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RESPIRATORY MEDICINE (1998) **92**, 1191–1198

Exercise training improves recovery in patients with COPD after an acute exacerbation*†

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Clinical experience suggests that exercise is beneficial for recovery after an acute exacerbation in patients with severe chronic obstructive pulmonary disease (COPD). The aim of this study was to quantify the clinical benefit of exercise in these patients.

Twenty-nine inpatients were randomly assigned to a training group (n=15, FEV_1 34% pred) or a control group (n=14, FEV_1 38% pred). On ten consecutive days, patients in the training group performed a 6-min treadmill walking test and, in addition, five walking sessions per day at ≥75% of the respective treadmill walking distance. Patients in the control group performed only treadmill walking tests on days 1, 5, and 10. To directly compare the possible benefit of exercise training all patients had an exercise test on day 11 at the same work load as on day 1.

In the training group, 6-min walking distance increased from 237 to 420 m, in the control group from 230 to 255 m over the 10 day period which was significantly different (P<0·0001). Minute ventilation and oxygen uptake increased significantly (P<0·05) in the training but not in the control group. When comparing exercise tests on days 1 and 11, minute ventilation, oxygen uptake, $PaCO_2$, lactic acid concentration, and Borg scale were significantly reduced to achieve the same work load (P<0·01) only in the training group. Intrathoracic gas volume and residual volume decreased, and FEV_1 and vital capacity increased in the training (P<0·05) but not in the control group.

Our data demonstrate that exercise training significantly improves the exercise capacity in patients with severe COPD after an acute exacerbation of their disease.

RESPIR. MED. (1998) **92**, 1191–1198

Introduction

Exercise training is an essential part of pulmonary rehabilitation programmes in patients with chronic obstructive pulmonary disease (COPD) (1). Studies have demonstrated beneficial effects of exercise training, such as improvement in exercise tolerance, reduction of exertional dyspnea, improvement in quality of life indices, and amelioration of ventilatory parameters (2–8). Most of these studies involved training programmes over several weeks or months. Therefore, long-term training appears to be effective in patients with COPD in a stable condition and with moderate degree of their disease.

In addition, clinical experience suggests that exercise can support the recovery after an acute exacerbation in patients with unstable severe chronic obstructive pulmonary disease (COPD). This practice, however, is largely based on casual observations and has not been studied in detail. Therefore, the aim of our study was to evaluate the clinical benefit of short-term exercise in patients with severe COPD after an acute exacerbation.

Received 6 January 1998 and accepted in revised form 15 June 1998.
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*Supported by the Landesversicherungsanstalt (LVA) Freie und Hansestadt Hamburg.
†This study is part of the doctoral thesis of C. Taube.

Materials and Methods

PATIENTS

We studied patients with severe COPD within a referral hospital after an acute exacerbation of their disease. The diagnosis and treatment of COPD followed international guidelines (1,9). The study was started 6–8 days after admission when patients had improved and were able to participate in the protocol. Thirty-one patients were included. At the beginning of the study period, patients were randomly assigned either to a training or a control group. Two patients had to be excluded during the study due to acute bronchitis or the development of ankle edema, respectively. Therefore, 29 patients completed the study. All patients showed a forced expiratory volume in 1 s (FEV_1) below 60% of their mean predicted values (10).

0954-6111/98/101191+08 $12.00/0

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TABLE 1. Baseline characteristics of patients with severe COPD

		Training group	Control group
n		15	14
Gender	m/f	12/3	14/0
Age	years	62·3 ± 9·1	65·6 ± 11·8
Height	cm	174·4 ± 8·1	174·3 ± 6·6
Weight	kg	70·7 ± 15·1	71·9 ± 15·1
BDI score*		4·7 ± 2·2	4·0 ± 1·6
Systemic steroids			
Day 0	mg	40·3 ± 15·6	40·7 ± 12·5
Day 11	mg	21·7 ± 7·7	19·8 ± 6·5
Theophylline serum level	mg/l	9·8 ± 6·0	12·0 ± 2·4
HBCO	mg %	1·50 ± 0·44	1·88 ± 0·76
Long-term oxygen therapy	yr/n	5/10	4/10

Mean values and standard deviations are given.
*Baseline dyspnea index.

They did not complain of lung diseases other than COPD; patients with unstable cardiac disease, cor pulmonale decompensation or other diseases, which prohibited the participation in the exercise programme, were not admitted to the study. Twenty-six of the patients took theophylline, 29 inhaled corticosteroids and 28 systemic corticosteroids, owing to their acute exacerbation which led to hospital admission. All patients inhaled β_2-adrenoceptor agonists and anticholinergic regularly and additionally on demand. Medication was continued through the whole period of training and did not differ between both groups. Patients were ex-smokers and smoking habits were controlled for by measurement of HBCO levels (Table 1).

