

Effect of three exercise programs on patients with chronic obstructive pulmonary disease

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We compared the effect of three different exercise programs on patients with chronic obstructive pulmonary disease including strength training at 50-80% of one-repetition maximum (1-RM) (ST; N = 11), low-intensity general training (LGT; N = 13), or combined training groups (CT; N = 11). Body composition, muscle strength, treadmill endurance test (TEnd), 6-min walk test (6MWT), Saint George's Respiratory Questionnaire (SGRQ), and baseline dyspnea (BDI) were assessed prior to and after the training programs (12 weeks). The training modalities showed similar improvements ($P > 0.05$) in SGRQ-total (ST = $13 \pm 14\%$; CT = $12 \pm 14\%$; LGT = $11 \pm 10\%$), BDI (ST = 1.8 ± 4 ; CT = 1.8 ± 3 ; LGT = 1 ± 2), 6MWT (ST = 43 ± 51 m; CT = 48 ± 50 m; LGT = 31 ± 75 m), and TEnd (ST = 11 ± 20 min; CT = 11 ± 11 min; LGT = 7 ± 5 min). In the ST and CT groups, an additional improvement in 1-RM values was shown ($P < 0.05$) compared to the LGT group (ST = 10 ± 6 to 57 ± 36 kg; CT = 6 ± 2 to 38 ± 16 kg; LGT = 1 ± 2 to 16 ± 12 kg). The addition of strength training to our current training program increased muscle strength; however, it produced no additional improvement in walking endurance, dyspnea or quality of life. A simple combined training program provides benefits without increasing the duration of the training sessions.

Key words: Chronic obstructive pulmonary disease; Exercises; Rehabilitation; Strength training

Publication supported by FAPESP.

Received December 4, 2007. Accepted January 15, 2009

Introduction

Skeletal muscle dysfunction is one of the most serious extrapulmonary manifestations of chronic obstructive pulmonary disease (COPD). This dysfunction limits exercise tolerance and is associated with complaints of fatigue and dyspnea even after minimal exertion (1). Deconditioning is almost certainly a contributing factor, given that patients with COPD have symptom-limited exercise tolerance, which compromises their cardiac fitness and further limits their exercise tolerance, leading to exacerbation of their symptoms after exertion (1).

Exercise programs aiming to restore muscle function could result in outcomes that are more favorable than those achieved with simple conditioning programs. The efficacy of pulmonary rehabilitation in COPD patients has been well established (2). Endurance training of the lower extremities, resulting in greater exercise tolerance, is an important component of these programs (3). However, the effect of endurance training on muscle weakness and wasting is less consistent (1). In addition, it is often difficult for COPD patients to perform high-intensity exercises due to dyspnea or hypoxemia (4). It has been reported that the increase in muscle strength obtained after strength train-

ing is higher than that obtained with endurance training (5), but the importance of this increase, mainly regarding the health-related quality of life in COPD patients, is unclear.

Pulmonary rehabilitation should be incorporated into COPD treatment strategies as part of long-term disease management (3). However, some barriers to treatment adherence by COPD patients include the monotony of exercise programs and the limited exercise tolerance. In addition, there are a limited number of structured programs available. Therefore, the efficacy of making training programs accessible to a greater number of COPD patients warrants further investigation.

Some randomized controlled clinical trials have shown that high-intensity interval training results in benefits related to dyspnea, health-related quality of life and exercise capacity, similar to those obtained by continuous endurance exercise (6,7). However, a recent systematic review concluded that there is a lack of evidence that high-intensity exercise is superior to low-intensity exercise (8). Therefore, further studies are necessary to investigate this hypothesis.

Low-intensity exercise programs are easy to implement and have been used as the standard rehabilitation program at the Botucatu Medical School for many years. Their effects on exercise tolerance and the sensation of dyspnea have been previously described (9,10). Low-intensity training (aerobic and strength) is well tolerated by COPD patients and is particularly suited to those with the severe form of the disease (11). In this context, we hypothesized that a combination of strength training (ST) and our current program of low-intensity general training (LGT) could result in additional benefits to COPD patients. Thus, the aim of the present study was to compare three different physical exercise programs in patients with COPD: moderate- to high-intensity ST, LGT, and combined training (CT).

Patients and Methods

Patients and design

Fifty-one consecutive patients admitted to the Rehabilitation Center of Paulista State University (UNESP), School of Medicine at Botucatu, SP, Brazil, were invited to participate in the study. Patients were included in the study if they met the global initiative for chronic obstructive lung disease criteria for a diagnosis of COPD (12). Patients considered clinically unstable (i.e., who presented changes in medication dose or frequency, disease exacerbation, or hospital admissions in the preceding 8 weeks) were excluded. The occurrence of exacerbation was evaluated by self-reporting during clinic visits and was confirmed by reviewing the medical record. The following factors were also considered grounds for exclusion: chronic diseases

such as malignant disorders, cardiovascular disease, insulin-dependent diabetes mellitus, osteoarthritis, use of oral corticosteroids, treatment non-compliance, and inability to perform the lung function test.

