Comparison of Effects of Strength and Endurance Training in Patients with Chronic Obstructive Pulmonary Disease

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We determined the effect of different exercise training modalities in patients with chronic obstructive pulmonary disease, including strength training (n = 17), endurance training (n = 16), and combined strength and endurance (n = 14) (half of the endurance and half of the strengthening exercises). Data were compared at baseline, the end of the 12-week exercise-training program, and 12 weeks later. Improvement in the walking distance was only significant in the strength group. Increases in submaximal exercise capacity for the endurance group were significantly higher than those observed in the strength group but were of similar magnitude than those in the combined training modality, which in turn were significantly higher than for the strength group. Increases in the strength of the muscle groups measured in five weight lifting exercises were significantly higher in the strength group than in the endurance group but were of similar magnitude than in the combined training group, which again showed significantly higher increases than subjects in the endurance group. Any training modality showed significant improvements of the breathlessness score and the dyspnea dimension of the chronic respiratory questionnaire. In conclusion, the combination of strength and endurance training seems an adequate training strategy for chronic obstructive pulmonary disease patients.

Keywords: chronic obstructive pulmonary disease; pulmonary rehabilitation; exercise training; skeletal muscle

Exercise training is now considered an essential component of pulmonary rehabilitation in patients with chronic obstructive pulmonary disease (COPD) (1, 2). Although it does not change pulmonary function, exercise training improves exercise capacity and reduces dyspnea. However, there is still no consensus about the optimal training strategy and the mechanisms of improvement (3, 4). Whether the goal of training should be strength, endurance, or both is still under investigation. On the other hand, exercise programs must be maintained because benefits generally disappeared rapidly if exercise is discontinued. The optimal frequency of follow-up sessions after a more intensive start remains uncertain (5, 6).

Lower extremity aerobic training consistently results in an increase in exercise endurance in patients with COPD without evidence of adverse outcome (3). The mechanism by which exercise improves endurance remains unclear, although muscle biopsy studies showing increased skeletal muscle oxidative capacity (capillarity, aerobic enzyme concentration, mitochondrial density) support for a true training effect (7, 8). However, endurance training has little effect on weakness and muscle atrophy, two problems that are common in patients with COPD and that can contribute to their exercise intolerance and poor quality of life.

It has recently been demonstrated that peripheral limb muscle strengths are significantly reduced in COPD patients compared with normal subjects (9); in addition, significant relationships were observed between symptom intensity and muscle strength and between work capacity and muscle strength. These results suggest that muscular weakness is in part responsible for the excessive symptoms and reduced work capacity observed in patients with cardiorespiratory disorders, in addition to the contribution of ventilatory, gas exchange, and circulatory impairments (10, 11). Studies demonstrate the effectiveness of peripheral musculature strength training in athletes and in cardiovascular or neuromuscular diseases (12–14). Because peripheral muscle weakness contributes to exercise limitation in patients with lung disease, greater strength of peripheral muscle after training may reduce perception of fatigue (15–18). Strength training has also been associated with increased skeletal muscle oxidative capacity (15) and may represent a useful addition to training in patients with COPD. However, strength-training programs have only modest effects on submaximal work rate endurance (7, 16).

There are few studies published on peripheral muscle strength training in COPD patients. Clark and colleagues (19) have shown that low-intensity isolated peripheral muscle conditioning with no extra external weight loading was followed by improvements in endurance of individual muscles and in treadmill walking. Simpson and coworkers (20) have reported that 8 weeks of strength training produced an improvement in muscle strength and in submaximal exercise tolerance in patients with COPD. In a recent study, Bernard and associates (21) showed that the addition of strength training to aerobic training was accompanied by a greater improvement in muscle mass and strength than was aerobic training alone, confirming that peripheral muscles may show structural adaptation with an appropriate training regimen despite severe ventilatory impairment.