STUDY PROTOCOL

Patients started the training immediately when they were stable enough to participate in the training programme, which was decided on clinical status and blood gas values. However, they were unstable in the sense that they were still in the process of gradual improvement as reflected in tapering off steroid doses (Table 1).

All patients participated in the baseline testing on study day 0. Both the training and the control group performed 6-min treadmill walking tests on study days 1, 5, and 10. Furthermore, on day 11, all patients performed a 6-min walking test at the same work load and average pace, respectively, which they had achieved on day 1, and the tests, which had been done on study day 0, were repeated. Whereas patients in the control group did not perform regular exercise during study days 1 to 10, patients in the training group performed a 6-min treadmill walking test on each day and, in addition, five walking sessions per day (Fig. 1).

LUNG FUNCTION TESTING AND BLOOD GAS ANALYSIS

On day 0 and day 11, after the treadmill test, FEV_1, vital capacity (VC), airway resistance (*R*AW), intrathoracic gas volume (ITGV), residual volume (RV), inspiratory capacity (IC), and expiratory reserve volume (ERV) were measured in a body plethysmograph (Materlab, Jaeger, Würzburg, Germany). The transfer factor for carbon monoxide (*T*LCO) and the transfer factor divided by alveolar volume (Krogh factor, *T*LCO/*V*A) were determined by the single breath method. *T*LCO was corrected for the concentration of hemoglobin (11). Predicted values were calculated according to the guidelines of the ERS (10). Maximal inspiratory pressure after 0·1 s ($P_{0\cdot1max}$) was measured in a suitably equipped body plethysmograph (Ganzhorn, Münnerstadt, Germany) during a maximal inspiratory maneuver from residual volume against a closed shutter. $P_{0\cdot1max}$ was defined as the pressure measured after 100 ms, the best of six trials being taken for analysis. Blood gas analysis was achieved from the hyperemic ear lobe to yield pH, $PaCO_2$, and PaO_2 (Blood gas analyzer model 278, Ciba Corning, Fernwald, Germany). Quality of life and overall dyspnea were assessed using a German translation (12,13) of the Baseline (BDI) Dyspnea Index (14).

TREADMILL EXERCISE TESTING

Exercise performance was assessed as the 6-min walking distance in a self-paced treadmill walking test (15) on a horizontal treadmill (LE 2000, Jaeger, Würzburg, Germany). The treadmill was equipped with a speed control module for the patient's use. At the beginning of each walking test, patients were instructed to walk as far as possible in 6 min; no further encouragement was given during the walk. Prior to the training, on day 0, patients

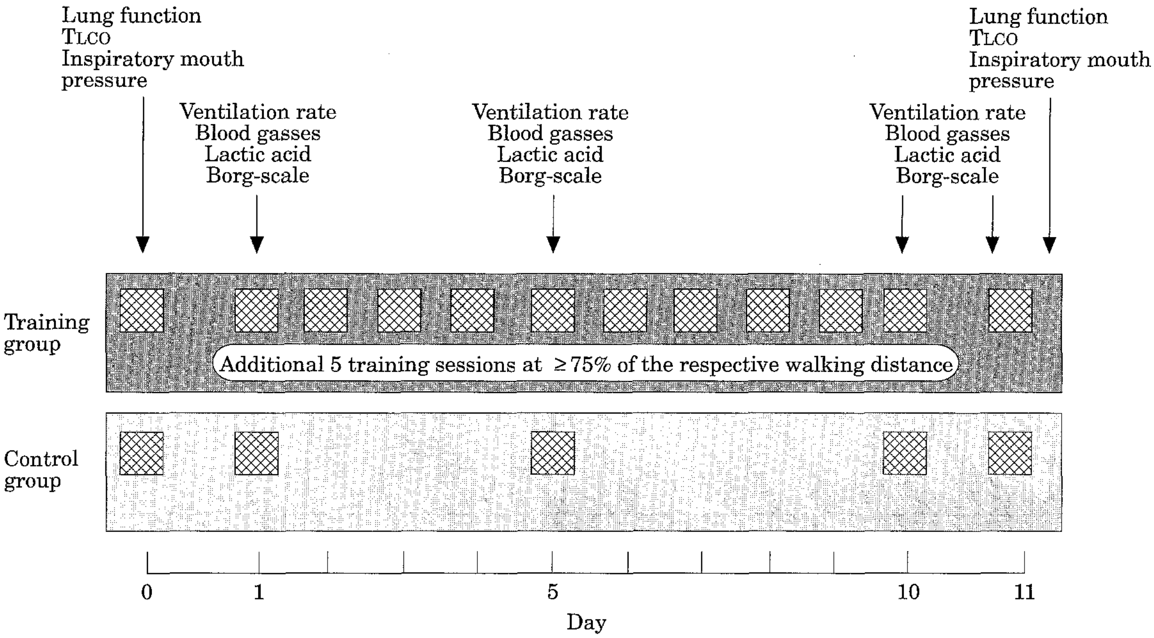

FIG. 1. Study protocol. ▩, Walking test.

had performed one walk to become familiar with the procedure.