In groups of 3, patients were randomly assigned to one of the training modalities (ST, LGT, or CT). Each program consisted of three 1-h sessions per week over a period of 12 weeks.

Four patients did not complete the baseline evaluation and were excluded from the study. Therefore, the final sample was composed of 47 patients. Upon the arrival of each subject, the purpose and procedures involved in the study were explained and written informed consent was obtained. All procedures were approved by the Research Ethics Committee of the UNESP School of Medicine at Botucatu.

Pulmonary function and arterial blood gas analysis

Spirometry was performed before and after 15 min of inhalation of 400 mg salbutamol (Med-Graph 1070; Medical Graphics Corporation, USA). Forced expiratory volume in the first second is reported as liters, as percent forced vital capacity and as percent of reference values (13). Blood was drawn from the brachial artery with the patients at rest and breathing room air. Arterial oxygen tension and carbon dioxide tension (PaO_2 and PaCO_2) were determined with a blood analyzer (Stat Profile 5 Plus; Nova Biomedical, USA).

Nutritional assessment

Body weight and height were measured, and body mass index ($\text{BMI} = \text{weight}/\text{height}^2$) was calculated. Body composition was evaluated using bioelectrical impedance (BIA 101A; RJL systems, USA). Resistance was measured on the right side of the body in the supine position. Fat-free mass (FFM, kg) was calculated using a group-specific regression equation developed by Kyle et al. (14). The FFM index ($\text{FFMI} = \text{FFM}/\text{height}^2$) was also calculated. Lean body mass depletion was defined as an $\text{FFMI} < 15 \text{ kg}/\text{m}^2$ for women and $< 16 \text{ kg}/\text{m}^2$ for men (15).

Health-related quality of life and dyspnea

The Brazilian versions of the Saint George's Respiratory Questionnaire (SGRQ) and of the Airways Questionnaire 20 (AQ20) were used to evaluate patient health-related quality of life (16,17) and the results are reported as percent (16,17). A similarly modified version of the baseline dyspnea index (BDI) (18), developed by Mahler et al. (19) was used to evaluate baseline dyspnea. Clinically significant improvement was defined as a decrease of $\geq 4\%$ in the total SGRQ score (20).

Respiratory pressures, handgrip and peripheral muscle strength

We measured maximal inspiratory pressure by the method of Black and Hyatt (21). Forearm muscle strength was measured on the basis of handgrip strength of the dominant hand measured with a dynamometer (TEC-60; Technical Products, USA).

Peripheral muscle strength was assessed by the determination of the one-repetition maximum (1-RM). The agreed convention for 1-RM is the heaviest weight that can be lifted throughout the complete range of motion related to the exercise performed. The 1-RM was assessed for exercises carried out on weight training equipment (22): leg press (quadriceps, gluteus, hamstrings, and calf muscles), leg extension (quadriceps), lat pull-down (latissimus dorsi, trapezius, and biceps), bench press (pectorals major and triceps), seated rowing (latissimus dorsi, trapezius and triceps), triceps pulley (triceps), and biceps curl (biceps). A warm-up of 3-5 min followed by 10 repetitions with a light load was performed prior to the test in order to minimize the effects of learning. The 1-RM test was initiated at a weight near the suspected maximum to minimize repetition fa-

tigue. All participants attained the 1-RM within 3-5 attempts. Two to 3 min of rest were allowed between repetitions. The Valsalva maneuver was avoided, and the proper exercise performance technique for each muscle group was emphasized.

Exercise tolerance

A maximal exercise tolerance test was performed. The test consisted of symptom-limited graded exercise on a treadmill with patient breathing room air and its objective was to determine possible cardiovascular contraindications of exercise programs using a modified Bruce protocol (23). A constant workload treadmill test, used to assess endurance capacity, was performed on a separate day, subsequent to that on which the incremental exercise test was performed. After 3 min of warm-up, the treadmill was set at 80% of the maximum inclination and at the speed achieved during the baseline maximal incremental exercise test. Patients were instructed to walk at 80% of their maximum power output (i.e., exercise intensity probably above the lactate threshold) for as long as they could.

A 6-min walk test (6MWT) was also conducted after a

Table 1. Low-intensity general training.

Walking

Indoor walking: Walking for 30 min at a self-determined velocity.

Parallel bar

Thoracic and upper-limb strength training: Patient in upright position with both hands on the parallel bar. Bringing the chest to the bar and returning to the initial position using the thoracic and upper-limb muscles (25 repetitions).

