Exercises Commonly Used in Rehabilitation of Patients With Chronic Obstructive Pulmonary Disease: Cardiopulmonary Responses and Effect Over Time

Hanneke A. van Helvoort, PhD, Roline C. de Boer, MD, Luc van de Broek, MSc, Richard Dekhuijzen, PhD, MD, Yvonne F. Heijdra, PhD, MD


Objectives: To compare conventional exercise-based assessment of pulmonary rehabilitation (PR) with improvement in training exercises employed during a PR program, and to describe the cardiopulmonary response of different training exercises during PR of patients with chronic obstructive pulmonary disease (COPD).

Design: Observational study.

Setting: Inpatient PR.

Participants: Patients with moderate to very severe COPD (N=18).

Interventions: Not applicable.

Main Outcome Measures: Cardiopulmonary responses to interval cycling, arm exercise, and a test of functional activities of daily living (ADLs) were evaluated during the PR training program using a mobile telemetric breath-by-breath system. The effects of PR were evaluated by comparing pre-PR and post-PR training activities, incremental and constant work-rate cycling, and a 6-minute walk test.

Results: Interval cycling and the ADLs test were moderate-intensity to heavy-intensity exercises (70%–80% of maximal oxygen consumption), while the arm exercise was a low-intensity activity (40% of maximal oxygen consumption). After 12 weeks of PR, cycle load, arm weights, and walking distances during training activities had increased alongside increased muscle mass. At iso-intensities, no cardiopulmonary changes in the training exercises were observed. Exercise duration of constant work-rate cycling and 6-minute walk distance increased by 160% and 14%, respectively, after PR, with concurrent right-shifts of anaerobic threshold and a decrease in heart rate.

Conclusions: Supervised increases in weight, load, and walking distance during training activities were useful clinical outcomes for patients, demonstrating the beneficial effects of progressive training on physical performance. However, for physiologic evaluation of PR, conventional tests, such as maximal incremental cycling, endurance cycling, and a 6-minute walk test, had greater validity. Physiologic evaluation of the training exercises showed that the training program complied with the training recommendations for PR.

Key Words: Exercise; Physiology; Pulmonary disease, chronic obstructive; Rehabilitation.

REHABILITATION PROGRAMS for patients with lung diseases are well established as a means of enhancing standard therapy in order to control and alleviate symptoms and optimize functional capacity. Although comprehensive PR programs include several different components,1-3 exercise training is considered essential and mandatory.

Because systematic reviews and meta-analyses support the established effects of exercise training in patients with COPD, the practical guidelines for PR in COPD1,3 recommend the following: (1) high-intensity and low-intensity exercise training, which produces cardiopulmonary benefits; (2) both lower-extremity and upper-extremity exercise; (3) interval training, which can be useful in promoting higher levels of exercise training; and (4) the addition of strength training to increase muscle strength and muscle mass. To fulfill all these recommendations, PR programs need to be made up of different training activities.

In healthy subjects, high-intensity and low-intensity training can be discriminated by increases in blood lactate levels. However, patients with chronic respiratory disease are mainly limited by respiratory impairment before achieving maximal heart rate or changes in lactate levels. For these patients, training activities above 60% of peak exercise capacity are empirically considered sufficient to elicit a training effect.4 In clinical practice, symptom scores5 or power output6 are used to adjust training load. The cardiopulmonary responses to these symptom-based or power output–based training activities are currently unknown.

Moreover, the best way to evaluate PR programs remains debatable.7 To determine the effectiveness of PR, outcome

**List of Abbreviations**

- ADL: activity of daily living
- COPD: chronic obstructive pulmonary disease
- FEV₁: forced expiratory volume in 1 second
- FFM: fat-free mass
- PR: pulmonary rehabilitation
- RER: respiratory exchange ratio
- VE: expired volume per unit time
- VCO₂: carbon dioxide production per unit time
- VO₂: oxygen consumption per unit time

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assessment is essential. Conventional exercise-based assessment of PR includes maximal incremental cycling, endurance cycling, and a 6-minute walk test. However, the link between the progression of rehabilitation exercise performance and final exercise assessment is not readily apparent. Endurance cycling tests seem the most responsive but are likely biased by the traditional use of cycle ergometry during training, thereby overestimating the training response. In addition, besides being less relevant for most patients, cycling tests may not adequately assess post-PR changes of walking activities, and probably do not adequately assess post-PR changes of ADLs.

