

ORIGINAL ARTICLE

Diaphragmatic Breathing Training Program Improves Abdominal Motion During Natural Breathing in Patients With Chronic Obstructive Pulmonary Disease: A Randomized Controlled Trial

Wellington P. Yamaguti, PhD, Renata C. Claudino, PT, Alberto P. Neto, PT, Maria C. Chammas, PhD, Andrea C. Gomes, MD, João M. Salge, PhD, Henrique T. Moriya, PhD, Alberto Cukier, PhD, Celso R. Carvalho, PhD

ABSTRACT. Yamaguti WP, Claudino RC, Neto AP, Chammas MC, Gomes AC, Salge JM, Moriya HT, Cukier A, Carvalho CR. Diaphragmatic breathing training program improves abdominal motion during natural breathing in patients with chronic obstructive pulmonary disease: a randomized controlled trial. *Arch Phys Med Rehabil* 2012;93:571-7.

Objective: To investigate the effects of a diaphragmatic breathing training program (DBTP) on thoracoabdominal motion and functional capacity in patients with chronic obstructive pulmonary disease.

Design: A prospective, randomized controlled trial.

Setting: Academic medical center.

Participants: Subjects (N=30; forced expiratory volume in 1s, 42%±13% predicted) were randomly allocated to either a training group (TG) or a control group (CG).

Interventions: Subjects in the TG completed a 4-week supervised DBTP (3 individualized weekly sessions), while those in the CG received their usual care.

Main Outcome Measures: Effectiveness was assessed by amplitude of the rib cage to abdominal motion ratio (RC/ABD ratio) (primary outcome) and diaphragmatic mobility (secondary outcome). The RC/ABD ratio was measured using respiratory inductive plethysmography during voluntary diaphragmatic breathing and natural breathing. Diaphragmatic mobility was measured by ultrasonography. A 6-minute walk test and health-related quality of life were also evaluated.

Results: Immediately after the 4-week DBTP, the TG showed a greater abdominal motion during natural breathing quantified by a reduction in the RC/ABD ratio when compared with the CG (F=8.66; $P<.001$). Abdominal motion during voluntary diaphragmatic breathing after the intervention was also greater in the TG than in the CG (F=4.11; $P<.05$). The TG showed greater diaphragmatic mobility after the 4-week

DBTP than did the CG (F=15.08; $P<.001$). An improvement in the 6-minute walk test and in health-related quality of life was also observed in the TG.

Conclusions: DBTP for patients with chronic obstructive pulmonary disease induced increased diaphragm participation during natural breathing, resulting in an improvement in functional capacity.

Key Words: Breathing exercises; Diaphragm; Exercise tolerance; Pulmonary disease, chronic obstructive; Quality of life; Randomized controlled trial; Rehabilitation.

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CHRONIC OBSTRUCTIVE PULMONARY disease (COPD) is characterized by an increased resistance to airflow, air trapping, and lung hyperinflation. As lung volume increases, the inspiratory muscles are passively shortened and thereby placed at a mechanical disadvantage.^{1,2} Therefore, patients with COPD frequently have a reduction of diaphragmatic mobility and its relative contribution to thoracoabdominal motion,³⁻⁵ enhancing the activity of chest wall respiratory muscles as a compensatory mechanism.^{6,7} It has been previously shown that both a reduction in diaphragmatic mobility and a higher activity of chest wall respiratory muscles are associated with increased dyspnea and exercise intolerance.⁸⁻¹⁰

Breathing strategies have been considered as part of self-management education actions in pulmonary rehabilitation¹¹ and include a range of techniques, including diaphragmatic breathing (DB). The principal aim of DB is to improve abdominal motion while reducing chest wall respiratory muscle ac-

List of Abbreviations

CG	control group
COPD	chronic obstructive pulmonary disease
DB	diaphragmatic breathing
DBTP	diaphragmatic breathing training program
FEV ₁	forced expiratory volume in 1 second
FVC	forced vital capacity
HRQOL	health-related quality of life
NB	natural breathing
RC/ABD ratio	amplitude of rib cage to abdominal motion ratio
RCT	randomized controlled trial
SGRQ	St. George's Respiratory Questionnaire
6MWT	6-minute walk test
TG	training group

From the Departments of Physical Therapy (Yamaguti, Claudino, Neto, Carvalho) and Radiology, Service of Ultrasound (Chammas, Gomes), School of Medicine, University of São Paulo, São Paulo; Pulmonary Division, School of Medicine, University of São Paulo, São Paulo (Salge, Cukier); and Biomedical Engineering Laboratory, School of Engineering, University of São Paulo, São Paulo (Moriya, Brazil).