The aim of this study was to compare the efficacy of endurance, strength, and the combination of strength and endurance exercise training in patients with COPD. Another aim of the study was to assess the outcome of the training intervention after 3 months. Although the study design included a control group, for the purpose of this report and

(*Received in original form July 17, 2001; accepted in final form June 25, 2002*)

Supported by grants from Fondo de Investigaciones Sanitarias (FIS 97/0472) and Consejería de Salud, Junta de Andalucía (96/67), Spain

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This article has an online data supplement, which is accessible from this issue's table of contents online at www.atsjournals.org

Am J Respir Crit Care Med Vol 166. pp 669–674, 2002
DOI: 10.1164/rccm.2107081
Internet address: www.atsjournals.org

to simplify comparisons, data in the control group are not shown.

METHODS

Patients with COPD were recruited for this study. The diagnosis was based on smoking history and on pulmonary function tests showing irreversible bronchial obstruction defined by less than 12% and less than a 200-ml increase of initial FEV_1 after administration of salbutamol (400 μg via a metered dose inhaler) (22, 23). The training program conducted at our institution was developed in 3 alternate days each week for 12 weeks. Subjects were randomly assigned to endurance training alone, strength training alone, combined training modality (endurance and strength), or a control group.

The endurance training consisted of 40-minute leg exercises on a calibrated ergocycle. The work rate corresponding to 70% of the peak work rate achieved during the baseline incremental exercise test was selected as the target training intensity (24). The strength-training program included different exercises, which were performed with the following weight lifting procedures: (*1*) "chest pull" (mainly for strengthening of the latissimus dorsi), (*2*) "butterfly" (mainly for the pectoralis major muscle), (*3*) "neck press" (mainly for the triceps brachii and deltoid), (*4*) "leg flexion" (mainly for the biceps femoris and grastrocnemius), and (*5*) "leg extension" (mainly for the quadriceps femoris). The weight lifting exercises were performed with gymnastic apparatus. The patients performed four series of six to eight repetitions for each of the exercises included in the strength-training program at a workload of 70 to 85% of the one repetition maximum. This test was repeated each 2 weeks for new adjustment of the workload. The combined training modality included two series of six to eight repetitions of the five weight-lifting procedures plus 20 minutes of cycling.

Subjects were evaluated on 2 consecutive days at baseline, at the end of the 12-week training program, and at 12 weeks after training. Spirometry was measured with a pneumotachograph (25). Static lung volumes were determined in a constant-volume whole-body plethysmograph. Arterial blood was sampled at the radial artery while the patients breathed room air for at least 1 hour in the sitting position (26).

Weight-lifting capacity was measured as the heaviest weight that could be lifted once throughout the complete range of movement (one repetition maximum). Testing took place on 2 separate days, and the heaviest weight lifted was recorded as the pretraining value (12, 27). Progressive exercise testing was performed to a symptom-limited maximum on an electronically braked cycle ergometer. Patients began with a 3-minute period of unloaded pedaling at 60 rpm followed by 1-minute stepwise increments of 10 W. The concentrations of expired O_2 and CO_2 were analyzed breath by breath with a zirconium dioxide-cell O_2 analyzer and an infrared CO_2 analyzer, respectively (28). A submaximal endurance cycling test was performed on a calibrated cycle ergometer at 70% of the maximum power output achieved during the baseline incremental exercise test. Other measurements included the shuttle-walking test in which patients were requested to walk between two cones placed 10 m apart (the end point was when the patient was unable to maintain the required speed) (29), chronic breathlessness using the modified Baseline Dyspnea Index (30), and health-related quality of life using a Spanish-validated version of the Chronic Respiratory Questionnaire (31, 32). The analysis of variance for repeated measures was used for within-group and between-group comparisons. Additional information on the methods can be accessed in the online data supplement.

RESULTS

Seventy-two patients with moderate to severe obstruction in a stable phase of COPD were studied (data of 18 control subjects are not shown). Of the 54 patients assigned to training interventions, seven patients (one in the strength group, two in the endurance group, and four in the combined group) failed to complete the program because of exacerbations of COPD requiring hospitalization (n = 4) or a lack of motivation for exercise training (n = 3). Baseline characteristics of the remaining 47 patients, who constituted the study population, are presented in Table 1. Patients had moderate to severe airflow obstruction. No differences in age, sex distribution, or pulmonary function were found in patients belonging to the three study groups.