Because functional improvement during ADLs is often one of the primary goals of patients, the present study included an ADLs test in both the training sessions and the evaluation of the PR program for patients with COPD. Accordingly, this study compared conventional exercise-based assessment of PR with improvement in training exercises used during a PR program. The cardiopulmonary responses to different recommended and commonly used training activities during PR of patients with COPD are also described.

METHODS

Subjects
Eighteen patients with moderate to very severe COPD (according to the Global Initiative for Chronic Obstructive Lung Disease classification) participating in a 12-week inpatient PR program at the University Lung Center Dekkerswald, Groesbeek, The Netherlands, were included in the study. Exclusion criteria were exercise-limiting comorbidity other than COPD or the use of supplemental oxygen. The study was approved by the regional ethics committee for human and clinical research. Written informed consent was obtained from all participants.

Study Design
Standard pulmonary function tests (Masterscreen PFT), body composition measurement (single-frequency bioelectric impedance analysis; Bodystat 1500), incremental and endurance cycling exercises, and a 6-minute walk test were performed at the start (pre) and end (post) of the PR program. Furthermore, 3 additional training exercises were selected for a more detailed physiologic investigation: an upper-limb exercise (an unsupported arm exercise), a lower-limb exercise (interval cycling), and a functional exercise (an ADLs test). The cardiopulmonary responses to these activities (see section headed “Cardiopulmonary Measures During Activities” below for details) were evaluated during the first and last week of the PR program using Oxycon Mobile (see Equipment and Measurements).

Equipment and Measurements
Cardiopulmonary responses to all activities and tests were evaluated using a portable breath-by-breath system (Oxycon Mobile) with an integrated pulse-oximeter and a polar belt (T61). The device was secured on the patient’s back by a harness. The harness and metabolic device did not limit the patient’s movements. A face mask with a dead space of 70mL was carefully placed on the patient’s face. The portable breath-by-breath system was validated prior to use.

Cardiopulmonary Measures During Activities
The following cardiopulmonary measures were assessed at every 30 seconds breath-by-breath: $\dot{V}O_2$, $\dot{V}CO_2$, and $V_e$. Heart rate and oxygen saturation were measured continuously during exercise. Anaerobic threshold was examined with the V-slope method. Oxygen pulse, RER, ventilatory requirement (as a percentage of the predicted maximal ventilation (37.5 × FEV1)), and ventilatory equivalent for CO2 ($\dot{V}e/\dot{V}CO_2$) were calculated using measured values.

Training Activities
The guidelines for PR state that upper-body, lower-body, high-intensity, and low-intensity exercises should be incorporated in a training program. To evaluate these aspects, training was carried out 3 times a week during the PR program, and the training activities listed were measured pre-PR and post-PR.

1. Interval cycling: patients cycled on an electronically braked cycle ergometer at a constant rate of 60 rotations a minute for 2 minutes, followed by 2 minutes of rest. This was repeated 5 times, resulting in a total test time of 20 minutes. Starting at week 1 at 50% of their maximal achieved workload, the workload was increased by 5 to 10W on a weekly basis, based on performance and perceived dyspnea by the patient. If a Borg score for dyspnea or fatigue of less than 4 to 6 was reached and the 20-minute interval training was completed, the workload was increased at the next training session. At the end of the PR program, the physiologic effects of interval training were evaluated both at the initial intensity (50% of initial maximal work load) and at the final intensity.