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Reprint requests to Celso R. Carvalho, PhD, Dept of Physical Therapy, School of Medicine, University of São Paulo, Av. Dr. Arnaldo, 455, Room 1210, 01246-903, Sao Paulo-SP, Brazil, e-mail: cscarvalho@usp.br.

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tivity.¹² A systematic review¹³ has pointed out some methodological problems in prior studies evaluating the benefits of DB for patients with COPD. Of 24 clinical investigations included in this review, only 3 were categorized as randomized controlled trials (RCTs).¹⁴⁻¹⁶ One of these studies included patients with asthma and bronchiectasis in addition to COPD, and the other investigations provided adjunctive therapies in addition to DB, which makes it difficult to determine the specific effects of DB for patients with COPD. Furthermore, the review demonstrated that the role of DB for patients with COPD remains controversial. Results from uncontrolled studies have demonstrated that DB might improve gas exchange,^{17,18} respiratory patterns,^{19,20} and the oxygen cost of breathing.²¹ On the other hand, other investigators have suggested that DB may lead to detrimental effects in a specific population of patients with severe COPD.^{17,22}

Despite these conflicting results, an improvement in abdominal motion and a reduction in thoracic excursion during voluntary DB have been described as common findings in several studies.^{17,20,22,23} To our knowledge, no controlled studies have investigated the change in abdominal motion naturally adopted after a diaphragmatic breathing training program (DBTP). We hypothesized that a short-term DBTP could induce higher participation of the diaphragm during natural breathing (NB). This modification in habitual breathing pattern would relieve respiratory symptoms and improve exercise tolerance and health-related quality of life (HRQOL). Therefore, in this RCT, we aimed to test the effects of a short-term DBTP on thoracoabdominal motion, diaphragmatic mobility, and functional capacity in patients with COPD.

METHODS

Participants

Ninety-four patients with COPD diagnosed according to the Global Initiative for Chronic Obstructive Lung Disease criteria²⁴ were recruited at a university hospital. Inclusion criteria were as follows: (1) age 50 to 80 years; (2) postbronchodilator forced expiratory volume in 1 second (FEV_1) $<80\%$ of predicted and an FEV_1 to forced vital capacity (FVC) ratio (FEV_1/FVC ratio) <0.7 ; (3) stable respiratory condition without changes in medication or symptoms for at least 4 weeks before enrollment in the study; and (4) receiving regular treatment with inhaled bronchodilators and steroids. Exclusion criteria were (1) the presence of other cardiopulmonary or musculoskeletal diseases; (2) previous engagement in any exercise training program in the prior 2 years; and (3) current smokers. The hospital ethics committee approved the study (Protocol no. 0348/08), and all patients provided written informed consent.

Study Design

This was a prospective, parallel-group, randomized and blinded clinical trial. Patients were evenly allocated (1:1) to either a training group (TG) or control group (CG). Randomization was stratified according to sex using random block sizes of 2 and 4. Regular medical treatment was established in both groups before the first visit and remained unchanged throughout the study. Patients in the TG completed a 4-week DBTP, while those in the CG received their usual care. Patients in both groups were evaluated at baseline and at the end of a 4-week period. The technicians who collected data for all outcome measures (R.C.C. and A.C.G.) were blinded to the patients' group allocation.

Training Program

The TG completed a DBTP consisting of three 45-minute weekly sessions (12 sessions total). The program was individualized and supervised by a single physiotherapist (A.P.N.). In each session, the patients were instructed to perform a total of 150 breathing exercises in the following positions: supine, right and left lateral decubitus, sitting, and standing (3 series of 10 repetitions in each position). Between each series of DB exercises, patients were instructed to breathe normally for 1 minute. The following verbal instructions were given during inhalation and exhalation, respectively: "perform a slow maximal inspiration allowing the air to go to your belly," and "perform a normal expiration without forcing abdominal retraction." Tactile feedback was provided by positioning one of the patient's hands on the abdomen and the other hand on the upper rib cage. If necessary, visual and auditory stimulation was provided to correct uncoordinated respiratory patterns. DB competency was considered if the respiratory pattern adopted was associated with at least a doubling of the abdominal tidal excursion observed during NB.^{13,22} No patient in the CG or TG was instructed to perform the exercises at home.