Effects of Exercise Training on Pulmonary Function and Peak Exercise Parameters

After the training period, no significant changes in pulmonary function tests were seen in any of the groups. Physiologic parameters obtained at peak exercise are shown in Table 2. At the end of 12-week training, changes in all parameters as compared with pretraining levels were statistically significant in only the endurance group. However, when comparing increments in these parameters in each training modality, there were no significant differences (Table 2). Three months after the training intervention, there were no significant changes in pulmonary function tests. All other within-group and between-group comparisons were not statistically significant except for a decrease in maximal work load (watts) (W_{max}) in the endurance group at the post-training evaluation.

Effects of Exercise Training on Exercise Capacity

After training, the improvement in the shuttle-walking test was only statistically significant in the strength-training group (from 457 ± 150 to 561 ± 204 m, $p < 0.015$). In the other training modalities, improvements in the distance walked were not significant. Comparisons between the three study groups were not significant either both at the end of the 12-week training period and at 12 weeks after training (Table 3).

At the end of the training period and at 12 weeks after training, all patients in the three groups showed significant increases in the duration of endurance testing as compared with

TABLE 1. PATIENT CHARACTERISTICS

	Strength Training (*n = 17*)	Endurance Training (*n = 16*)	Strength + Endurance (*n = 14*)
Age, yr	66 ± 6	66 ± 8	60 ± 9
Sex, M/F	14/3	14/2	13/1
FVC, L	2.54 ± 0.49	2.50 ± 0.6	2.38 ± 0.55
FVC, % predicted	72 ± 13	71 ± 19	67 ± 13
FEV_1, L	1.12 ± 0.4	1.13 ± 0.34	0.93 ± 0.4
FEV_1, % predicted	40 ± 14	41 ± 11	33 ± 12
FRC, %	161 ± 42	172 ± 48	173 ± 34
TLC, %	113 ± 16	120 ± 28	117 ± 20
Pa_{O_2}, mm Hg	71 ± 7	65 ± 10	73 ± 9
Pa_{CO_2}, mm Hg	44 ± 7	45 ± 7	44 ± 6

Definition of abbreviation: TLC = total lung capacity (% of predicted values).
Values are mean ± SD.

TABLE 2. PHYSIOLOGIC PARAMETERS AT PEAK EXERCISE BEFORE AND AFTER DIFFERENT TRAINING MODALITIES

	VO_{2max} (*L/min*)	VO_{2max} (*% predicted*)	W_{max} (*W*)	W_{max} (*% predicted*)	VE_{max} (*L/min*)
Pretraining (t0)					
Strength	1.3 ± 0.52	66 ± 20	50 ± 19	35 ± 13	39 ± 15
Endurance	1.32 ± 0.4	63 ± 17	39 ± 18	28 ± 13	36.3 ± 8
Combined	1.26 ± 0.26	61 ± 9	41 ± 16	30 ± 13	38.1 ± 8
End 12-week training (t1)					
Strength	1.43 ± 0.43	75 ± 18	55 ± 20	39 ± 15	42.6 ± 14
Endurance	1.48 ± 0.44*	70 ± 18*	50 ± 18*	35 ± 13*	42 ± 11*
Combined	1.34 ± 0.26	64 ± 10	46 ± 9	33 ± 8	38.4 ± 9
12 weeks after training (t2)					
Strength	1.3 ± 0.43	68 ± 20	48 ± 20	34 ± 14	40.6 ± 15
Endurance	1.41 ± 0.32	67 ± 17	45 ± 16†	31 ± 12†	40 ± 13
Combined	1.24 ± 0.39	58 ± 12	43 ± 13	32 ± 10	35.7 ± 10
Changes t1 versus t0					
Strength	0.13 ± 0.35	10 ± 20	5 ± 12	4 ± 9	3.6 ± 11.6
Endurance	0.15 ± 0.28	7 ± 15	11 ± 12	8 ± 9	5.6 ± 8.2
Combined	0.08 ± 0.18	4 ± 11	5 ± 17	4 ± 12	0.3 ± 6
Changes t2 versus t1					
Strength	−0.14 ± 0.26	−8 ± 16	−7 ± 8	−5 ± 6	−2.6 ± 8.6
Endurance	0 ± 0.28	1 ± 12	−7 ± 11	−6 ± 8	0 ± 2.9
Combined	0 ± 0.24	−5 ± 12	−4 ± 7	−2 ± 5	0.2 ± 5.9