Squat: Patient in upright position with both hands on the parallel bar. Squatting to approximately 50° of hip and knee flexion and returning to the initial position (15 repetitions).

Diagonal upper-limb strength training: Patient in upright position. Raising one arm diagonally without any added weight (20 repetitions/arm).

Free weights

Diagonal upper-limb strength training: Patient in upright position. Raising one arm diagonally while holding dumbbells (20 repetitions/arm).

Biceps curl: Patient lying comfortably on a mat, holding dumbbells with the palms of the hands turned upward. Flexing the forearms to approximately 90° and returning to the initial position (25 repetitions).

Shoulder flexor strength training: Patient lying comfortably on a mat, holding dumbbells with the palms of the hands turned down. Flexing the shoulders to approximately 45° with the ground with forearm extension and returning to the initial position (25 repetitions).

Pectoralis strength training: Patient lying comfortably on a mat with shoulders abducted, holding dumbbells with the palms of the hands turned upward. Horizontal adduction of the arms to the medial line of the trunk and returning to the initial position (25 repetitions).

Triceps curl: Patient lying comfortably on a mat, arms and shoulders flexing to 90° and forearm in total flexing and neutral position, holding dumbbells. Extending the forearm completely and slowly returning to the position near the head (25 repetitions each arm).

Mat work

Hip abductor strength training: Patient in lateral decubitus with the leg closest to the ground in knee flexion to 90° and the other leg in knee extension. Abducting the superior hip in knee extension and returning to the initial position (25 repetitions for each leg).

Hip and lumbar extensor strength training: Patient on all fours. Performing hyperextension of the hip in one of the lower limbs and returning to the initial position (25 repetitions for each leg).

Abdominal exercises: Patient in supine position with the knees in 90° flexion and the hips in 45° flexion. Tightening of abdominal muscles, with eyes fixed on the navel, holding for 2 s. Return to starting position (50 repetitions).

few minutes of practice, with the patients being instructed to walk on an oval 33.12-m course, attempting to cover the greatest distance possible in 6 min. A research assistant timed the walk, and standardized verbal encouragement was given to each patient. Peripheral oxygen saturation (SpO₂) was monitored throughout the test using a pulse oximeter (Ohmeda Biox 3700; Ohmeda, USA). Patients who presented hypoxia at baseline, as well as those whose SpO₂ decreased to <85% during the test, were given oxygen by a physical therapist, who wheeled an oxygen tank in a handcart alongside the patient. Before and after the test, the following data were obtained: SpO₂, heart rate, respiratory rate, dyspnea (Borg), and blood pressure. The distance covered was measured in meters. The minimal clinically significant improvement was also recorded (≥ 54 m) (24).

Exercise training programs

The ST consisted of seven exercises performed on weight training machines. Patients were submitted to three sets of 12 repetitions with a 2-min rest between sets and with a workload at 50-80% of that achieved on the 1-RM test. The 1-RM test was repeated every 3 weeks to re-establish the workload.

As can be seen in Table 1, the LGT consisted of 30 min of walking at a self-determined intensity and an additional 30-min of low-intensity resistance training with free weights, on exercise mats and on parallel bars. The LGT performed in our study corresponds to three metabolic equivalents of energy expenditure and can be classified as a low-intensity exercise program according to the American College of Sports Medicine recommendations for older adults (25,26). The number of repetitions used in the LTG was based on physiologic endurance principles, including a high number of repetitions with a low load (26). The CT consisted of 30 min of ST with only two series of 8 repetitions with a workload at 50-80% of 1-RM. The remaining 30 min were devoted to LGT at half the volume (i.e., 15 min of walking at a self-determined intensity and an additional 15 min at half the number of repetitions of low-intensity resistance training with free weights, on exercise mats and on parallel bars). All exercise regimens were conducted in 60-min sessions, which included pacing for breathing.

Statistical analysis

Data were analyzed statistically using the SigmaStat (version 2.03) statistical software (SPSS, Inc., USA). The sample size, calculated taking into consideration minimal clinically important differences in health-related quality of life (SGRQ total score $\geq 4\%$), was N = 10 for each training group. The following tests were carried out: Kolmogorov-

Smirnov to assess the normality of variable distribution; descriptive analysis of data with values reported as means \pm SD; repeated two-way ANOVA for comparisons between pre- and post-training values, taking into consideration the comparison among groups and the effect of training; one-way ANOVA for comparison of groups at baseline, and chi-square and Goodman tests to compare proportions. A covariance model of repeated measures analysis on independent groups was performed for the adjustment by sex of variables with gender influence (exercise tolerance and muscle strength). Percent changes (Δ) of all variables were calculated and the Pearson or Spearman coefficient of correlation was used to assess correlation between Δ values. Values of P < 0.05 were considered significant.