Outcome Measures

Primary and secondary outcomes. Improvements in abdominal motion during NB and in diaphragmatic mobility, from baseline to post-DBTP, were used, respectively, as primary and secondary outcomes. Patients from the CG and TG were instructed to practice voluntary DB before the first evaluation of thoracoabdominal motion. This procedure aimed at evaluating whether a single instruction session was as effective to change abdominal motion during NB as a supervised DBTP. Dyspnea, HRQOL, and exercise tolerance were also evaluated.

Thoracoabdominal motion. Improvement in abdominal motion was evaluated by means of a reduction in the amplitude of the rib cage to abdominal motion ratio (RC/ABD ratio) recorded using a computer-assisted respiratory inductive plethysmography system (Respirace).^a Teflon-coated inductance bands^a of appropriate size were placed around the rib cage and abdomen and connected to an oscillator module and calibration unit.²⁵ Each subject was measured in a quiet, private room, and data acquisition was performed in a supine position²⁶ for a total period of 9 minutes, equally distributed as follows: (1) at rest—basal NB; (2) during DB exercise—voluntary DB; and (3) post-DB exercise. Pulse oximetry was continuously monitored, and dyspnea sensations were evaluated every minute using the modified Borg scale.²⁷ Rib cage and abdominal wall movement waveforms were digitized, and the RC/ABD ratio was calculated from the absolute changes in the circumference of these compartments.²²

Diaphragmatic mobility. An ultrasonography examination was used to assess the craniocaudal displacement of the left branch of the portal vein in order to measure diaphragmatic mobility.²⁸ Patients were evaluated in the supine position using an ultrasound scanner^b in B-mode. A 3.5-MHz convex transducer was positioned over the right subcostal region, and the position of the left branch of the portal vein was marked with the cursor during forced expiration and inspiration. Three reproducible measurements were performed, and the best value was used for the analysis.

Functional capacity. Spirometry and whole-body plethysmography were performed using standard equipment^c according to the American Thoracic Society and the European Respiratory Society recommendations.²⁹ Reported spirometry results were based on the best curve from 3 acceptable efforts (after the inhalation of 200 μ g of salbutamol); they are pre-

sented as a percentage of the predicted value.³⁰ Dyspnea symptoms at rest were assessed using the modified Medical Research Council dyspnea scale.³¹ COPD-specific HRQOL was evaluated by means of a validated version of the St. George's Respiratory Questionnaire (SGRQ).^{32,33} The 6-minute walk test (6MWT) was used to assess exercise tolerance and performed according to American Thoracic Society recommendations.³⁴ The largest distance from 2 tests was used in the analysis, and the normal values used were those described by Iwama et al.³⁵ The body mass index, airflow obstruction, dyspnea, and exercise capacity values were integrated into a score—the BODE index.³⁶

Statistical Analysis

Sample size was calculated using the results from the first 10 patients enrolled in our study for the primary outcome. A sample of 15 patients per group, for an alpha value of .05 and a power of 0.8, would allow for the detection of a reduction in the RC/ABD ratio during NB of up to .14 with an SD of .18 in the TG compared with the CG. An intention-to-treat approach with baseline values carried forward for any patient lost to follow-up was used for all analyses.³⁷ A per-protocol analysis was also performed as a sensitivity analysis. An independent *t* test was used to compare baseline values between groups, and a chi-square test was applied to evaluate sex. Analysis of covariance was used to test for intervention group differences with the baseline measure as the covariate. Effect sizes between the groups were calculated using the Cohen method.³⁸ An effect size of .20 was considered small, .50 medium, and .80 large. A linear relationship was evaluated by a Pearson correlation test. The level of significance used for all tests was 5%. Data are presented as means (95% confidence interval). All analyses were performed using SPSS version 19.0.^d

RESULTS

Ninety-four patients were assessed for eligibility, and 30 patients were randomly assigned to groups. There were 3

protocol deviations in the CG because of either an acute COPD exacerbation or other health problems. These patients were retained to respect the intention-to-treat analysis (fig 1). There was no difference between groups with regard to baseline values of disease severity, functional capacity, anthropometric data, or other baseline characteristics (table 1).

