF. Specifically, a number of studies using either short

**Table 2** *Components of cardiopulmonary rehabilitation*

Exercise training sessions (including aerobic and resistance training)
Medical therapy assessment and optimisation
Respiratory physical therapy and breathing techniques
Psychological support and behavioural management
Diet and nutritional counselling

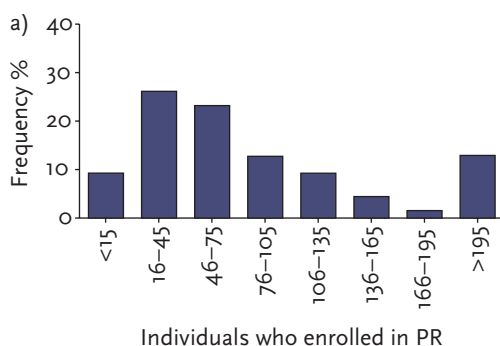
**Table 3** *Benefits of interval exercise training in COPD and CHF*

Prolongs exercise duration
Lowers cardiovascular demand
Lowers ventilatory requirement
Allows higher exercise intensity
Reduces symptoms of dyspnoea and leg discomfort

(3 weeks) or longer-term (18 weeks) exercise programmes, demonstrated a significant increase in daily physical activity levels following the completion of aerobic and/or resistant supervised training programmes [37–40]. On the other, there have been numerous studies that failed to show significant effects of conventional exercise training on daily physical activity levels [41–43].

## The potential of telemedicine interventions

While the benefits of participation in a cardiopulmonary exercise programme are important in patients with COPD or CHF, these benefits are reversible and can be attenuated few weeks after completion of the rehabilitation programme. Furthermore, hospital-based programmes are generally resource demanding and are limited by low adherence rates. In a recent study, representatives of 430 centres from 40 countries completed a global survey in regards to the content and organisational aspects of cardiopulmonary rehabilitation in patients with COPD [44]. The results of the survey showed that, in terms of patient numbers, only a small fraction of COPD patients enrolled to rehabilitation programmes per year (fig. 2) [44]. In addition, a systematic review attempted to identify the barriers to uptake and completion of cardiopulmonary rehabilitation programmes [45]. The review reported that on average 10–30% of enrolled participants failed to complete a cardiopulmonary rehabilitation programme due to a number of barriers, including lack of family support, depression, transport difficulties, lack of perceived benefit by the patient, inconvenient timing or disruption of established routine of the patients [45].



**Figure 2**  
Estimated number of individuals who enrolled in each pulmonary rehabilitation (PR) programme in 2011 [44].

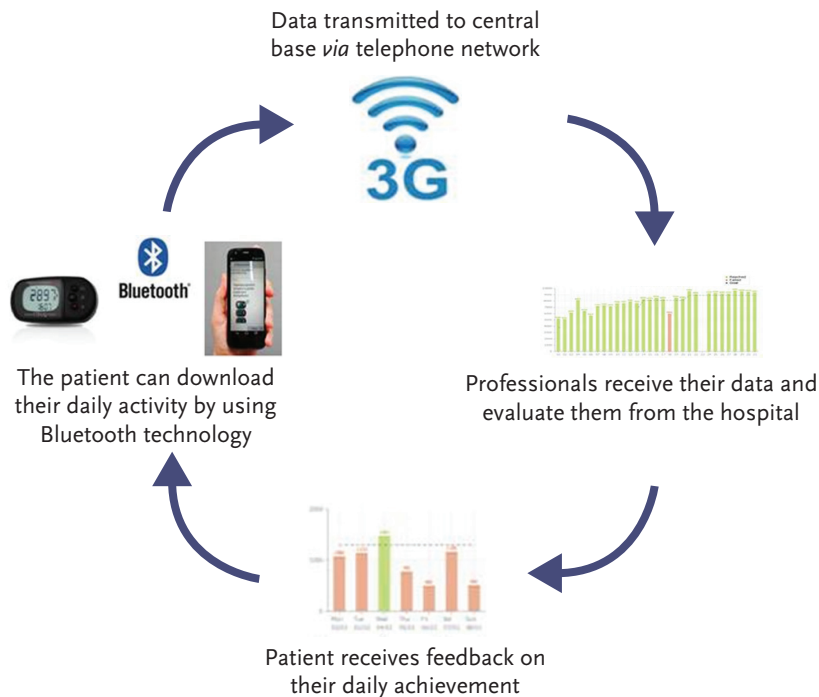
Accordingly, alternative models for providing pulmonary rehabilitation should be undertaken in order to improve its access and uptake. Tele-rehabilitation, which links expert rehabilitation healthcare providers with others at remote sites or with patients in their homes, has the potential to improve access. Initial small-scale studies demonstrate feasibility and suggest that clinical benefits may be achievable [46–49]. Consequently, interactive remote monitoring services using information and communication technologies (ICT) may be useful as interventions for maintaining and/or increasing physical capacity in patients with COPD or CHF.

## Tele-coaching programme to enhance physical capacity in COPD and CHF

Interactive remote monitoring interventions allow clinicians and doctors to check a patient remotely with reference to physiological signs, symptoms and activity levels using a wide range of technological equipment. The efficacy of these home-based tele-monitoring programmes has been evaluated in patients with COPD or CHF and the results show significant increase in clinical, functional and quality of life status [50–55]. Besides improvement in health status in patients with COPD or CHF, the major clinical important finding derived from these studies is that this kind of intervention is associated with decreasing rates of hospital readmissions secondary to cardiovascular events or due to COPD exacerbations [53, 56–59].

Such an interactive remote physical training intervention is currently under investigation in patients with COPD aiming at enhancing and maintaining daily physical activity levels ([www.proactivecopd.com/about/news/telecoaching-to-enhance-physical-activity/](http://www.proactivecopd.com/about/news/telecoaching-to-enhance-physical-activity/)). A 3-month coaching intervention including a step counter, an exercise booklet, an application installed on a smartphone device, text messages and telephone contact with investigators when necessary is underway. An example of the basic components is shown on figure 3.

Preliminary results from tele-rehabilitation studies in COPD or CHF show good compliance with the ICT along with improvement in daily physical activity levels [51, 54, 60–62]. However more studies are warranted to establish whether carefully structured



**Figure 3**  
Example of the basic components of tele-coaching programme.

home-based tele-rehabilitative programmes are feasible, effective and lead to long-term training adaptations as well as an adoption of health-enhancing behavior, such as regular physical activity.

## Conclusions

Despite the fact that the primary system impairment is different in patients with COPD or CHF, the underlying symptoms

reported by these patients during exercise are common and are related predominantly to leg discomfort but also to shortness of breath. Cardiopulmonary rehabilitation programmes significantly increase functional capacity in patients with COPD or CHF but their effects are rapidly attenuated after the completion of the programme. Interestingly, home-based interventions using tele-monitoring equipment may constitute a promising intervention to maintain and/or further improve physical capacity in patients with COPD or CHF.

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