Results

Of the 47 patients initially evaluated, 13 (4 in the ST group, 6 in the LGT group, and 3 in the CT group) failed to complete the 12 weeks of the conditioning program due to one of the following reasons: disease exacerbation (N = 4), socioeconomic difficulty (N = 1), lack of motivation (N = 6), job conflict (N = 1), and nonspecific skeletal muscle complaints (N = 1). However, comparisons of these patients with those completing the programs did not show significant differences at baseline. Thirty-five patients concluded the training protocols with adequate adherence (ST = 11; CT = 11; LGT = 13), having completed more than 85% of the scheduled sessions.

General characteristics of the study population

Baseline characteristics of the remaining 35 patients are presented in Table 2. No differences were found between groups in terms of age, gender, body composition, airflow obstruction, or arterial blood gases. On average, the patients presented a moderate airflow obstruction. No patient presented evidence of arterial hypoxemia, defined as PaO₂ <55 mmHg/SpO₂ <89%. Three patients (1 in the CT group and 2 in the LGT group) presented a BMI <21 kg/m². Another three (one in the ST group and two in the LGT group) presented an FFMI <15 kg/m² (women) or <16 kg/m² (men). One LGT patient presented a low BMI and a low FFMI. At the end of the training period, none of the groups presented significant changes in lung function or body composition.

Effects of exercise training on health-related quality of life and dyspnea

No differences were observed in pre- or post-intervention scores for health-related quality of life and dyspnea in any training modalities studied (Table 3). Patients in the ST

group presented a significant post-training improvement in the SGRQ symptoms domain, activities domain and total scores, as well as in the AQ20 total score. Those in the CT group presented a significant post-training improvement in the SGRQ activities domain, impact domain, total scores, and in the AQ20 total score. Those in the LGT group presented a significant post-training improvement in the SGRQ symptoms domain and total scores. In addition, minimal clinically significant improvement in the total SGRQ score was found for 7 patients in the ST group (63.6%), 9 patients in the CT group (72.7%), and 9 patients in the LGT group (69.2%; $P > 0.05$). Although significant improvement in BDI was found only in the ST group, there was a minor, though consistent, trend towards improvement in BDI score in the CT and LGT groups.

Effects of exercise training on functional exercise tolerance

Results related to functional exercise tolerance are shown in Table 4. It can be observed that there was a significant increase in the 6-min walked distance and in the endurance time in the CT and ST groups. A minimal clinically significant improvement in the 6MWT was observed in 6 patients in the ST group (54.5%) and in 4 patients in the CT group (36.4%). In addition, we observed a tendency to a significant increase in 6MWT values and in the treadmill endurance time in the LGT group. Four LGT patients (30.8%) presented minimal clinically significant improvements in the 6MWT results.

Effects of training on respiratory and peripheral muscle strength

Pre- and post-training values of respiratory

and peripheral muscle strength are presented in Table 4. Baseline peripheral muscle strength did not differ significantly among groups. Patients in the ST and CT groups presented a significant post-training improvement in all 1-RM values, whereas no significant changes in 1-RM values were observed in the LGT group. With the exception of the leg press exercise, 1-RM values were comparable for the ST and CT groups at baseline and at the end of training. With the exception of bench press in the CT group, all 1-RM values were significantly higher at the end of the program in the ST and CT groups than in the LGT group. In the ST group, the change in the 6-min walk

Table 2. Baseline characteristics of the study population randomly assigned to strength training (ST), combined training (CT), and low-intensity general training (LGT).

	ST (N = 11)	CT (N = 11)	LGT (N = 13)
Age (years)	61.3 ± 8.8	62.1 ± 10	65.4 ± 9.2
Sex (male/female)	9/2	7/4	10/3
Height (cm)	164.5 ± 8	161 ± 8	164.8 ± 8
Weight (kg)	72 ± 14.5	68.9 ± 13.6	64.8 ± 13
BMI (kg/m ²)	26.8 ± 4.4	27.1 ± 5.8	23.6 ± 5.4
FFMI (kg/m ²)	18.5 ± 2	17.8 ± 1.2	17 ± 2.4
FVC (L)	2.9 ± 0.7	3.1 ± 1	2.8 ± 0.6
FVC (%predicted)	93.7 ± 24.4	98.6 ± 20	93.1 ± 21
FEV ₁ (L)	1.3 ± 0.4	1.3 ± 0.5	1.2 ± 0.5
FEV ₁ (%predicted)	59.3 ± 24.4	59.4 ± 27	57.9 ± 23.7
FEV ₁ /FVC (%)	44.5 ± 6.3	44.3 ± 16.9	43.4 ± 12.7
PaO ₂ (mmHg)	68.8 ± 11.1	69.8 ± 10.6	75.9 ± 8.6
PaCO ₂ (mmHg)	42 ± 8	36.5 ± 4.7	39.5 ± 6.3
SpO ₂ (%)	92.6 ± 3.3	94 ± 2.5	94.8 ± 1.4