Thoracoabdominal and Diaphragmatic Mobilities

Immediately after the 4-week DBTP, the TG showed a greater abdominal motion during NB quantified by a reduction in the RC/ABD ratio when compared with the CG ($F=8.66$; $P<.001$). Abdominal motion during voluntary DB after the intervention was also greater in the TG than in the CG ($F=4.11$; $P<.05$) (fig 2). DB competency was observed in all TG patients. Finally, the TG showed a greater diaphragmatic mobility after the 4-week DBTP than did the CG ($F=15.08$; $P<.001$) (fig 3). Effect sizes were medium to large in favor of the TG on the diaphragmatic mobility ($d=.46$) and RC/ABD ratio during both voluntary DB ($d=-.69$) and NB ($d=-.96$). The RC/ABD ratio and diaphragmatic mobility remained unchanged in CG patients.

Functional Capacity

Dyspnea was lower in the TG after the 4-week DBTP compared with the CG ($F=5.1$; $P<.05$) (table 2). An improvement in HRQOL for the TG was observed by a 10-point reduction in the total SGRQ score ($F=9.7$; $P<.001$) (see table 2). The benefits in different SGRQ domains (symptom and impact) for the TG were statistically significant compared with the CG, and they were also clinically relevant (reduction >4 in the score) (fig 4). However, no change in the TG was observed for the activity domain. Finally, after the 4-week follow-up period, the TG showed a better performance in the 6MWT compared with the CG ($F=4.9$; $P<.05$) (see table 2). Effect sizes were small to medium in favor of the TG on the 6MWT ($d=.31$), dyspnea ($d=-.41$), and HRQOL ($d=-.64$). Spirometry values and lung volume data remained unchanged in both groups (table 3). The statistical analysis performed when the 3

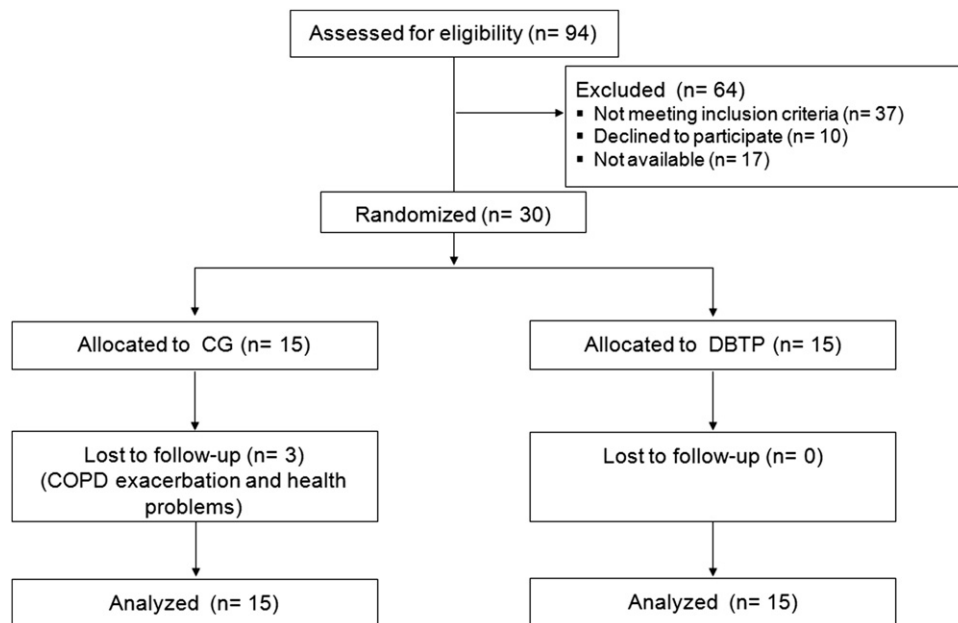


Fig 1. Study flow diagram.

Table 1: Baseline Characteristics of the Studied Patients

Characteristics	CG (n=15)	TG (n=15)	P
Anthropometric data			
Sex (W/M)	4/11	4/11	1.00
Age (y)	66.4 (54.2–77.6)	66.5 (54.2–78.2)	.97
BMI (kg/m ²)	27.2 (22.1–32.2)	27.5 (19.0–35.0)	.87
Pulmonary function			
GOLD class (I, II, III, and IV) (n)	0/4/7/4	0/3/8/4	NA
FEV ₁ (% predicted)	42.4 (18.2–74.8)	43.4 (24.0–63.0)	.87
TLC (% predicted)	116.2 (82.4–138.8)	122.4 (102.2–157.4)	.36
DL _{CO} (% predicted)	50.8 (12.8–102.0)	44.1 (19.0–87.5)	.44
MVV (% predicted)	37.0 (16.6–74.4)	36.1 (18.5–60)	.88
Thoracoabdominal motion			
DM (mm)	33.9 (20.8–51.6)	32.5 (25.5–58.6)	.44
RC/ABD ratio	0.57 (0.37–0.95)	0.65 (0.25–0.89)	.21
Functional capacity			
6MWD (% predicted)	67.7 (32.9–94.2)	68.74 (35.0–90.0)	.87
SGRQ total score	54.0 (25.9–84.6)	53.6 (23.9–77.5)	.96
BODE index score	4.4 (0.2–7.0)	4.3 (2.0–7.5)	.83