Definition of abbreviation: W_{max} = maximal work load (watts).
Values are mean ± SD.
p = NS for all other within-group and between-group comparisons.
* $p < 0.05$ before training versus the end of 12 weeks of training.
† $p < 0.03$ after training versus the end of 12 weeks of training.

pretraining values. However, increases in pretraining versus end of 12-week training obtained in the endurance group (33.6 ± 20.6 minutes) were significantly higher than those observed in the strength group (8.3 ± 15.9 minutes) ($p < 0.001$) but were of similar magnitude than those in the combined training group (24 ± 17 minutes), which in turn were significantly higher ($p < 0.017$) than those in the strength group (Table 3). However, between-group comparisons of decreases observed at the post-training assessment as compared with end of 12-week training were not significant.

TABLE 3. EXERCISE PERFORMANCE AND MUSCLE STRENGTH BEFORE AND AFTER DIFFERENT TRAINING MODALITIES

	Shuttle Walking Test (*m*)	Endurance Test (*minutes*)	Strength Measurements (*kg*)				
			Chest Pull	Butterfly	Neck Press	Leg Flexion	Leg Extension
Pretraining, t0							
Strength	457 ± 150	35.3 ± 22	39 ± 10	16 ± 5	21 ± 5	15 ± 5	36 ± 13
Endurance	457 ± 172	33.4 ± 20	43 ± 8	19 ± 4	21 ± 4	15 ± 5	39 ± 8
Combined	434 ± 141	24.9 ± 20	38 ± 10	16 ± 5	22 ± 4	17 ± 6	36 ± 11
End of 12 weeks of training, t1							
Strength	561 ± 204*	43.6 ± 21†	55 ± 9¶	28 ± 6¶	30 ± 7¶	31 ± 6¶	55 ± 11¶
Endurance	501 ± 214	67 ± 21†	48 ± 10¶	22 ± 8¶	22 ± 6¶	20 ± 6¶	47 ± 9¶
Combined	493 ± 155	48.9 ± 29†	53 ± 9¶	25 ± 6¶	30 ± 6¶	32 ± 5¶	55 ± 10¶
12 Weeks after training, t2							
Strength	532 ± 184	45.1 ± 18†	52 ± 8¶	23 ± 7¶	27 ± 6¶	27 ± 6¶	53 ± 13¶
Endurance	479 ± 173	66.6 ± 26†	46 ± 9¶	22 ± 4¶	22 ± 4¶	22 ± 8¶	43 ± 14¶
Combined	498 ± 193	42 ± 23†	48 ± 8¶	20 ± 5¶	26 ± 5¶	28 ± 5¶	51 ± 9¶
Changes t1 versus t0							
Strength	104 ± 158	8.3 ± 15.9	16 ± 6‖	12 ± 4‖	8 ± 3‖	16 ± 5‖	19 ± 8‖
Endurance	39 ± 99	33.6 ± 20.6‡	5 ± 3	3 ± 6	1 ± 3	5 ± 4	8 ± 6
Combined	59 ± 145	24 ± 17§	16 ± 7**	9 ± 4**	8 ± 5**	14 ± 5**	19 ± 5**
Changes t2 versus t1							
Strength	−29 ± 97	−0.8 ± 13	−3 ± 4††	−5 ± 3††	−3 ± 4	−3 ± 6††	−2 ± 6
Endurance	−49 ± 148	−6.5 ± 13.7	1 ± 2	−1 ± 2	−0 ± 2	3 ± 8	−2 ± 9
Combined	−2 ± 97	−8 ± 22.6	−4 ± 3‡‡	−4 ± 4‡‡	−4 ± 3††	−4 ± 4‡‡	−2 ± 5

Values are mean ± SD.
Shuttle-walking test: * $p < 0.015$ before versus the end of 12 weeks of training, p = NS for all other within- and between-group comparisons.
Endurance test: † $p < 0.05$ before versus end of 12 weeks of training and before versus after training; ‡ $p < 0.001$ endurance versus strength groups and § $p < 0.01$ combined modality versus strength.
Strength test: ¶ $p < 0.05$ before versus end of 12-week training and before versus after training; ‖ $p < 0.001$ strength versus endurance groups and ** $p < 0.01$ combined modality versus endurance; †† $p < 0.05$ strength versus endurance groups and ‡‡ $p < 0.05$ combined modality versus endurance.

