ORIGINAL ARTICLE

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

ABSTRACT. van Helvoort HA, de Boer RC, van de Broek L, Dekhuijzen R, Heijdra YF. Exercises commonly used in rehabilitation of patients with chronic obstructive pulmonary disease: cardiopulmonary responses and effect over time. Arch Phys Med Rehabil 2011;92:111-7.

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 COPD[1,3] 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 scores[5] or power output[6] 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
FEV_1	forced expiratory volume in 1 second
FFM	fat-free mass
PR	pulmonary rehabilitation
RER	respiratory exchange ratio
$\dot{V}_E$	expired volume per unit time
$\dot{V}_{CO_2}$	carbon dioxide production per unit time
$\dot{V}_{O_2}$	oxygen consumption per unit time

From the Department of Pulmonary Diseases, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands.

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Reprint requests to Hanneke A. van Helvoort, PhD, Radboud University Nijmegen Medical Center, Dept of Pulmonary Diseases (454), PO Box 9101, 6500 HB Nijmegen, The Netherlands, e-mail: *H.vanHelvoort@long.umcn.nl.*

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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[8] but are likely biased by the traditional use of cycle ergometry during training, thereby overestimating the training response.[9] In addition, besides being less relevant for most patients, cycling tests may not adequately assess post-PR changes of walking activities,[8] 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)[10] 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[11] (Masterscreen PFT[a]), body composition measurement (single-frequency bioelectric impedance analysis; Bodystat 1500[b]), incremental[12] and endurance cycling exercises, and a 6-minute walk test[10] 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[a] (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[a]) with an integrated pulse-oximeter and a polar belt (T61[c]). 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.[13]

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 $\dot{V}E$. Heart rate and oxygen saturation were measured continuously during exercise. Anaerobic threshold was examined with the V-slope method.[14] Oxygen pulse, RER, ventilatory requirement (as a percentage of the predicted maximal ventilation ($37.5 \times FEV_1$), and ventilatory equivalent for CO_2 ($\dot{V}E/\dot{V}CO_2$) 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[d] 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[5] 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[5] 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[15] and the Glittre test.[16]

Perceived dyspnea and (leg/arm) muscle fatigue were assessed at the start and at the end of each exercise using a modified Borg score.[17]

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.[12]