NOTE. Values are presented as mean (95% confidence interval) or number of subjects (sex and GOLD class). Abbreviations: BMI, body mass index; BODE index, body mass index, degree of airflow obstruction and dyspnea, and exercise capacity index; DL_{CO}, diffusing capacity of the lung for carbon monoxide; DM, diaphragmatic mobility; GOLD, Global Initiative for Chronic Obstructive Lung Disease; M, men; MVV, maximal voluntary ventilation; NA, not applicable; 6MWD, 6-minute walk distance; TLC, total lung capacity; W, women.

CG dropouts were excluded (per-protocol analysis) showed results similar to those of the intention-to-treat analysis for all outcomes (data not shown).

Linear Relationship Between the Improvement in Abdominal Motion and Baseline Characteristics

Improvement in abdominal motion (Δ RC/ABD ratio) after DBTP was inversely related to the baseline RC/ABD ratio

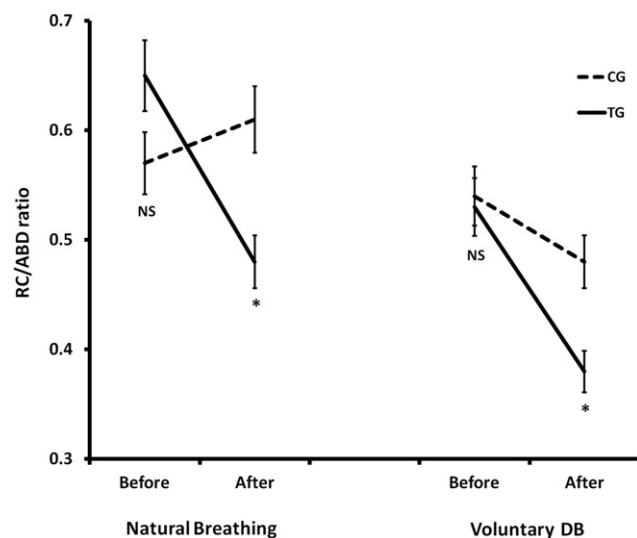


Fig 2. The RC/ABD ratio during NB and voluntary DB at baseline and after a 4-week follow-up period in the CG and TG. Reduction in the RC/ABD ratio reflects improvements in abdominal motion. Abbreviation: NS, not significant (compared with CG). * $P < .05$ compared with CG for both conditions (NB and DB).

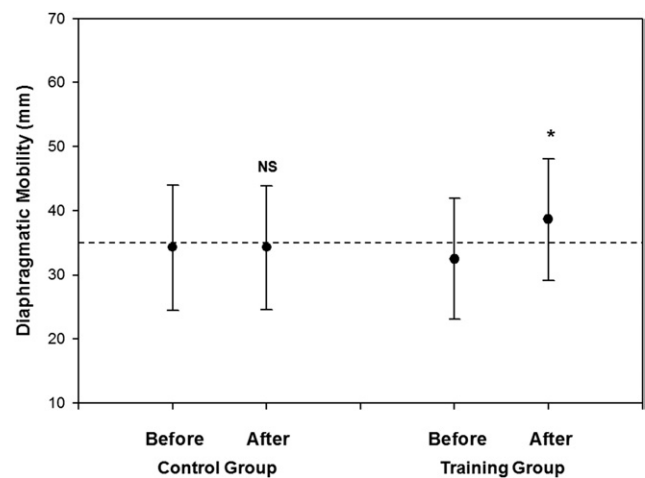


Fig 3. Diaphragmatic mobility in patients with COPD after the 4-week follow-up period in the CG and TG. The dotted line represents the threshold for diaphragmatic dysfunction.¹⁰ Circles represent the mean, and whiskers represent 95% confidence intervals. * $P < .001$ compared with baseline.