MEASUREMENTS PERFORMED DURING TREADMILL EXERCISE TESTING

In the treadmill walking tests, patients breathed ambient air through a mouthpiece, with a noseclip in place. Expired air was analyzed for flow rate, O_2, and CO_2 concentration. Minute ventilation ($\dot{V}E$), oxygen uptake ($\dot{V}O_2$), and carbon dioxide output ($\dot{V}CO_2$) were determined as half-minute average values (Oxycon, Jaeger, Würzburg, Germany). From these parameters, oxygen uptake per body weight ($\dot{V}O_2$/kg), oxygen pulse ($\dot{V}O_2$/HR) were computed. Heart rate (HR) and oxygen saturation were measured by a pulse oximeter at the ear lobe (Biox III, Ohmeda, U.S.A.). For analysis, mean values over the 6-min walking period were taken. In each of the four treadmill exercise tests, venous blood samples were drawn at the beginning during resting ventilation and within the last minute of the exercise. Aliquots (20 μl) of each sample were mixed with iced perchlorate solution (200 μl) and centrifuged, the supernatant being analyzed for lactic acid concentration (16). Blood gases were measured from the hyperemic ear lobe during the last minute of exercise test. The alveolo-arterial partial pressure difference of oxygen (PA-aO_2) was estimated using the alveolar gas formula for calculation of alveolar oxygen partial pressure (PAO_2). Exertional breathlessness was assessed by the categorical scale according to Borg (17). In addition, changes in overall dyspnea and quality of life were determined by the Transition Dyspnea Index (TDI) (12–14).

EXERCISE IN THE TRAINING GROUP

The additional exercise, which the patients in the training group performed, comprised five self-controlled walking sessions per day in the corridor. Patients were instructed to achieve at least 75% of the distance which they had shown in the treadmill walking test on the respective day but without time limit. The training was supervised by nurses and one of the investigators (C.T.).

DATA ANALYSIS

Throughout the study, parametric tests were used for parameters which were normally distributed and non-parametric tests for other parameters. For lung function, blood gas, exercise parameters, and Borg scale, arithmetic mean values and standard deviations of mean (SEM) were computed. Baseline characteristics obtained on days 0 and 1 were compared between the training and control group by the unpaired t-test or the Mann-Whitney U-test. In both groups, paired t-tests or Wilcoxon matched-pairs signed-rank tests were employed to compare values obtained on different study days. TDI scores were analyzed by the sign test versus a median value of zero.

Comparison between groups was achieved by repeated measures analysis of variance for the values obtained on study days 1, 5, and 10. This type of analysis revealed differences between groups during the training period mainly via the interaction term. Furthermore, to analyze specifically at the single time points, the per cent changes on days 5, 10, and 11 were compared between groups by the unpaired t-test or the Mann-Whitney U-test.

