Pulmonary rehabilitation in chronic obstructive pulmonary disease

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"Pulmonary rehabilitation is a process which systematically uses scientifically based diagnostic management and evaluation options to achieve the optimal daily functioning and health-related quality of life of individual patients, suffering from impairment and disability due to chronic respiratory disease as measured by clinically and/or physiologically relevant outcome parameters." This recent definition by the European Respiratory Society (ERS) task force "Rehabilitation and chronic care" [1] stresses the aims of a pulmonary rehabilitation treatment: "optimal daily functioning" and "quality of life". It also indicates that outcome parameters should be measured, and that they should be clinically and physiologically relevant. The ERS-position paper further requires that all existing treatment options available for the widest possible range of patients with chronic lung disease should be applied in rehabilitation. Components of such a programme are: exercise training; gymnastic exercise; respiratory muscle training; chest physiotherapy and breathing retraining; education; psychological counselling; nutritional therapy; ventilatory support, long-term oxygen therapy, and nursing care.

Consequently, pulmonary rehabilitation is a very complex and expensive treatment, and should be performed by a team of several professionals working in close co-operation in one institute. The cost is such, that a careful selection of motivated patients, a scientifically based diagnosis and a meticulous quantification of the outcome is mandatory. The place for rehabilitation in asthma, cystic fibrosis, or in the context of lung volume reduction surgery has been outlined by several authors, but remains outside the scope of this editorial.

The above suggests that the efficacy of all treatment modalities is unequivocal. This is not always true. Previously, there was an almost universal agreement that the impairment at the level of lung function can hardly be improved by rehabilitation. However, recent findings by CASABURI [2] showed that in patients with severe chronic obstructive pulmonary disease (COPD), the forced expiratory volume in one second (FEV$_1$) can also improve by 9%. This seems to be a small change in FEV$_1$, but considering the hyperbolic relationship between airway resistance and FEV$_1$, this modest improvement in the low ranges of FEV$_1$ means a considerable decrease in airway resistance. It is not clear how and why this change in FEV$_1$ was brought about; it must have contributed to the improvement in exercise performance of 36%, probably by a less dynamic hyperinflation during exercise? The latter will contribute to a lower level of exercise dyspnoea [3].

Impairment of peripheral muscle function occurs in patients with COPD, due to a reduced amount of oxidative enzymes [4, 5]. Apart from the ventilatory limitation due to airway obstruction and limited respiratory muscle function, this peripheral muscle weakness substantially contributes to the exercise limitation in patients with COPD. GOSSELINK et al. [6] showed that the maximal oxygen consumption (V'$_{O_2}$,max) and the 6 min walking distance correlated significantly with the maximal force of the quadriceps muscle. Nutritional depletion can be one of the factors in the malfunctioning of peripheral and respiratory muscles: the energy expenditure of patients with COPD often exceeds the caloric intake. Nutritional supplementation, anabolic steroids, and training can improve the function of these muscle groups, and also improve exercise performance [7, 8].

Dysfunction of peripheral muscles can be substantially reversed by training in patients with COPD. An increase in oxidative enzyme content in peripheral muscles was shown to occur after endurance training at 60% of pretreatment work loads, in patients with severe COPD (FEV$_1$ 36% pred), thus improving oxidative exercise capacity. The lactate threshold increased, and exercise hyperpnoea decreased significantly [9]. Similar high work loads for training were used by CASABURI et al. [2] and by RIES et al. [10]. However, high intensity training cannot always be sustained by patients with COPD, especially in the first weeks of treatment, and may not always be necessary [11]. Even low intensity training of peripheral muscles at home, as performed in a study by CLARK et al. [12] during a 12 week period, improved the performance on a treadmill test, at the same level of V'$_{O_2}$,max. This means that the efficiency of the working muscles must have improved. Upper extremity exercise may be of special importance in the rehabilitation of patients with COPD, since working with the arms requires a disproportional amount of V'$_{O_2}$,max and a disproportional high minute ventilation (V'Ve) [13]. Training of muscles of the upper extremities improved the exercise capacity of these muscle groups. However, there were no crossover effects to other types of work [14].