2. Unsupported arm exercise: patients lifted a dumbbell of 1 to 3kg and placed it in a rack at eye level. The dumbbell was then taken out of the rack, and after holding it at the side of the body, it was placed in another rack at umbilical level. This exercise was repeated for 2.5 minutes with each arm, for a total exercise time of 5 minutes. Patients were allowed to determine their own pace, and the total number of arm lifts was determined. The weight of the dumbbell was increased by 0.5kg on a weekly basis, based on the patient’s performance and perceived dyspnea. Again, when a Borg score for dyspnea or fatigue less than 4 to 6 was reached and the 2.5-minute arm training was completed for both arms, the weight of the dumbbell was increased at the next training session. At the end of the PR, the physiologic results for the initial weight and the final weight were assessed.

3. Functional ADLs test: in a 5-minute sit-walk exercise, the patient started in the sitting position on a chair, stood up, and slalomed around 3 cones to another chair, where the patient sat down again. The 2 chairs were 4m apart, with 1m between every cone. Patients were allowed to determine their own pace. Total walking distance was determined. This functional ADLs test is specific to our rehabilitation center and was chosen because it is a simple test that resembles some of the basic and frequently performed activities at home. It is a variant of the earlier described sit-to-stand test and the Glittrer test.

Perceived dyspnea and (leg/arm) muscle fatigue were assessed at the start and at the end of each exercise using a modified Borg score.

Evaluation of PR, Exercise Tests
The conventional exercise tests listed were used to evaluate the training effects of PR.

1. Maximal incremental, symptom-limited cycling, according to the guidelines of the American Thoracic Society.
Subjects cycled at 60 rotations a minute on an electronically braked cycle ergometer. After unloaded pedaling for 3 minutes, the workload was increased every minute by 5 to 20W until the patient was exhausted. The rate of increase was calculated in order to reach the predicted maximal work-rate (maximal work-rate = predicted VO₂ − basal VO₂/10) within 10 minutes of exercise. Arterial blood samples were taken to evaluate the gas exchange limitations during exercise.

2. A constant work-rate cycling test at 75% of initial maximal achieved work-rate was performed at the same ergometer and at the same rotation speed (60 rotations a minute). After unloaded pedaling for 3 minutes, the workload was increased up to the 75% level within 1 minute. Subjects were asked to cycle until symptom limitation or for a maximum of 30 minutes. Incremental and constant work-rate cycling were performed separately on 2 subsequent days to prevent the influence of fatigue.

3. A 6-minute walk test was performed according to the guidelines of the American Thoracic Society. All patients were familiar with the test because they had already performed a practical trial during the intake for PR. A straight-walking course of 30m was used with 2 cones marking the turnaround points. After starting the exercise, patients were given encouragement every minute using standardized phrases. Patients were allowed to stop and rest during the 6 minutes of exercise. The 6-minute walk distance was used as the outcome parameter.

All of these standardized exercise tests and the 3 training activities mentioned were used to evaluate the effects of PR. Maximal workloads, distance, weight, or endurance were compared pre-PR and post-PR. In addition, and when possible, the cardiopulmonary responses were compared at iso-workload, iso-weight, iso-distance, and iso-time.

**PR Program**

The study was performed during a standard 12-week inpatient PR program consisting of 1.5-hour exercise sessions, 3 times a week, which included the aforementioned exercises.

Other elements of the training program that were not evaluated in this study included resistance training to increase abdominal-muscle, shoulder-muscle, and leg-muscle force, and an endurance walking exercise (for 6–12min) on a treadmill (at speed of 2–4km/h). Besides physical exercise, the PR program included education, physical therapy, breathing retraining, and psychosocial support sessions on a weekly basis. Nutritional intervention was applied if the FFM index was decreased (women, \(<15kg·m^{-2}\); n=4; men, \(<16kg·m^{-2}\); n=5).

### Statistical Analysis

Patient characteristics and cardiopulmonary responses to the training activities are represented as mean ± SEM. For steady-state exercises (arm exercise, ADLs test, endurance cycling), the mean cardiopulmonary recordings during the steady-state period are shown (at least 3min was required to reach steady-state). For incremental and interval exercises, peak values are shown. Training effects of the PR were evaluated using the Wilcoxon signed-rank test (for a small number of patients and nonlinear distributions). Statistical significance was taken at the P less than .05 level.