TABLE 2. Mean values and standard deviations of mean for exercise parameters

		Training group			Control group		
		Day 1	Day 10	Day 11	Day 1	Day 10	Day 11
Walking distance	m	237 ± 28	420 ± 42‡	– §	230 ± 23	255 ± 27‡	– §
Borg scale		3·9 ± 0·2	4·4 ± 0·3	2·7 ± 0·2*	4·5 ± 0·3	4·4 ± 0·3†	4·2 ± 0·4
$\dot{V}$E	l/min	29·9 ± 2·1	35·0 ± 2·7‡	25·6 ± 1·5*	32·9 ± 2·8	33·3 ± 3·0	30·3 ± 2·6
Breathing frequency	/min	24·5 ± 1·5	25·0 ± 1·0	21·8 ± 1·0*	26·0 ± 1·3	26·4 ± 1·6	24·4 ± 1·8
Heart rate	/min	112·1 ± 2·0	114·3 ± 4·6	102·4 ± 3·0*	107·9 ± 3·3	110·4 ± 3·7	107·6 ± 3·5
$\dot{V}O_2$/kg	ml/(min* kg^{-1})	12·7 ± 0·8	15·5 ± 0·8‡	10·6 ± 0·6*	13·4 ± 1·0	13·9 ± 1·0	12·8 ± 0·8
$\dot{V}O_2$/HR	ml/beat	8·0 ± 0·8	9·7 ± 0·9‡	7·4 ± 0·6	9·0 ± 0·9	9·2 ± 0·9	8·6 ± 0·8
PaO_2 exercise‖	mmHg	59·2 ± 2·2	59·3 ± 2·1	63·2 ± 1·7*	61·8 ± 2·2	59·3 ± 2·0‡	60·4 ± 2·2
$PaCO_2$ exercise‖	mmHg	41·4 ± 1·9	41·6 ± 2·0	37·9 ± 1·9*	42·7 ± 1·8	42·2 ± 1·8	41·9 ± 1·7
PA-aO_2	mmHg	41·5 ± 3·1	41·4 ± 3·4	39·6 ± 2·5	39·2 ± 2·4	41·1 ± 2·2	38·3 ± 2·5
Lactic acid	mmol/l	1·75 ± 0·19	1·80 ± 0·25	0·86 ± 0·08*	1·70 ± 0·31	1·69 ± 0·24	1·55 ± 0·21

*Significantly (P<0·05) different from values on day 1; †significantly (P<0·05) different from values on day 5; ‡significantly different (P<0·05) different from values on day 1 and 5; §walking distance identical to that on day 1; ‖measured during the last minute of exercise test.

TABLE 3. Mean values and standard errors of mean for lung function parameters before and after the training period

		Training group		Control group	
		Day 0	Day 11	Day 0	Day 11
VC	%predicted	80·8 ± 3·3	88·4 ± 4·5*	70·7 ± 5·5	74·3 ± 4·0
TLC	%predicted	124·7 ± 3·8	122·3 ± 3·6	123·3 ± 5·5	122·2 ± 6·4
ITGV	%predicted	182·6 ± 8·2	168·1 ± 6·6†	179·8 ± 12·6	176·1 ± 13·9
RV	%predicted	210·2 ± 15·1	188·4 ± 12·8*	220·1 ± 20·3	209·8 ± 20·1
FEV_1	%predicted	34·3 ± 2·6	38·2 ± 3·1*	37·7 ± 3·4	38·1 ± 3·0
IC	Liter	2·04 ± 0·66	2·38 ± 0·95*	2·07 ± 0·79	2·04 ± 0·79
RAW	kPa/L s^{-1}	6·8 ± 0·6	6·3 ± 0·6	6·6 ± 0·6	5·4 ± 0·5
$P_{0\cdot1max}$	kPa	2·77 ± 0·39	3·27 ± 0·46†	2·21 ± 0·39	2·65 ± 0·41
TLCO	%predicted	76·8 ± 6·7	75·4 ± 6·2	73·9 ± 6·4	74·7 ± 6·4
PaO_2 at rest	mmHg	65·8 ± 2·1	66·2 ± 1·8	64·3 ± 2·1	65·1 ± 2·2
$PaCO_2$ at rest	mmHg	40·2 ± 1·8	39·2 ± 1·7	40·4 ± 1·6	40·6 ± 1·7

Level of statistical significance for comparison of day 0 and 11: P<0·05*, P<0·01†.

For correlation analysis, Spearman's rank correlations coefficients were used. All tests were performed two-tailed. The level of statistical significance was assumed at P=0·05.

The maximum improvements in walking distance in patients of the control group were 79 m and 27%, respectively (see Results). Choosing about twice these maximum changes, we selected cut-off values of 140 m and 60% in order to define responders and non-responders in terms of absolute or relative increase in walking distance.

Results

Fifteen patients were assigned to the training group and 14 patients to the control group. Patients' characteristics are shown in Table 1 and baseline values are given in Table 2 (day 1) and 3 (day 0). Both groups did not differ significantly with respect to their physical characteristics and medical treatment. Similarly, lung function parameters, blood gas values, BDI scores, 6-min walking distance, spiroergometric data, and Borg scale showed no significant differences (Tables 1–3).