($r = -0.8$; $P < .001$) and baseline diaphragmatic mobility ($r = .58$; $P = .02$) (fig 5). The bottom right area in figure 5A reveals that most patients who improved their abdominal motion had a baseline predominance of costal breathing (RC/ABD ratio > 0.5). Figure 5B reveals that patients with a lower baseline diaphragmatic mobility demonstrated a higher improvement in abdominal motion after DBTP. Changes in abdominal motion did not correlate with any other baseline outcomes in the TG. The Δ RC/ABD ratio after a 4-week follow-up period was not related to the baseline RC/ABD ratio or baseline diaphragmatic mobility in the CG ($P > .05$).

DISCUSSION

This RCT was designed to investigate the isolated effects of a short-term DBTP in patients with COPD. It demonstrated an improvement in abdominal motion during both NB and voluntary DB, as well as an increase in diaphragmatic mobility. We also observed that DBTP leads to benefits in dyspnea symptoms, HRQOL, and exercise tolerance. These results support the hypothesis that DBTP can induce a modification in habitual breathing patterns and increase diaphragmatic excursion, thereby relieving symptoms and improving the functional capacity of patients with COPD.

Our results demonstrate that during voluntary DB, patients were able to increase abdominal motion, which is consistent with previous findings.^{17,22} In addition, we also showed that patients with COPD who completed DBTP demonstrated an increase in abdominal motion during NB. However, Gosselink et al²² did not report permanent changes in abdominal motion after the diaphragmatic learning period, suggesting that DB patterns may not be adopted naturally. Our study includes some methodological differences that might elucidate the discordance in results between our study and Gosselink's study. First, our training program was longer (12 sessions vs 9 sessions). Second, in their study, DB was performed only in the supine and sitting positions, while in our program, DB was also performed in the lateral decubitus and standing positions. Third, our patients had less airflow obstruction compared with those studied by Gosselink (43% vs 34% FEV₁). Finally, all our patients were considered competent to perform DB after the intervention, whereas no description of DB competency

Table 2: Functional Capacity of Patients With COPD Before and After the 4-Week Follow-up in the CG and TG

Outcomes	Group	Before	After	ANCOVA		
				F	P	Effect Size (TG vs CG)
MMRC dyspnea scale score	CG	2.8 (1.0–4.0)	2.5 (1.0–4.0)	5.1	.03*	-.41
	TG	2.6 (0.25–4.0)	2.0 (0.25–3.75)			
SGRQ total score	CG	54.0 (25.9–84.6)	54.8 (26.1–74.9)	9.7	.004*	-.64
	TG	53.6 (23.9–77.5)	43.9 (19.0–72.1)			
BODE index score	CG	4.4 (0.2–7.0)	4.1 (0.2–7.6)	0.94	.34	-.20
	TG	4.3 (2–7.5)	3.6 (1.25–6.75)			
6MWD (m)	CG	375.7 (179.5–531.5)	367.3 (168.0–499.0)	4.9	.03*	.31
	TG	371.2 (190.5–499.5)	397.5 (248.5–539.0)			

NOTE. Values are mean (95% confidence interval) or as otherwise indicated. Lower values were considered as an improvement for the MMRC dyspnea scale score, SGRQ score, and BODE index. Statistical analysis was performed using ANCOVA.

Abbreviations: ANCOVA, analysis of covariance; BODE index, body mass index, degree of airflow obstruction and dyspnea, and exercise capacity index; MMRC, modified Medical Research Council; 6MWD, 6-minute walk distance.

* $P < .05$ TG vs CG after intervention (group effect).

was provided in the other study.²² All those differences between the studies could explain the benefit observed in our patients.

Diaphragmatic dysfunction is an important consequence of respiratory alterations in patients with COPD.⁵ We have previously reported that patients with reduced diaphragmatic mobility (≤ 33.99 mm) have a lower exercise tolerance and increased dyspnea after physical effort.¹⁰ In the present study, patients from both groups had an impairment of diaphragmatic mobility at baseline, evidenced by a lower excursion than the critical point for diaphragmatic dysfunction (≤ 33.99 mm), and only patients who participated in DBTP showed improvement in diaphragmatic mobility beyond the point of impairment. Based on these findings, the increase in diaphragmatic mobility is expected to improve dyspnea symptoms and functional capacity.