### RESULTS

#### Subjects

The baseline characteristics of the patients are shown in Table 1. Patients were classified as having moderate to very severe COPD (moderate, n=4; severe, n=11; very severe, n=3). Diffusion capacity was severely impaired (<50% predicted value), and static hyperinflation (increased ratio of residual volume and total lung capacity (>40)) existed in 13 patients. Pre-PR, maximal exercise capacity (table 2) and 6-minute walk distance (mean ± SEM, 425±22m) were lower than predicted in all patients. All patients were ventilatory-limited because they reached their maximal ventilatory capacity (n=18) and/or had increasing arterial partial pressure of carbon dioxide (n=16) during maximal incremental cycling (n=16). Additionally, 4 patients showed an oxygen-uptake problem with increasing alveolar-arterial oxygen difference to greater than 4.6kPa and hypoxemia (arterial partial pressure of oxygen <8kPa) (data not shown). The high Ve/VO₂ at anaerobic threshold and increasing carbon dioxide uptake problem with increasing alveolar-arterial oxygen difference.

**Table 1: Baseline Patient Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female (n)</td>
<td>12/6</td>
</tr>
<tr>
<td>Age (y)</td>
<td>58 ± 2</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>25.8 ± 1.3</td>
</tr>
<tr>
<td>FFM index (kg·m⁻³)</td>
<td>16.1 ± 0.7</td>
</tr>
</tbody>
</table>

**Table 2: Incremental Cycling Test**

<table>
<thead>
<tr>
<th>Incremental Cycling</th>
<th>Pre-PR (max)</th>
<th>Post-PR (max)</th>
<th>Post-PR (iso-watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload (W)</td>
<td>89 ± 6</td>
<td>93 ± 6</td>
<td>89 ± 6</td>
</tr>
<tr>
<td>VO₂peak (mL·min⁻¹)</td>
<td>1230 ± 95</td>
<td>1315 ± 89</td>
<td>1199 ± 77</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>130 ± 4</td>
<td>123 ± 4</td>
<td>121 ± 4*</td>
</tr>
<tr>
<td>Anaerobic threshold (mLVO₂·min⁻¹)</td>
<td>750 ± 74</td>
<td>916 ± 59¹</td>
<td>926 ± 68³</td>
</tr>
<tr>
<td>Ve (L·min⁻¹)</td>
<td>47 ± 4</td>
<td>47 ± 6</td>
<td>43 ± 3</td>
</tr>
<tr>
<td>Ve/VO₂</td>
<td>38 ± 2</td>
<td>38 ± 1</td>
<td>36 ± 2</td>
</tr>
<tr>
<td>Borg score</td>
<td>7.3 ± 0.7</td>
<td>6.0 ± 0.4</td>
<td>5.9 ± 0.4</td>
</tr>
<tr>
<td>Legs</td>
<td>6.6 ± 0.8</td>
<td>5.1 ± 0.8</td>
<td>5.0 ± 1.0</td>
</tr>
</tbody>
</table>

**NOTE.** Values are presented as mean ± SEM. Peak values are shown. Anaerobic threshold estimated with V-slope method. Ve/VO₂ at anaerobic threshold or lowest value if anaerobic threshold was not reached.

Abbreviations: bpm, beats per minute; max, maximum; VO₂peak, peak oxygen consumption per unit time.

¹P<.05, ¹P<.01 vs pre-PR.
resembled inefficient ventilation caused by dead-space ventilation in this group.