TRAINING GROUP

Comparison of Values during Training on Days 1, 5, and 10

In the training group, the 6-min walking distance increased from day 1 to day 5, day 1 to day 10, and day 5 to day 10

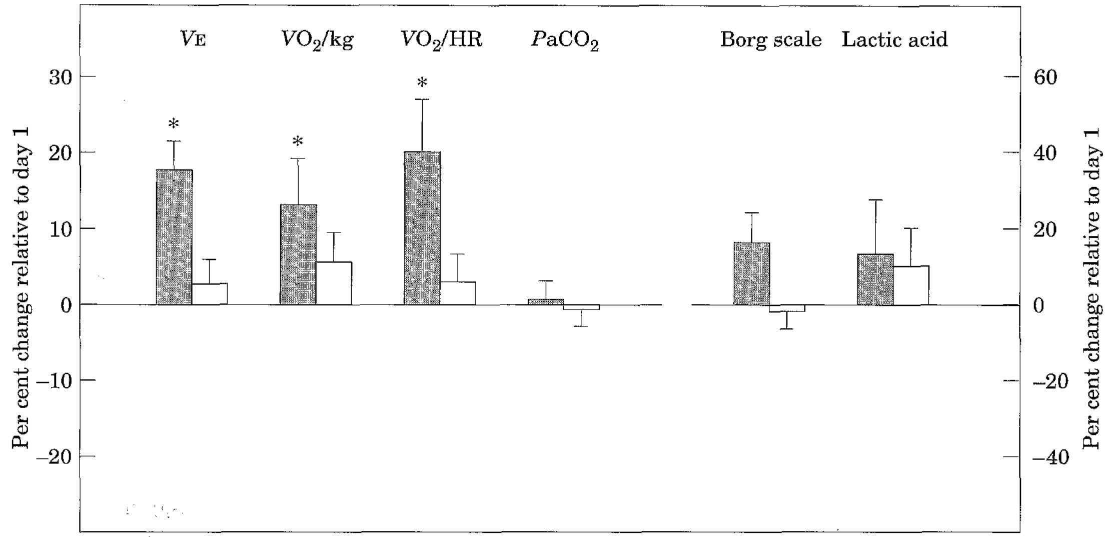

FIG. 2. Mean values and SEM of per cent changes in minute ventilation ($\dot{V}E$), oxygen uptake ($\dot{V}O_2$/kg), oxygen pulse ($\dot{V}O_2$/HR), arterial blood gas pressure of carbon dioxide ($PaCO_2$), Borg scale, and lactic acid concentration in venous blood samples during treadmill exercise on day 10. These values refer to the maximum gain in walking distance achieved in the training group (▩) or control group (□) as compared to baseline values on day 1. *Indicates significant ($P<0{\cdot}05$) difference from day 1.

($P \leq 0{\cdot}0001$ each) (Table 2). Among the 15 patients, 11 patients demonstrated an improvement in walking distance by at least 60% and 11 patients by at least 140 m; the maximum improvements were 189% and 372 m, and the minimum improvements 24% and 21 m, respectively. Furthermore, minute ventilation, $\dot{V}O_2$/kg, and $\dot{V}O_2$/HR were increased on day 10 compared to day 1 and on day 10 compared to day 5 ($P<0{\cdot}05$ each) (Fig. 2). TDI scores were higher than zero on day 5 and day 10 ($P \leq 0{\cdot}0002$ each). Other parameters did not change significantly.

Comparison at the Same Work Load on Day 1 and Day 11

We performed an additional exercise test on day 11 at the same work load achieved on day 1. This comparison revealed that on day 11, minute ventilation ($P=0{\cdot}0006$), breathing frequency (BF) ($P=0{\cdot}010$), heart rate ($P=0{\cdot}008$), $\dot{V}O_2$/kg ($P=0{\cdot}0004$), $PaCO_2$ during exercise (p=0·0002), lactic acid concentration ($P=0{\cdot}0006$), and the ratings on the Borg scale ($P=0{\cdot}002$) were reduced (Table 2, Fig. 3). PaO_2 during exercise was increased ($P=0{\cdot}016$). Other exercise parameters did not show significant changes.

Lung function Parameters on Day 11 and Day 0

On day 11, ITGV ($P=0{\cdot}003$) and RV ($P=0{\cdot}017$) were significantly reduced compared to day 0, whereas $P_{0{\cdot}1max}$ ($P=0{\cdot}009$), VC ($P=0{\cdot}046$), IC ($P=0{\cdot}03$), and FEV_1 ($P=0{\cdot}03$) were raised (Table 3).

CONTROL GROUP

In the control group, 6-min walking distance raised significantly from day 1 to day 10 ($P=0{\cdot}0035$) and from day 5 to day 10 ($P=0{\cdot}0017$) (Table 2). Among the 14 patients, 12 patients showed an increase in walking distance in day 10 *vs.* day 1 by less than 20%, 12 patients by less than 60 m, and 9 patients by less than 30 m. The maximum increases were 27% and 79 m, respectively. PaO_2 during exercise was reduced on day 10 compared to day 1 and 5 ($P<0{\cdot}05$ each) and TDI scores were greater than zero on day 5 and day 10 ($P \leq 0{\cdot}002$ each). There were no other statically significant changes in exercise parameters (Table 2) on days 5, 10, and 11 compared to day 1, or in lung function parameters on day 11 compared to day 0 (Table 3).

