ORIGINAL ARTICLE

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

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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.

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 rehabilitation[11] 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

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tivity.[12] A systematic review[13] 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 criteria[24] 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 (Respitrace).[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 position[26] 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 200μg of salbutamol); they are pre-