BMI = body mass index; FFMI = lean body mass index; FVC = forced vital capacity; FEV₁ = forced expiratory volume in 1 s; PaO₂ = arterial oxygen tension; PaCO₂ = arterial carbon dioxide tension; SpO₂ = peripheral (pulse oxymetry) oxygen saturation. There were no statistical differences among the groups (one-way ANOVA).

Table 3. Pre- and post-training mean values of quality of life and dyspnea for patients in the strength training (ST), combined training (CT), and low-intensity general training groups (LGT).

	SGRQ symptoms (%)	SGRQ activities (%)	SGRQ impact (%)	SGRQ total (%)	AQ20 total (%)	BDI
Pre-training						
ST	59 ± 28	63 ± 20	42 ± 21	48 ± 19	55 ± 23	1.8 ± 1.4
CT	42 ± 24	61 ± 22	36 ± 20	45 ± 20	45 ± 23	1.9 ± 1.2
LGT	55 ± 22	61 ± 16	42 ± 16	50 ± 13	48 ± 21	1.6 ± 0.8
Post-training						
ST	36 ± 24*	44 ± 27*	32 ± 22	35 ± 20*	39 ± 19*	2.4 ± 1.2*
CT	32 ± 22	48 ± 23*	24 ± 19*	33 ± 17*	32 ± 16*	2.5 ± 1.3
LGT	30 ± 14*	51 ± 19	34 ± 21	39 ± 17*	44 ± 25	2.0 ± 1.3

Data are reported as mean ± SD. SGRQ = Saint George's Respiratory Questionnaire; AQ20 = Airways Questionnaire 20; BDI = baseline dyspnea index. * $P < 0.05$, post-training compared to pre-training (two-way repeated measures ANOVA).

Table 4. Pre- and post-training mean values of functional exercise tolerance, as well as respiratory and peripheral muscle strength for patients in the strength training (ST), combined training (CT), and low-intensity general training groups (LGT).

	6MWT (m)	TEnd (min)	Mean values of one repetition maximum (kg)					
			Leg press	Leg extension	Bench press	Lat pull down	HGS (kgF)	PImax (cmH ₂ O)
Pre-training								
ST	601 ± 85	18 ± 8	98 ± 26	36 ± 12	35 ± 11	44 ± 12	38 ± 7	-80 ± 26
CT	511 ± 62 ⁺	17 ± 10	78 ± 23	33 ± 8	34 ± 7	39 ± 8	33 ± 8	-63 ± 25
LGT	560 ± 109	12 ± 5	68 ± 15	34 ± 8	34 ± 8	41 ± 10	36 ± 5	-64 ± 20
Post-training								
ST	645 ± 73 [*]	29 ± 19 [*]	155 ± 60 ^{**†}	52 ± 11 [†]	46 ± 11 [†]	56 ± 13 [†]	38 ± 7	-81 ± 26
CT	559 ± 52 ^{**}	28 ± 15 [*]	116 ± 32 ^{*#}	46 ± 13 ^{*#}	40 ± 8 [*]	50 ± 11 ^{*#}	35 ± 8	-74 ± 22
LGT	592 ± 76	19 ± 4	85 ± 20	37 ± 9	36 ± 10	42 ± 12	39 ± 7	-66 ± 27

Data are reported as mean ± SD. 6MWT = 6-min walk test; TEnd = constant workload treadmill endurance test; HGS = handgrip strength; PImax = maximal inspiratory pressure. *P < 0.05, post-training compared to pre-training (ANCOVA); ⁺P < 0.05, CT compared to ST; [†]P < 0.05, ST compared to LGT; [#]P < 0.05, CT compared to LGT (two-way repeated measures ANOVA).

distance presented significant positive correlations with changes in 1-RM in the lat pull down ($r = 0.64$; $P = 0.0452$), 1-RM in the bench press ($r = 0.62$; $P = 0.0395$), and 1-RM in the leg extension ($r = 0.60$; $P = 0.0467$).

Discussion

The aim of the present study was to compare the results of three different exercise programs regarding body composition, quality of life, dyspnea, peripheral muscle strength, and exercise tolerance of COPD patients. We found that the strength-training component produced additional improvements in peripheral muscle strength. However, this type of training did not promote any additional benefit in exercise tolerance, dyspnea or health-related quality of life.