TRAINING GROUP VERSUS CONTROL GROUP

Comparison of values on days 1, 5, and 10

The increase in 6-min walking distance on day 5 and day 10 compared to day 1 was significantly larger in the training group than in the control group ($P<0{\cdot}0001$ each). Repeated measures analysis of variance showed that during the training period (day 1 to day 10) the course of minute ventilation, $\dot{V}O_2$/kg, $\dot{V}O_2$/HR, and Borg Scale was significantly different between groups ($P<0{\cdot}05$ each) (Fig. 2). Specifically, on day 10, the per cent increases in minute ventilation and $\dot{V}O_2$/kg were higher in the training than in the control group ($P<0{\cdot}05$ each). TDI scores were larger on day 5 and day 10 in the training than in the control group ($P<0{\cdot}05$ each).

Comparison of Values on Day 11

On day 11, per cent reductions in lactic acid concentration ($P=0{\cdot}004$), $PaCO_2$ during exercise ($P=0{\cdot}017$), $\dot{V}O_2$/kg, and Borg scale ($P=0{\cdot}0035$) as well as per cent increases in PaO_2

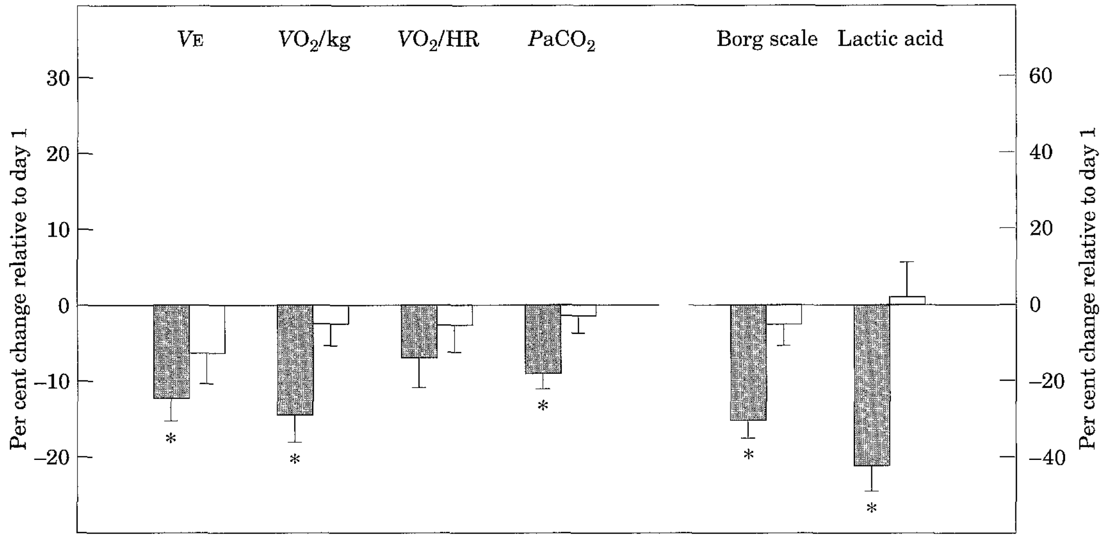

FIG. 3. Mean values and SEM of per cent changes of exercise parameters (cf. Fig. 1) on day 11 compared to day 1. Note that these values were obtained at the same individual walking distance as on day 1. ▨, Training group; □, control group. *Indicates significant ($P<0{\cdot}05$) difference from day 1.

during exercise ($P=0{\cdot}003$) were significantly larger in the training group compared to the control group (Table 2, Fig. 3).

The percent changes in lung function parameters did not differ between the training group and the control group.

In addition, we determined by discriminant analysis the relative strength of the parameters in separating both groups according to their percent changes achieved on day 11. The rank order was: lactic acid, Borg scale and $PaCO_2$. When these three parameters were included in the analysis, other parameters did not add further information.

CORRELATION ANALYSIS IN THE TRAINING GROUP

Within the training group, the absolute ($r=0{\cdot}87$) and the per cent increases ($r=0{\cdot}90$) in 6-min walking distance achieved on days 5 and 10 relative to day 1 were ($P<0{\cdot}0001$) correlated with each other. There were no significant correlations between the per cent increase in walking distance on day 10 and the corresponding changes in ventilatory parameters, blood gases, or Borg scale.