TABLE 4. CHANGES IN DYSPNEA AND HEALTH-RELATED QUALITY OF LIFE BEFORE AND AFTER DIFFERENT TRAINING MODALITIES

	Baseline Dyspnea Index (*Score*)			Chronic Respiratory Questionnaire (*Score*)			
	Magnitude of Task	Magnitude of Effort	Functional Impairment	Dyspnea	Fatigue	Emotion	Mastery
Pretraining, t0							
Strength	1.6 ± 0.6	1.7 ± 0.7	1.7 ± 0.9	3.4 ± 0.7	4.1 ± 1.2	4.3 ± 1.1	5 ± 1.1
Endurance	2.1 ± 0.9	2.2 ± 0.9	1.9 ± 0.9	3.5 ± 1	4.6 ± 1.5	4.8 ± 1.5	5.1 ± 1.5
Combined	1.9 ± 0.8	2.1 ± 0.9	2.2 ± 1.1	3.6 ± 1.3	5.1 ± 0.9	5.2 ± 0.7	5.6 ± 1.3
End of 12 weeks of training, t1							
Strength	2.1 ± 0.8*	2.4 ± 0.9*	2.1 ± 1.1*	4.2 ± 1.1*	5 ± 1*	5.1 ± 0.9*	5.4 ± 1
Endurance	2.4 ± 0.7*	2.6 ± 0.6*	2.7 ± 0.8*	4.3 ± 1.1*	5.1 ± 1*	4.9 ± 1.1	5.4 ± 1.1
Combined	2.4 ± 0.8*	2.6 ± 1.1*	2.5 ± 1.2*	4.3 ± 1.2*	5.5 ± 0.8	5.8 ± 0.6*	5.9 ± 1.1
12 Weeks after training, t2							
Strength	2.1 ± 1*	2.4 ± 0.8*	2.1 ± 1*	4.4 ± 1.3*	4.8 ± 1.1*	5.2 ± 0.9*	5.4 ± 1
Endurance	2.5 ± 0.5*	2.6 ± 0.8*	2.8 ± 0.8*	4.5 ± 1*	5.2 ± 1.2*	5.1 ± 1.1	5.4 ± 0.8
Combined	2.6 ± 1*	2.6 ± 1*	2.5 ± 1.1*	4.6 ± 1.1*	5.4 ± 0.7	6 ± 0.6*	6 ± 0.8

Values as mean ± SD.
* $p < 0.05$ before versus the end of 12 weeks of training and before versus after training.

Effects of Exercise Training on Peripheral Muscle Strength

At the end of the training period and at 12 weeks after training, all patients in the three groups showed statistically significant increases in the strength of the muscle groups measured in the five exercises, as shown in Table 3. In the endurance group, increases in the strength measures involving the upper extremities were lower compared with increases in the strength measures involving the lower extremities. On the other hand, increases in pretraining versus the end of 12-week training obtained in the strength group were significantly higher than those observed in the endurance group but were of similar magnitude to those in the combined training group, which in turn showed significantly higher increases than subjects in the endurance-training group. There were no statistically significant differences in the increases in muscle strength between the strength-training modality and the combined group except for pectoralis major (butterfly) (12 ± 4 versus 9 ± 4 kg, $p < 0.017$) (Table 3). On the other hand, decreases in muscle strength observed at 12 weeks after training as compared with the end 12-week training were significantly greater in the strength group as compared with the endurance group for latissimus dorsi (chest pull), pectoralis major (butterfly), and biceps femoris/gastrocnemius (leg flexion). That reduction in peripheral muscle strength of the combined group was comparable to that seen in the strength group, with no significant differences existing between them.