Cardiopulmonary Response to Training Activities During PR

The cardiopulmonary responses to the training activities are shown in tables 3 to 5 and plotted as a percentage of predicted values in figure 1. For comparison, maximal incremental cycling values pre-PR are included in figure 1. Both VO2peak and heart rate values indicate that interval cycling and ADLs exercise during the PR program were exercises of moderate to high intensity (~70% and ~80% of maximal values achieved during maximal incremental cycling). Net training time at these intensities was 10 minutes during interval training and approximately 3 minutes during the steady-state phase of the ADLs test. Arm exercise only modestly increased cardiopulmonary parameters and Borg scores. Figure 1 clearly shows the interval test. Arm exercise only modestly increased cardiopulmonary intensities was 10 minutes during interval training and approximately 3 minutes during the steady-state phase of the ADLs test. Arm exercise only modestly increased cardiopulmonary parameters and Borg scores. Figure 1 clearly shows the interval aspect of the cycling exercise with sinus-shaped VO2peak, V̇e, and heart rate responses, while ADLs exercise and arm exercise resembled inefficient ventilation caused by dead-space ventilation in this group.

Training Effects After PR

All patients completed the 12-week PR program, although 13 of them (72%) exacerbated during rehabilitation, resulting in treatment with antibiotics and prednisone. Training intensity was temporarily reduced during exacerbations. Post-PR lung function (data not shown) remained unaltered in comparison with pre-PR lung function. Although body mass index remained stable, mean FFM index slightly increased after PR (16.1 ± 0.7 kg·m⁻² pre-PR vs 17.9 ± 0.6 kg·m⁻² post-PR; P = .03). This FFM index increased in both the normative and the nutritionally depleted patients.

Data for all different exercise modalities measured pre-PR and post-PR are presented and compared in tables 2 to 6. The maximal workload during incremental cycling (see table 2) did not improve after PR (89W pre-PR vs 93W post-PR), but comparison at the highest possible iso-workload showed a decrease in heart rate and a right-shift of the anaerobic threshold, indicating an improvement in physical condition. Furthermore, both dyspnea and leg complaints showed a declining trend after PR not reaching statistical significance (P = .06 and P = .09, respectively). In accordance with this, the constant work-rate cycling test (see table 6) clearly showed an improvement in exercise capacity after the PR program, reflected as a greater than 150% increase in cycling duration, a right-shift of anaerobic threshold, and a tendency toward a decreased heart rate (P = .08). In addition, the 6-minute walk distance significantly and relevantly increased by 63m after PR (425 ± 22m pre-PR vs 488 ± 22m post-PR; P < .01).

Evaluation of the training activities showed that cycle load, arm weights, number of repetitions, and walking distance significantly increased after the 12-week PR program (see tables 3–5). These increases were observed with the same physiologic demand, except for a slightly increased V̇e and RER during the interval cycling. Only during arm exercise, muscle fatigue of the arms increased significantly with progressively increasing training weights. Comparing interval cycling and arm exercise pre-PR and post-PR at iso-workload or iso-weight, no cardiopulmonary changes were measured; heart rate, VO2peak, and ventilatory demand remained unaltered, and although dyspnea scores decreased by approximately 1 point on the Borg scale after PR, this did not reach statistical significance. PR effects observed with both the standardized exercise tests and training.
activities within the subgroup of 5 patients who became ventilatory-limited during training activities did not differ from those of the other patients.

**DISCUSSION**

This study compared conventional exercise-based assessment of PR (maximal incremental cycling, endurance cycling, 6-min walk test) with improvement in training exercises used during a PR program for patients with COPD. Rehabilitation improved anaerobic threshold and decreased heart rate during maximal cycling exercise, improved endurance cycling time, and improved walking distance. Supervised increases in arm weight and cycle load could be achieved alongside improved FFM, as could increased walking distance during an ADLs test. However, improvement in oxygen consumption and related parameters, typically expected after rehabilitation, was not readily detected in the training exercises evaluated. The increases in weight, load, and walking distance during training activities seemed very useful as clinical outcomes for patients, reflecting progressive training ability and better physical performance. However, conventional tests, such as maximal incremental cycling, endurance cycling, and a 6-minute walk test, had greater validity as physiologic measures.