Respiratory muscle training is a controversial issue. It seems that respiratory muscles do not benefit from general exercise training [15]. The selection of patients who might benefit from specific training of inspiratory muscles should be directed to those patients who show a ventilatory limitation (pump-failure) of exercise capacity. When such a criterion is used, additional inspiratory muscle training during pulmonary rehabilitation can yield an additional improvement in timed walking distance [16]. It can also improve nocturnal saturation in patients with severe COPD [17]. The method of inspiratory muscle training might be relevant. Resistance breathing will often induce the patient to increase the duration of inspiration, with low

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flow, and low inspiratory pressures. Thus the inspiratory muscles will be neither exerted, nor trained. Imposing a resistance and a mouth pressure [18], or imposing a resistance and an inspiratory flow [16], forces the patient to generate a targeted pressure (60–70% of maximal inspiratory pressure (\(P_{\text{I, max}}\)), and consequently will provide an adequate training-stimulus for the inspiratory muscles. Also a threshold loading system for inspiratory muscle training, as described by Nickerson and Keens [19], is potentially an adequate training device, since it requires the patient to generate a targeted pressure at every breath. In normal subjects, training with the threshold loading system indeed improved maximal inspiratory pressure, and inspiratory muscle endurance [20].

Gosselin \textit{et al.} [21], discusses in an extensive review on exercise training in COPD six basic issues regarding this subject: 1) that its significance is almost universally acknowledged; 2) that the optimal intensity of training should be rather high; 3) modalities of training such as upper-lower extremities and isolated muscle training and the possible transfer-effects; 4) additional effects of medication, nutrition and oxygen; 5) maintenance programmes after the actual rehabilitation treatment are essential, and 6) the fact that in- or out-patient programmes are adequate, since home care rehabilitation does not improve the performance of patients.

Agreement seems to be present on the improvement of exercise capacity after rehabilitation. This will certainly contribute to attaining the first goal of pulmonary rehabilitation: "optimal daily functioning". The latter is mostly measured by means of questionnaires; in the future we might need to develop more functional tests to quantify this "optimal daily functioning". Out of 11 studies that were meta-analysed by Lacasse \textit{et al.} [22], 10 showed an improvement in performance. Most of the quantifications of this outcome parameter are given in terms of an incremental bicycle ergometry, or a 6 min walking distance; both rather short tests. Hardly any data are available on endurance capacity. However, "optimal daily functioning" of most patients with pulmonary disease only infrequently requires short bouts of exhausting work (i.e. climbing a flight of stairs), but more often longer lasting endurance is wanted for e.g. resuming gainful employment during an 8 h working day. Endurance was evaluated by Ries \textit{et al.} [10], but this did not extend beyond approximately 12 additional minutes of treadmill walking. In Casaburi \textit{et al.} study [2], the endurance of a constant work rate test at 80% of maximal work load improved from 5.8 to 10.2 min. In a study by Goldstein \textit{et al.} [23] patients improved their submaximal cycling time significantly by 4.7 min. Thus, improvements in "endurance capacity" after rehabilitation may be statistically significant, but one might question whether adding a few minutes of endurance is clinically relevant. It should be considered whether in the future, rehabilitation regimens should focus more on substantial improvements of endurance capacity, instead of maximal exercise performance.

There is also major agreement on the reduction of dyspnoea after rehabilitation. Dyspnoea correlates quite well with overall health status. O'Donnell \textit{et al.} [24] showed that, for a given level of workload, and for a given \(V'\text{E}\), the Borg score decreased significantly. An increased tolerance to the sensory perturbations that induce breathlessness was proposed. Reduction of dyspnoea is almost a universal finding after rehabilitation, and this will certainly add to the second important goal: "improvement of quality of life". Furthermore, O'Donnell \textit{et al.} [24] also showed a 12% improvement of efficiency (work rate/\(V'O_2\)). Similar improvements in efficiency were found in other studies [2, 12]. Lower \(V'O_2\) implies lower ventilation, and subsequently lower dyspnoea, at the same level of external work.