Effects of Exercise Training on Breathlessness and Quality of Life

As shown in Table 4, there was a significant effect of any modality of exercise training on the breathlessness score and on the dyspnea dimension of the chronic respiratory questionnaire. In other dimensions of health status, the strength group showed significant improvements in both fatigue and emotion, whereas statistically significant improvements were observed only in the dimension of fatigue for the endurance group and in the dimension of emotion for the combined modality group. Although differences between groups were not observed, improvements in the dyspnea index and dyspnea dimension of the chronic respiratory questionnaire stayed significant after 3 months of exercise training in all patients. However, as compared with pretraining, the patient's feeling of control over the disease (mastery) had remained unchanged in all training modalities.

DISCUSSION

This study confirms the beneficial effects of the three modalities of exercise training (strength, endurance, or combined) on dyspnea and quality of life in patients with COPD. Improvement of these parameters persisted at 3 months after the training intervention. Strength training was well tolerated and was superior to endurance to improve muscle strength. Endurance training was superior to strength to improve submaximal exercise tolerance, and the combined modality produced improvements in peripheral muscle strength and endurance comparable to those obtained by each modality alone. The combined group acquired most of the benefits of each intervention and seems an optimal strategy for patients with COPD. These results may therefore contribute to optimizing training and to provide guidance for the design of rehabilitation exercise programs.

Exercise intolerance is often the COPD patient's chief complaint. There is accumulating evidence that the skeletal muscles (most importantly, the muscles of deambulation) do not function normally and that this dysfunction contributes to exercise intolerance (7). In a recent study in which needle biopsies of the vastus lateralis before and after endurance training were obtained (33), patients with COPD showed a reduced ability to adapt to endurance training reflected in lower capacity to synthesize the antioxidant, reduced glutathione. The cause of physical impairment in COPD has received increasing attention. It has been shown that dynamic hyperinflation reduces the ability to increase tidal volume during exercise in patients with COPD and contributes importantly to dyspnea and exercise intolerance (34, 35). Reduced diaphragm pressure-generating capacity during exhaustive exercise in patients with COPD is secondary to the development of dynamic hyperinflation rather than to an inhibition of central drive (36). In addition, improvement in exercise endurance with hyperoxia has been explained by a combination of reduced ventilatory demand, a decrease in end-expiratory volume, and dyspnea alleviation (37). It has been recently suggested that the addition of domiciliary noninvasive positive pressure ventilation to an exercise-training program in severe COPD may produce greater benefits in exercise tolerance and quality of life than after training alone (38).

On the other hand, extensive deconditioning is a major contributor to the muscle dysfunction seen in COPD patients. In addition to using exercise training in motivating patients toward a higher level of activity and desensitization to dyspnea (39), rigorous programs of endurance training are primarily of value because they are capable of inducing physiologic changes in muscles of ambulation that improve exercise tolerance in patients with both moderate and severe COPD (40–43). The majority of established exercise programs are based on endurance training of the lower limbs with different exercise modalities, such as walking, treadmill, and stationary bicycle. Although exercise rehabilitation programs have systematically omitted activities of strength training primarily because of fear of an abrupt increase in heart rate and arterial pressure associated with isometric contractions in small muscle groups, recent studies (19–21), including these findings, have shown that strength training is beneficial and well tolerated as well. Moreover, in patients with mild COPD, Clark and colleagues (18) identified reduced isokinetic muscle function as compared with healthy subjects and showed that intervention with weight training was effective in countering this deficit.

Some aspects of this study deserve to be mentioned. Data based on small samples should be interpreted taking this limitation into account, and further studies with a larger number of patients in each training modality group will help to confirm these findings. In this respect, the absence of statistically significant differences in submaximal exercise capacity between the endurance-training group (33.6 minutes) and the combined training modality group (24 minutes) was probably caused by a type II error as a β level of 0.20 may not have been sufficiently high to show equivalence between treatment groups. Changes in muscle mass were not measured as opposed to the study of Bernard and colleagues (21). These authors showed that the addition of strength training to aerobic training was associated with significantly greater increases in the thigh muscle cross-sectional area measured by computed tomographic scanning than in the aerobic group, but in this study, a strength-training group was lacking.