In addition, the cardiopulmonary response to different recommended and commonly used training activities for PR in patients with COPD are described. The results show that interval cycling and the functional ADLs test were both aerobic activities at 70% to 80% of the patient’s maximum oxygen consumption. In contrast with interval cycling, the ADLs test and arm exercise resembled continuous exercises. Although both interval cycling and the ADLs test were moderate-intensity to high-intensity exercises, ventilatory demand and dyspnea scores remained much lower compared with the incremental cycling test. The arm exercise was shown to be a

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**Table 6: Constant Work-Rate Cycling**

<table>
<thead>
<tr>
<th>Constant Work-Rate (75% of initial maximal workload)</th>
<th>Pre-PR (max)</th>
<th>Post-PR (iso-watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload (W)</td>
<td>67±6</td>
<td>67±6</td>
</tr>
<tr>
<td>Duration (min)</td>
<td>3.9±0.8</td>
<td>10.4±3.7*</td>
</tr>
<tr>
<td>VO₂ (L·min⁻¹)</td>
<td>1.1±0.1</td>
<td>1.0±0.1</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>122±6</td>
<td>115±4</td>
</tr>
<tr>
<td>Anaerobic threshold (mL VO₂·min⁻¹)</td>
<td>934±146</td>
<td>1153±147*</td>
</tr>
<tr>
<td>VO₂ (L·min⁻¹)</td>
<td>40±5</td>
<td>38±3</td>
</tr>
<tr>
<td>VO₂/VO₂ CO₂</td>
<td>38±2</td>
<td>38±2</td>
</tr>
<tr>
<td>Borg score</td>
<td>6.6±0.9</td>
<td>5.9±0.8</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>6.6±0.9</td>
<td>5.9±0.8</td>
</tr>
<tr>
<td>Legs</td>
<td>4.4±0.9</td>
<td>4.8±1.2</td>
</tr>
</tbody>
</table>

**NOTE.** Values are presented as mean ± SEM. Steady-state values during endurance cycling are shown. Abbreviations: bpm, beats per minute; max, maximum. *P<.05 vs pre-PR.
low-intensity activity. In accordance with the practical guidelines for PR, training exercises at low and high intensity were indeed incorporated in the training sessions. In addition, both the upper and the lower (ambulatory) extremities were trained using interval and endurance activities.

Characteristics of Training Exercises

Exercise training is one of the key components of PR. The American Thoracic Society and European Respiratory Society recommend exercise training at high intensity (60%–80% of peak work-rate [achieved during a maximal incremental exercise test]) for at least 30 minutes, 3 to 5 times a week. This recommendation is primarily based on training studies in healthy elderly subjects because the characteristics of exercise programs in PR for COPD have been poorly investigated. The current extensive physiologic evaluation of patients with COPD carrying out frequently used training exercises taught us more about the use of interval and endurance exercises, high-intensity and low-intensity exercises, and upper-extremity and lower-extremity training. For example, the sit-walk exercise, a typical example of a functional ADL, unexpectedly seemed to be a high-intensity endurance training exercise for patients with COPD. Of note, it was shown that patients’ walking distance significantly increased after the PR program. This knowledge of cardiopulmonary responses to different training activities is indispensable in optimizing training programs for patients with COPD and as a basis for exercise recommendations for PR training in this population.

Training Effects

Demonstration of the physiologic benefits of exercise training has been a critical step in convincing the medical community about the efficacy of this intervention. Traditionally, PR was evaluated by comparing patients’ maximal exercise capacity pre-PR and post-PR. Because ventilatory limitation plays an important role in exercise capacity of patients with COPD, it is not surprising that although physical condition and muscle strength/endurance are improved during PR, not all studies were able to find an increase in maximal exercise capacity. Indeed, the current 12-week PR program did not improve maximal workload, but heart rate at iso-workload was decreased and anaerobic threshold was right-shifted, indicating an improvement in cardiovascular condition. Nowadays, submaximal exercise tests are increasingly used to evaluate PR programs because they seem more sensitive to training effects. Increase in endurance time has been shown to be the most responsive index. However, because the power–duration relationship for this type of exercise is hyperbolic, absolute and relative increases in exercise duration during a constant work-rate exercise must be interpreted with caution regarding the physiologic benefits that have been realized by the intervention. Indeed, in the current study, exercise duration and walking distance during submaximal exercise tests (constant work-rate cycling, 6-min walk test) increased by 160% and 14%, respectively, and both of these have been reported to be of clinical relevance. Although these results should be interpreted with caution, the right-shifted anaerobic threshold and the decrease in heart rate still supported the finding of physiologic benefits from the PR program.