Several additional interventions can be made during rehabilitation, in order to improve exercise capacity. Addition of oxygen to the inspiratory air is quite widely practised in patients who show exercise hypoxia. Indeed, oxygen given in the acute exercise test improved the work capacity, and lowered sensations of dyspnoea [25]. One might hypothesize that this would allow a higher training intensity, and thus result in a better outcome of a rehabilitation programme. Results from two groups suggest that maximal exercise capacity does not yield extra improvement in groups trained with additional oxygen [26, 27]. There are indications that a training effect on peripheral muscles is achieved by some extent of peripheral hypoxia [28]. Terrados \textit{et al.} [29] showed an increase in citrate synthetase activity when training subjects in hypobaric conditions, that was greater than training in normobaric conditions. In a study by Maltais \textit{et al.} [9], citrate synthetase was shown to be low in peripheral muscles of patients with COPD. McDonald \textit{et al.} [30] studied 26 patients with COPD (FEV1 0.9±0.4 L), and provided either oxygen or compressed air in a double-blind cross-over design, for 6 weeks at home, to be used during any activity that would normally produce dyspnoea. At the end of each period, the 6 min walking distance, and a step test was performed on air and on oxygen. Again, in the acute comparison, the test with oxygen was better than the one without. However, the long-term home oxygen period did not yield better performance than the home-air period. One might thus question the rationale for training patients with COPD with additional oxygen during the training sessions. If it does not help to further improve the effects of training, there still may be some other reasons to continue such a therapy: i.e. relief of dyspnoea, or prevention of ischaemic cardiac complications.

Quality of life is one of the important goals of pulmonary rehabilitation. It is impaired in patients with COPD by anxiety, depression, and dyspnoea especially. Wiesner \textit{et al.} [31] found an improvement in quality of life measured using the Chronic Respiratory Disease Questionnaire after 18 months of rehabilitation. In the meta-analysis by Lacasse \textit{et al.} [22], there were 12 trials that had measured quality of life. The overall effect of rehabilitation on quality of life, on dimensions of dyspnoea, fatigue, emotional function and mastery showed an improvement of 0.5–0.8 SD units of the pooled SD of the outcome parameters, which equalled or exceeded the minimal clinically important differences of 0.5 units. In the study by Ries [10], the change in quality of life in the rehabilitation treatment group was not different from that in the education group.

There are suggestions that survival might be longer in the rehabilitation group, though this did not reach significance in the study by Ries \textit{et al.} [10]. Gerardi \textit{et al.} [32] treated 158 patients with several pulmonary diseases (87% had COPD), and found a 3 yr survival that did not differ from a comparable group in the literature. The post re-
habilitation 12 min walking distance was the most important predictor for 3 yr survival: if <750 m: 68% survival, if >750 m: 92% survival. Adequate analyses of cost-effectiveness of rehabilitation programmes are still to be made.

As stated earlier, rehabilitation according to the ERS definition is an expensive treatment, requiring the patients to be admitted to a clinic, or to come to the clinic several times a week, and be treated by a team of professionals who work very closely. "Home rehabilitation" has thus been investigated as an alternative and cheaper option. In this modality, 45 patients with COPD (FEV1 1.2 L) visited the local physiotherapist twice weekly for 1 month. The physiotherapist taught patients the exercises that were to be performed at home, twice daily for 30 min [33].

These exercises were performed for 18 months, with intermittent visits to the local general practitioner, local nurse and local physiotherapist. The "home rehabilitation" group did not improve on the bicycle ergometer test, nor in the 6 min walking distance, whereas the control group showed a significant decrease in exercise performance. Thus the "home rehabilitation" seems to prevent the natural course of decline in exercise performance in patients with COPD, but did not achieve the approximately 30% improvement in performance, that can be gained in a hospital-based rehabilitation programmes [2, 16]. Alternatively, such a "home rehabilitation" programme could be an excellent way to maintain the achievements of a hospital based rehabilitation programme.

Considering again the definition of pulmonary rehabilitation, one can conclude that most programmes indeed meet the goals of such treatment modality: achieving "optimal daily functioning" and an "improvement of the quality of life". The results can be measured by clinically and physiologically relevant outcome parameters. Changes in the degree of impairment of the pulmonary function seem to be virtually absent in most studies. However, it becomes increasingly clear, that impairment at levels of peripheral or respiratory muscle functioning, efficiency of work, nutritional status, and psychological functioning, play an important role in the disability of patients with chronic obstructive pulmonary disease and can be considerably improved by a rehabilitation treatment.

References

23. Goldstein RS, Gort EH, Stubbing D, Avendano MA,