After training, the improvement in the shuttle-walking test was only statistically significant in the strength-training group, whereas in the endurance- and combined-training modalities, improvements in the distance walked were not significant. However, between-group differences were not found. Atrophy of type II fibers have been shown in cross-sectional areas of muscle biopsies in patients with COPD (44). On the other hand, strength training in healthy subjects results in selective hypertrophy of type II fibers (12, 27), which are mainly recruited for explosive effort. Because of this effect, it may be possible that strength training might have a greater effect on the shuttle-walking test. It is incremental in nature and therefore more a measure of exercise capacity than of endurance. It has been shown, however, that assessing patient performance during a 6-minute walking test is improved when factors other than the distance walked (including endurance capacity, the pattern of heart rate, perceived symptoms, and impairment of oxygen transport) are also measured (45).

These results suggest that there is a certain degree of specificity in the training response as patients in the combined training modality improved muscle strength and endurance at comparable levels than in the training modalities of strength and endurance alone, but in a significantly higher magnitude in strength compared with the endurance-training modality alone as well as in endurance compared with the strength-training modality alone. Moreover, in the endurance-training modality, increases in the strength measures involving the upper extremities were lower compared with increases in the strength measures involving the lower extremities and also markedly lower (and probably with little clinical significance) than those obtained for the lower extremities in the strength-training group and in the combined-training modality. This may be explained by different factors, such as general improvement in muscle function after a regular program of endurance training, the effect of calisthenic exercises involving the upper extremities performed in the warm-up sessions (46), or isometric contractions of the muscles of the upper extremities when leaning arms against handlebars during cycling.

Although rehabilitation improves exercise tolerance and quality of life and may also benefit aspects of cognitive performance (47) in patients with COPD, it is not known whether these improvements are related to different modalities of exercise training. In the three training modalities tested in this study, improvements in different dimensions of the baseline dyspnea index and the chronic respiratory questionnaire were obtained. However, there were no differences when comparing increments in the scales of these instruments in each training modality. Bernard and colleagues (21) concluded that the addition of strength training to aerobic training achieved an increase in peripheral muscle strength but did not offer additional advantages as far as quality of life. Perhaps changes in peripheral muscle function in our study are not large enough to be reflected in the tests used, or perhaps these are not sensitive enough to capture said changes. Another possible explanation of the dissociation could be the relative specificity of the training stimulus so that greater function improvements take place in those tests using trained movements. This would imply that these movements should be similar to the most relevant activities in the patient's daily life. This way perhaps we could achieve greater improvement in quality of life. Another explanation could be lack of adjusting the training modality to individualized needs. It is likely that according to baseline characteristics (e.g., severe muscle atrophy) some patients with COPD could be benefited more by a program designed to improve strength and thus would gain more benefits in quality of life.

Exercise programs should be maintained because benefits disappeared if exercise is discontinued. However, benefits seem to continue for some time, regardless of whether follow-up training sessions are incorporated in the long-term management of patients with COPD. In a critical review and meta-analysis of studies evaluating the long-term effects of pulmonary rehabilitation (48), significant summary effect sizes (computed by pooling standardized mean differences as well as raw mean differences) were found up to 9 months after finishing pulmonary rehabilitation for maximal exercise capacity and 6-minute walking distance. In this critical review, however, patients with asthma and COPD were included. In our study, the comparisons between the end of 12 weeks of training and 3 months after the training intervention should be interpreted with caution. At 3 months after the training intervention, endurance parameters hardly varied in any of the training modality groups, whereas a greater loss in muscle strength was observed in the strength and combined training modality groups compared with the endurance-training group. There was no loss in strength in the endurance group because gain in strength during the training period was significantly lower than in the other two groups.

In summary, combined exercise training, including strength and endurance, seems more physiologically complete, achieving significant improvements in strength and endurance that were comparable to those obtained by each specific training program alone. These effects, however, were similar in respect to amelioration of dyspnea and benefits in quality of life. Three months after the training intervention, peripheral muscle strength seemed to diminish more rapidly than endurance gains, but the benefits of any training modality on endurance, breathlessness, and quality of life remained almost unchanged.

Acknowledgment: The authors are indebted to Marta Pulido, M.D., for editing the manuscript and editorial assistance.

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