The current study also included the training activities in the evaluation. During the 12 weeks of training, all patients were able to perform training activities with higher loads and weight for a longer duration, and with a trend toward less dyspnea and fatigue. At least part of these improvements might be related to the increased muscle mass. Next, it should be investigated whether correlations exist between better performance of training exercises and performance and complaints during ADLs at home. In this study, walking distance during both the 6-minute walking test and the ADLs test improved significantly by approximately 14%. No correlation between both improvements could be found (data not shown). The disparity between laboratory-measured improvements after PR and functional improvements at home is also the object of recent debate, and lifestyle changes seem to need more time than PR.

This study has confirmed that the evaluation of training activities is useful. The patients themselves were encouraged by their better performance and fewer complaints during their ADLs, as demonstrated by these evaluations. With regard to the cardiopulmonary response, however, the training exercises did not contribute to the evaluation of PR. The most plausible reason for an apparent lack of cardiopulmonary benefit in the training exercises is based on the concept that critical power is needed to show a training effect sensitively. Because the training exercises were evaluated at the initial intensities at which most patients are not physiologically limited (neither ventilatory or conditionally), and no anaerobic threshold was reached, a cardiopulmonary effect may not be expected. Only dyspnea or leg/arm fatigue scores might have been improved after the PR program. In general, outcomes based on training exercises are always affected by learning effects and are thereby less useful for physiologic evaluations.

Study Limitations

Because this was the first observational study extensively studying the cardiopulmonary aspects of training during PR of patients with COPD, no control group was included. From a practical point of view, not all training exercises could be measured with the Oxycon Mobile. Therefore, no complete cardiopulmonary exercise program has been evaluated. Although recommended and commonly used training exercises were evaluated, these remain part of an institution-specific program that cannot simply be extrapolated to other programs. However, other PR programs are expected to have comparable exercises because they are recommended by the practical guidelines.

As reported, 72% of the patients exacerbated during the PR program, which seems a high proportion. Possible explanations for this finding might be (1) the seasonal influence (most participants of this study were enrolled between October and March), and (2) a possible overdiagnosis of exacerbations because only inpatients, under hospital supervision, were enrolled in the study. Improvements in 6-minute walk distance and other parameters, however, are typical for this sample size, despite exacerbation frequency.

Finally, it should be mentioned that neither the Borg scale for arm fatigue nor the institution-specific ADLs test has been validated.

CONCLUSIONS

This study compared conventional exercise-based assessment of PR with improvements in training exercises during PR and described the cardiopulmonary characteristics of different recommended and commonly used training exercises of a comprehensive PR program for patients with COPD. It was shown that increases in weight, load, and walking distance during training activities are useful clinical outcomes for patients, reflecting progressive training ability and better physical performance. Cardiopulmonary responses to training exercises have been used for the first time to verify that a PR program complied with the training recommendations for PR, but for physiologic evaluation of PR, conventional tests, such as a
maximal incremental cycling test, an endurance cycling test, and a 6-minute walk test, have greater validity.

References

Suppliers
a. VIASYS Healthcare GmbH, Leibnizstr 7, D-97204 Hoechberg, Germany.
b. Biostat Ltd, Bodystat 1500, PO Box 103, Ashurst Palmerston North 4810, New Zealand.
c. Polar Electro Oy, Professorintie 5, FIN-90440 Kemplele, Finland.