In the present study, ST, alone or combined with LGT, was effective in increasing the strength of the muscle groups trained. Supporting this finding, there is strong evidence that ST alone or combined with endurance training can lead to a significant improvement in muscle strength in COPD patients (5,8,27,28). In contrast with previous studies that showed increased muscle strength and higher endurance in COPD after low-intensity resistance training, we did not find a significant increase in muscle strength in the LGT group (9,10). Studies using cycling and arm cranking as a training modality have shown significant increases in lower and upper limb muscle strength (5,23,24). On the other hand, Mador et al. (29) did not observe any change in peripheral muscle strength after endurance training. These discrepancies may be attributable to the differences in the modalities and the intensity of training employed.

No significant changes in BMI, FFM or FFMI were found in our study in any group evaluated. This finding is in agreement with previous reports of increases in total FFM only when the rehabilitation process included nutritional support or supplementation with specific agents, such as testosterone or creatine (30-32). Moreover, body impedance is not accurate enough to detect small changes in body mass composition (14).

The ST and CT modalities produced significant and similar changes in health-related quality of life in the present study. The magnitude of the improvements shown in the present study (SGRQ total change = 11 ± 10 to $13 \pm 14\%$) has been reported by others in Brazilian patients (33). The dyspnea in the ST group improved significantly, whereas it did not change significantly in the CT or LGT groups. The between-group difference for the change in dyspnea, however, was not significant. In fact, a recent systematic review of randomized controlled trials comparing different exercise programs for COPD showed that ST produced greater improvements in the dyspnea domain and in the total score of the Chronic Respiratory Disease Questionnaire when compared to endurance training (8).

The 6-min walking distance and the endurance time were higher in the ST and CT groups, in agreement with other reports (5,28). In the present study, the mean increase in the 6-min distance walked was less than 54 m. However, for some of the patients, the absolute value was greater than 54 m (54.4% in the ST, 36.4% in the CT, and 30.8% in the LGT). Mador et al. (29) reported similar results in patients submitted to a combined exercise program (strength and aerobic exercises). Moreover, Spruit et al. (28) and Ortega et al. (5) also showed an improvement in endurance time in COPD patients after an exercise

program. The continuous (oval) tracks and number of practice tests related to 6MWT in the present study might have influenced our results (34). Recently, the distance walked on a continuous circular track exceeded the distance walked on a straight track by 13 ± 17 m in patients with COPD (34). The coefficient of repeatability for 3-day sessions was 51 and 65 m for the straight and circular tracks, respectively. Thus, for an individual patient, performing the test in different layouts results in less variability in 6-min walk distance than performing the test on a different day. Regarding the execution of a practice walk test, the distance walked is only slightly greater in a second test according to ATS recommendations (35).

We found a tendency towards increased exercise tolerance in the LGT group. Clark et al. (9), comparing the results obtained for a group of patients following a low-intensity exercise program with those found for a control group, also observed a significant increase in endurance time in the trained group. Similar results were reported by Normandin et al. (10). The low intensity of the LGT program and the reduced number of patients performing this training modality in our study might explain the lack of a statistical effect. Nevertheless, all exercise training programs studied were able to produce significant and similar changes in health-related quality of life, in agreement with previous reports (5,10,27,29).

In the literature, two different modalities of CT, shorter and longer sessions of endurance training combined with ST, have been compared to endurance training alone (5,27,29). The longer CT session protocols resulted in increased muscle strength but provided no greater improvement in exercise tolerance or health-related quality of life than did endurance training alone (27,29). Interestingly, the shorter CT session protocols provided the best benefits for the patients and have been suggested to represent an optional strategy for patients with COPD (5). This is in agreement with our findings showing that a combination of training modalities is effective without increasing the duration of the sessions.

An interesting finding of the present study was the correlation between changes in muscle strength and in 6-min walk distance. We were able to find only one study (36) that showed a significant correlation between percent changes in leg muscle function and constant workload treadmill endurance test performance after strength training alone. However, the cited study did not assess trunk muscle strength (latissimus dorsi, trapezius, pectoralis major) as assessed in the present study. Some of these trunk muscles may take on an accessory respiratory function when the primary respiratory muscles are dysfunctional or cannot meet the ventilatory demand (37). There-

fore, improvement of trunk muscle strength may benefit respiratory mechanics, resulting in better exercise capacity (38).