It has been demonstrated that both increased activity of chest wall respiratory muscles and the impairment of diaphragm

activity are associated with higher sensations of dyspnea.^{8,9}

This suggests that interventions aimed at reversing the extensive use of chest wall respiratory muscles and enhancing diaphragmatic function might alleviate dyspnea in patients with COPD.^{39,40} Our results reveal that patients who participated in DBTP had higher abdominal motion during NB and higher diaphragmatic mobility after the training, as well as a reduction in dyspnea symptoms. Based on these findings, we can speculate that the reduction in dyspnea could be at least partially explained by a higher participation of the diaphragm and a lower activity of chest wall respiratory muscles.

We also observed an improvement in HRQOL only in patients who completed DBTP. Interestingly, the benefits in SGRQ scores (total, symptoms, and impact) were statistically and clinically (changes >4 units) significant.⁴¹ Unfortunately, we are not aware of any other trials that have investigated the benefits of DBTP on HRQOL for patients with COPD, which makes it difficult to compare our results. Finally, patients who participated in DBTP showed improvements in a 6MWT. Recent studies^{42,43} have demonstrated that the minimal important difference for a 6MWT in patients with COPD is approximately 26m. The improvement of 26.3m observed in our study suggests that DBTP could be recommended as an adjunctive strategy to improve exercise tolerance in patients with COPD.

Our results revealed that patients who started the program with lower diaphragmatic mobility and a predominance of costal breathing showed a greater improvement in abdominal motion. These results suggest that patients with a higher impairment of diaphragmatic function and a higher activity of chest wall respiratory muscles would experience greater benefits from DBTP and should be preferentially selected to participate in these programs.

The new contribution of our study lies in the fact that DBTP not only improves respiratory mechanics at NB but also impacts functional outcomes. Furthermore, this strategy is feasible, inexpensive, and promising for application in group therapy and home-based pulmonary rehabilitation. However, further studies must be designed to test these applications of DB.

Study Limitations

The present study has some limitations. First, we did not evaluate the long-term benefits of DBTP, and it remains unknown for how long patients will continue to have higher participation of the abdomen during NB. Second, patients in the CG did not undergo a sham treatment and received only

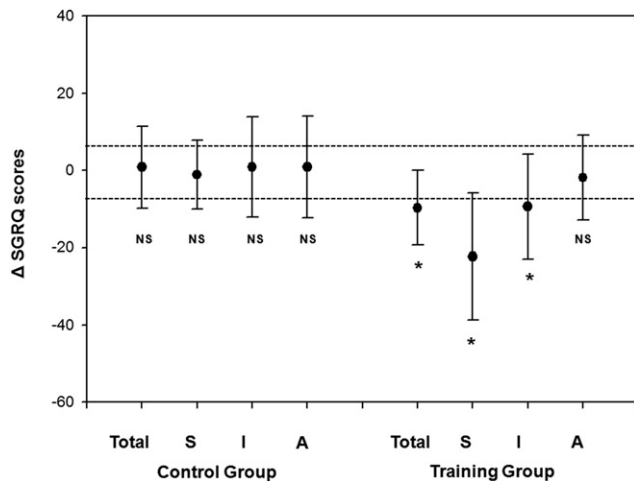


Fig 4. Changes in SGRQ scores in patients with COPD after the 4-week follow-up in the CG and TG (negative difference is interpreted as an improvement). A difference >4.0 (deterioration) and <-4.0 (improvement) is considered clinically important. The dotted line indicates the minimal clinically important difference for SGRQ scores.⁴¹ Circles represent the mean, and whiskers represent 95% confidence intervals. Abbreviations: A, activity; I, impact; NS, not significant (compared with CG); S, symptom; Total, SGRQ total score. * $P < .05$ compared with CG.

Table 3: Pulmonary Function of Patients With COPD Before and After the 4-Week Follow-up in the CG and TG

Outcomes	Group	Before	After	ANCOVA	
				F	P
FEV ₁ (% predicted)	CG	42.4 (18.2–74.8)	42.7 (22.0–74.4)	0.28	.60
	TG	43.4 (24.0–63.0)	42.7 (22.25–66.25)		
FVC (% predicted)	CG	79.3 (49.8–113.8)	78.4 (57.8–113.8)	0.21	.65
	TG	80.6 (61.2–94.7)	81.1 (61.5–111.0)		
FEV ₁ /FVC (%)	CG	39.9 (22.2–64.4)	40.8 (23.0–70.0)	1.86	.18
	TG	40.3 (26.0–58.7)	39.3 (26.5–56.0)		
MVV (% predicted)	CG	37.0 (16.6–74.4)	38.0 (18.3–74.4)	0.66	.42
	TG	36.1 (18.5–60.0)	36.7 (18.5–58.0)		
RV (% predicted)	CG	194.8 (87.4–259.0)	187.9 (89.9–259.0)	0.62	.43
	TG	196.6 (131.2–285.5)	195.6 (131.7–279.5)		
TLC (% predicted)	CG	116.2 (82.4–138.8)	114.5 (83.3–137.9)	0.06	.79
	TG	123.2 (102.2–157.4)	119.1 (97.0–151.0)		