Discussion

This study demonstrates the effectiveness of a short-term exercise training programme during recovery from an acute exacerbation in patients with severe COPD. Compared to control patients, walking distance and maximum minute ventilation were significantly improved after the short- term exercise programme. The benefits became most obvious when ventilation rate, oxygen uptake, Borg scale, and lactic acid were compared between exercise tests performed at the same work load.

Long-term exercise training is a well-established part of pulmonary rehabilitation programmes in patients with stable or moderate COPD (7,8,18,19). It has not been studied, however, to which extent a short-term training protocol supports patient's recovery after an acute exacerbation. This is surprising because in clinical practice patients are often encouraged by physicians to exercise. Indeed, our study provides evidence that a controlled short-term training markedly improves recovery.

As patients were studied after admission to the hospital it was likely that the effects of exercise were superposed onto the effects of continued medical care including standard physical therapy. We accounted for this by inclusion of a control group without exercise. Thus, the control group was an essential part of our study. Since the improvements were much larger in the training than in the control group, our results suggest that the training protocol which was used incorporated more intense exercise than is usual in clinical practice.

The 6-min walking test is a suitable measure of exercise capacity in patients with COPD (12,13,20,21). Indeed, exercise capacity in terms of 6-min walking distance showed the most striking results in our study which may have been favoured by the fact that walking distance was chosen as outcome measure. It is known that the 6-min walking distance can be influenced by learning and motivation. Learning, which has been described for stable COPD, could account for an improvement of about 33% (21) and changes of more than 54 m have been stated to be clinically relevant (20). All but one patient in the training group outran both values at the end of the 10 days period. Therefore, it is unlikely that the increases in 6-min walking distance owed to learning. The maximum improvements demonstrated by the patients in the control group were 79 m and 27%. Therefore, we defined a positive response to the exercise to be about twice these values, i.e. larger than 140 m or 60%, and found 13 of the 15 patients in the training group to be responders. One patient showed an increase by at least 140 m as well as 60%; this patient was among those demonstrating low baseline values (113 m). Patients who showed an increase of less than 140 m showed a lower than average baseline walking distance, and patients who showed an increase of less than 60% showed a higher than average baseline value. These results suggest that a suitable definition of responders should require an absolute change and/or a relative change in walking distance.

It has been suggested that the ability to achieve the anaerobic threshold predicts larger improvements after training (18). In our study, however, the anaerobic threshold was not reached in the majority of tests, similarly to previous data (7,22,23). Probably, the mechanism responsible for the positive effects of exercise was the combination of muscle training below the anaerobic threshold as indicated by lactic acid concentrations, reduced dyspnea as indicated by Borg scale, improved lung function, and increased motivation (24) and coordination.

Lung function parameters showed significant improvements after training; intrathoracic gas volume and residual volume were reduced and FEV_1 was increased. However, changes were small and their clinical significance remains questionable. In addition, TDI scores improved in the training group, which indicates a gain in quality of life through the training protocol. There were no correlations between changes in lung volumes, FEV_1, and exercise capacity. It may be noted that, according to a previous study (13), exercise capacity, lung hyperinflation, and airway obstruction represent three independent factors in patients with stable severe COPD.

The increase in exercise capacity on day 10 was associated with increases in oxygen uptake and minute ventilation. Similar findings have been reported after short-term training in patients with stable COPD (25) which was accompanied by an improvement in mid-expiratory and peak flow rates. The effect of the training program was most obvious when comparing two exercise tests performed at the same work load before and after training. After training, significant reductions in lactic acid concentration, carbon dioxide arterial pressure and oxygen uptake as well as Borg scale and an increase in arterial oxygen pressure occurred, indicating improved metabolic performance at lower exercise levels. The reduction in Borg scale could be related to desensitization of dyspnea (26), the improved respiratory efficiency to the decrease in intrathoracic gas volume (19) and residual volume and the increase in FEV_1.

In summary, our data demonstrate that a controlled short-term exercise training program adds significantly to the recovery after an acute exacerbation in patients with severe COPD.