The present study has some methodological limitations. Although we used reliable tools to evaluate patient ability to carry out daily life activities, such as the 6MWT (39), we were unable to directly assess maximal oxygen uptake due to equipment limitations. Moreover, the reduced number of patients in the LGT group may have influenced the amount of benefits of this type of training. As previously mentioned, the sample size was calculated considering minimal clinically important differences in health-related quality of life (SGRQ total score improvement $\geq 4\%$), that indicated $N = 10$ in each training group. It is possible that the number of patients studied (ST = 11; CT = 11; LGT = 13) was not sufficient to observe differences related to other variables in the LGT group, probably due to a type II error. However, it is unlikely that including more patients in the study would have changed the conclusion that, except for the peripheral muscle strength, the improvements were similar for the three study groups. In a systematic review, O'Shea et al. (40) showed that strength training was found to have strong evidence for improving peripheral muscle strength; however, no strong evidence for strength training was found for outcome measures such as exercise capacity, dyspnea or health-related quality of life. Further investigations are required to evaluate the impact of strength training programs on activities of daily living, balance, upper-limb function, and self-care in patients with COPD.

The low-intensity training regarding LGT may also have influenced our results. However, the literature shows that this training type can result in significant benefits for patients with COPD (6,9,10). Rehabilitation programs are scarce and just a small number of patients have access to this treatment, mainly in Brazil, where resources are limited. The available structure allows training with mats, free weights, parallel bars, and free walking and this has been our rehabilitation strategy for many years. Therefore, the present study was designed to determine whether the addition of strength training performed on gym equipment can maximize the benefits of our current program. In addition, although the various CT programs have yielded significant benefits, our design did not allow us to assess patient motivation or preference for any of the training modalities. Four of the 6 patients who dropped out of the LGT stated a lack of motivation. Since the statistical analysis did not show significant differences among the groups, no conclusions can be drawn regarding the effects of different exercise modalities and session durations on COPD patient adherence to the training programs. Finally,

an unblinded assessment was necessary, similar to some previous studies (5,28,36).

The results of the present study support the view that the addition of a strength-training component to an endurance training program of COPD patients increases muscle strength. However, it cannot promote additional increases in exercise endurance, dyspnea, or health-related quality of life. Moreover, a relatively simple training program com-

bining LGT and ST can produce significant improvements in muscle strength, in exercise tolerance and in health-related quality of life, even when the sessions are of standard duration. Finally, the benefits of physical conditioning for healthy status in patients with COPD seem to be independent of the modality or intensity of the exercise training undertaken.