NOTE. Values are mean (95% confidence interval) or as otherwise indicated. Statistical analysis was performed using ANCOVA. Abbreviations: ANCOVA, analysis of covariance; MVV, maximal voluntary ventilation; RV, residual volume; TLC, total lung capacity.

usual care; however, this experimental design has been widely used to evaluate the effects of pulmonary rehabilitation programs.⁴⁴ Third, patients with missing outcomes were included

in the analyses, with baseline values carried forward for any patient lost to follow-up. Although imputation of the missing data might enhance the likelihood of finding no reliable change in the CG, in our study both analyses (intention-to-treat and per-protocol) showed similar results. Fourth, the use of inducance bands could lead patients to change their breathing pattern; however, a greater diaphragmatic mobility in the TG was also confirmed using ultrasound. Despite these limitations, to our knowledge this is the first RCT investigating the clinical benefits of DBTP in patients with stable COPD.

CONCLUSIONS

We conclude that DBTP in patients with COPD leads to improvements in abdominal motion during NB and in functional capacity. We also showed that patients with a baseline level predominance of costal breathing and worse diaphragmatic mobility experienced a greater improvement in abdominal motion. These patients are probably stronger candidates for DB training. Therefore, this study underscores the importance of DB as an adjunctive treatment modality for patients with COPD.

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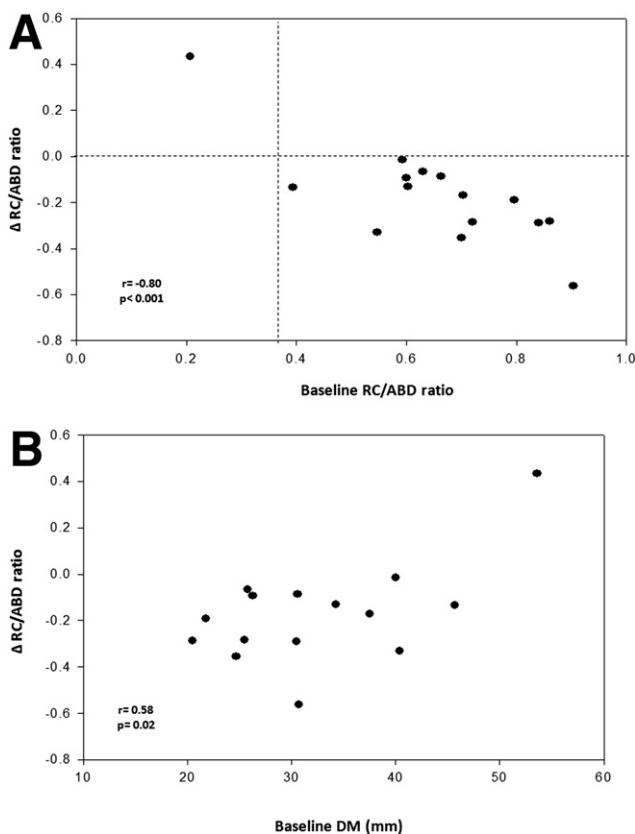


Fig 5. Linear relationship between baseline RC/ABD ratio (A), baseline diaphragmatic mobility (B), and the improvement in abdominal motion (Δ RC/ABD ratio) during NB in patients that completed DBTP. Negative changes in the RC/ABD ratio reflect improvement in abdominal motion. In A, the points included in the bottom right area correspond to patients who improved their abdominal motion. Note that 92.9% of the patients who showed an improvement in abdominal motion after DBTP had a baseline predominance of costal breathing. Abbreviation: DM, diaphragmatic mobility.

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Suppliers

- a. Ambulatory Monitoring Inc, 731 Saw Mill River Rd, Ardsley, NY 10502.
- b. Logiq 500, Pro Series; GE Medical Systems, 8200 West Tower Ave, Milwaukee, WI 53223.
- c. GS II; Collins, 908 Main, Braintree, MA 02184.
- d. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.