References

1. European Respiratory Society. ERS consensus statement: optimal assessment and management of chronic obstructive pulmonary disease (COPD). *Eur Respir J* 1995; **8:** 1398–1420.
2. Patessio A, Carone M, Ioli F, Donner CF. Ventilatory and metabolic changes as a result of exercise training in COPD patients. *Chest* 1992; **101**(Suppl 5): 274–278.
3. O'Donnell D, Webb K, McGuire M. Older patients with COPD: benefits of exercise training. *Geriatrics* 1993; **48:** 59–66.
4. Niederman MS, Henderson Clemente P, Fein AM, Feinsilver SH, Robinson DA, Ilowite JS, Berstein MG. Benefits of a multidisciplinary pulmonary rehabilitation program. *Chest* 1991; **99:** 799–804.
5. Wanke Th, Formanek D, Lahrmann H, Brath H, Wild M, Wagner Ch, Zwick G. Effects of combined inspiratory muscle and cycle ergometer training on exercise performance in patients with COPD. *Eur Respir J* 1994; **7:** 2205–2211.
6. ZuWallack R, Patel K, Rardon JZ, Clark III BA, Normandin EA. Predictors of improvement in the 12-minute walking distance following a six-week outpatient pulmonary rehabilitation program. *Chest* 1991; **99:** 805–809.
7. O'Donnell DE, McGuire M, Samis L, Webb KA. The impact of exercise reconditioning on breathlessness in severe chronic airflow limitation. *Am J Respir Crit Care Med* 1995; **152:** 2005–2013.
8. Vale F, Reardon JZ, ZuWallack RL. The long-term benefits of outpatient pulmonary rehabilitation on exercise endurance and quality of life. *Chest* 1993; **103:** 42–49.
9. American Thoracic Society. Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease (COPD) and asthma. *Am J Respir Crit Care Med* 1995; **152:** 77–120.
10. Quanjer PhH. Standardized lung function testing. *Eur Respir J* 1993; **16** (Suppl 6): 5–100.
11. American Thoracic Society. Single breath carbon monoxide diffusing capacity, recommendations for a standard technique. *Am Rev Respir Dis* 1987; **136:** 1299–1307.
12. Kirsten D, Wegner R, Jörres R, Magnussen H. Effects of theophylline therapy withdrawal in severe chronic obstructive pulmonary disease. *Chest* 1993; **104:** 1101–1107.
13. Wegner RE, Jörres RA, Kirsten DK, Magnussen H. Factor analysis of exercise capacity, dyspnoea ratings and lung function in patients with severe COPD. *Eur Respir J* 1994; **7:** 725–729.
14. Mahler DA, Rosiello RA, Harver A, Lentine T, McGovern JF, Daubenspeck JA. Comparison of clinical dyspnea ratings and psychophysical measurements of respiratory sensations on obstructive airway disease. *Am Rev Respir Dis* 1987; **135:** 1229–1233.
15. Beaumont A, Crockroft AM, Guz A. A self paced treadmill walking test for breathless patients. *Thorax* 1987; **42:** 773–778.
16. Bergmeyer HU, Noll F. *Methode der Enzymatischen Analyse*, 3rd edn, 1974, Vol. II, p. 1521.
17. Borg G. Psychophysical basis of perceived exertion. *Med Sci Sports Exerc* 1982; **14:** 377–381.
18. Casburi R, Patessio A. Iolio F, Zanaboni S, Donner CF, Wassermann K. Reductions in exercise lactic acidosis and ventilation as a result of exercise training in patients with obstructive lung disease. *Am Rev Respir Dis* 1991; **143:** 9–18.

19. O'Donnell DE, Webb KA. Exertional breathlessness in patients with chronic airflow limitation. The role of lung hyperinflation. *Am Rev Respir Dis* 1993; **148:** 1351–1357.
20. Redelmeier FA, Bayoumi AM, Goldstein RS, Guyatt GH. Interpreting small differences in functional status: the six minute walk test in chronic lung disease patients. *Am J Respir Crit Care Med* 1997; **155:** 1278–1282.
21. Knox AJ, Morrison JFJ, Muers MF. Reproducibility of walking test results in chronic obstructive airway disease. *Thorax* 1988; **43:** 388–392.
22. Belman MJ, Epstein LJ, Doornbos D, Elashoff JD, Koerner SK Mohsenifar Z. Noninvasive determinations of the aerobic threshold. Reliability and validity in patients with COPD. *Chest* 1992; **102:** 1028–1034.
23. Kanarek D, Kaplan D, Kazemi H. The anaerobic threshold in severe chronic obstructive lung disease. *Bull Eur Physiopath Resp* 1979; **15:** 163–169.
24. LoRusso TJ, Belman MJ, Elashoff JD, Koerner SK. Prediction of maximal exercise capacity in obstructive and restrictive pulmonary disease. *Chest* 1993; **104:** 1748–1754.
25. Carter R, Nicotra B, Clark L, Zinkgraf S, Williams J, Peavler M, Fields S, Berry J. Exercise conditioning in the rehabilitation of patients with chronic obstructive pulmonary disease. *Arch Phys Med Rehabil* 1988; **69:** 118–122.
26. Belman MJ. Exercise in patients with chronic obstructive pulmonary disease. *Thorax* 1993; **48:** 936–946.