References

- American Thoracic Society-European Respiratory Society Statement. Skeletal muscle dysfunction in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1999; 159: 1s-28s.
- Ries AL, Kaplan RM, Limberg TM, Prewitt LM. Effects of pulmonary rehabilitation on physiologic and psychosocial outcomes in patients with chronic obstructive pulmonary disease. *Ann Intern Med* 1995; 122: 823-832.
- Celli BR, MacNee W. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. *Eur Respir J* 2004; 23: 932-946.
- Maltais F, LeBlanc P, Jobin J, Berube C, Bruneau J, Carrier L, et al. Intensity of training and physiologic adaptation in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1997; 155: 555-561.
- Ortega F, Toral J, Cejudo P, Villagomez R, Sanchez H, Castillo J, et al. Comparison of effects of strength and endurance training in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2002; 166: 669-674.
- Vogiatis I, Nanas S, Roussos C. Interval training as an alternative modality to continuous exercise in patients with COPD. *Eur Respir J* 2002; 20: 12-19.
- Coppoolse R, Schols AM, Baarends EM, Mostert R, Akkermans MA, Janssen PP, et al. Interval versus continuous training in patients with severe COPD: a randomized clinical trial. *Eur Respir J* 1999; 14: 258-263.
- Puhan MA, Schunemann HJ, Frey M, Scharplatz M, Bachmann LM. How should COPD patients exercise during respiratory rehabilitation? Comparison of exercise modalities and intensities to treat skeletal muscle dysfunction. *Thorax* 2005; 60: 367-375.
- Clark CJ, Cochrane L, Mackay E. Low intensity peripheral muscle conditioning improves exercise tolerance and breathlessness in COPD. *Eur Respir J* 1996; 9: 2590-2596.
- Normandin EA, McCusker C, Connors M, Vale F, Gerardi D, ZuWallack RL. An evaluation of two approaches to exercise conditioning in pulmonary rehabilitation. *Chest* 2002; 121: 1085-1091.
- Gosselink R, Troosters T, Decramer M. Exercise training in COPD patients: the basic questions. *Eur Respir J* 1997; 10: 2884-2891.
- Fabbri LM, Hurd SS. Global strategy for the diagnosis, management and prevention of COPD: 2003 update. *Eur Respir J* 2003; 22: 1-2.
- Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B. Changes in the normal maximal expiratory flow-volume curve with growth and aging. *Am Rev Respir Dis* 1983; 127: 725-734.
- Kyle UG, Pichard C, Rochat T, Slosman DO, Fitting JW, Thiebaud D. New bioelectrical impedance formula for patients with respiratory insufficiency: comparison to dual-energy X-ray absorptiometry. *Eur Respir J* 1998; 12: 960-966.
- Schols AM, Soeters PB, Dingemans AM, Mostert R, Frantzen PJ, Wouters EF. Prevalence and characteristics of nutritional depletion in patients with stable COPD eligible for pulmonary rehabilitation. *Am Rev Respir Dis* 1993; 147: 1151-1156.
- Souza TC, Jardim JR, Jones P. Validação do questionário do hospital Saint George na doença respiratória (SGRQ) em pacientes portadores de doença pulmonar obstrutiva crônica no Brasil. *J Pneumol* 2000; 26: 119-125.
- Camelier A, Rosa F, Jones P, Jardim JR. Validação do questionário de vias aéreas 20 ("Airways questionnaire 20" - AQ20) em pacientes portadores de doença pulmonar obstrutiva crônica (DPOC) no Brasil. *J Pneumol* 2003; 29: 28-35.
- Martinez JAB, Pádua AI. Dispneia: novos conhecimentos sobre um velho problema. In: Terra-Filho M, Fernandes ALG, Stirbulov R (Editors), *Pneumologia: atualização e reciclagem. Volume IV*. São Paulo: Vivali; 2001. p 1-12.
- Mahler DA, Weinberg DH, Wells CK, Feinstein AR. The measurement of dyspnea. Contents, interobserver agreement, and physiologic correlates of two new clinical indexes. *Chest* 1984; 85: 751-758.
- Jones PW. St George's Respiratory Questionnaire: development, interpretation and use. *Eur Respir Rev* 2002; 12: 63-64.
- Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. *Am Rev Respir Dis* 1969; 99: 696-702.
- American College of Sports Medicine. *Diretrizes do ACSM para os testes de esforço e sua prescrição*. 3rd edn. Rio de Janeiro: Guanabara Koogan; 2003.
- Bruce RA, Kusumi F, Hosmer D. Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. *Am Heart J* 1973; 85: 546-562.
- Redelmeier DA, 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.
25. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000; 32: S498-S504.
 26. American College of Sports Medicine Position Stand. Exercise and physical activity for older adults. *Med Sci Sports Exerc* 1998; 30: 992-1008.
 27. Bernard S, Whittom F, LeBlanc P, Jobin J, Belleau R, Berube C, et al. Aerobic and strength training in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1999; 159: 896-901.
 28. Spruit MA, Gosselink R, Troosters T, De Paepe K, Decramer M. Resistance versus endurance training in patients with COPD and peripheral muscle weakness. *Eur Respir J* 2002; 19: 1072-1078.
 29. Mador MJ, Bozkanat E, Aggarwal A, Shaffer M, Kufel TJ. Endurance and strength training in patients with COPD. *Chest* 2004; 125: 2036-2045.
 30. Casaburi R, Bhasin S, Cosentino L, Porszasz J, Somfay A, Lewis MI, et al. Effects of testosterone and resistance training in men with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2004; 170: 870-878.
 31. Franssen FM, Broekhuizen R, Janssen PP, Wouters EF, Schols AM. Effects of whole-body exercise training on body composition and functional capacity in normal-weight patients with COPD. *Chest* 2004; 125: 2021-2028.
 32. Fuld JP, Kilduff LP, Neder JA, Pitsiladis Y, Lean ME, Ward SA, et al. Creatine supplementation during pulmonary rehabilitation in chronic obstructive pulmonary disease. *Thorax* 2005; 60: 531-537.
 33. Tanni SE, Vale SA, Lopes PS, Guiotoko MM, Godoy I, Godoy I. Influence of the oxygen delivery system on the quality of life of patients with chronic hypoxemia. *J Bras Pneumol* 2007; 33: 161-167.
 34. Bansal V, Hill K, Dolmage TE, Brooks D, Woon LJ, Goldstein RS. Modifying track layout from straight to circular has a modest effect on the 6-min walk distance. *Chest* 2008; 133: 1155-1160.
 35. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002; 166: 111-117.
 36. Clark CJ, Cochrane LM, Mackay E, Paton B. Skeletal muscle strength and endurance in patients with mild COPD and the effects of weight training. *Eur Respir J* 2000; 15: 92-97.
 37. Epstein SK. An overview of respiratory muscle function. *Clin Chest Med* 1994; 15: 619-639.
 38. Dourado VZ, Antunes LC, Tanni SE, de Paiva SA, Padovani CR, Godoy I. Relationship of upper-limb and thoracic muscle strength to 6-min walk distance in COPD patients. *Chest* 2006; 129: 551-557.
 39. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2005; 171: 972-977.
 40. O'Shea SD, Taylor NF, Paratz J. Peripheral muscle strength training in COPD: a systematic review. *Chest* 2004; 126: 903-914.