Technology and Health Care 29 (2021) S359–S366
DOI 10.3233/THC-218034
IOS Press

Effects of core-postural stabilisation on fluoroscopy diaphragmatic measurement and dyspnea in chronic obstructive pulmonary disease: A randomized single-blinded clinical trial

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Abstract.
BACKGROUND: While respiratory and core-postural stabilisation has recently gained a widespread acceptance to improve pulmonary function and dyspena, the therapeutic effects of and rationale underlying the use of respiratory and core-postural stabilisation in the management of patients with chronic obstructive pulmonary disease have not been investigated.
OBJECTIVE: This study aimed to compare the effects of abdominal breathing and respiratory and core-postural stabilisation on diaphragmatic movement and pulmonary function.
METHODS: Fourteen patients with moderate chronic obstructive pulmonary disease were randomly assigned to either the respiratory and core-postural stabilisation or abdominal breathing group. All patients underwent fluoroscopy-guided chest X-ray imaging and pulmonary function tests before and after the interventions; the modified Medical Research Council questionnaire was also administered before and after the interventions. Six sessions of either intervention were consistently provided. The obtained data were assessed using independent t-tests and Wilcoxon signed-rank test with a significance threshold of $P < 0.05$.
RESULTS: Respiratory and core-postural stabilisation was more effective in increasing diaphragmatic movements than abdominal breathing ($P < 0.05$). Pulmonary function tests revealed more significant differences in the forced vital capacity ($\text{FVC}(\%)_{\text{predicted}}$) only after respiratory and core-postural stabilisation ($P = 0.004$). The Medical Research Council questionnaire score was significantly different within the Respiratory and core-postural stabilisation group ($P = 0.014$).
CONCLUSIONS: Our novel results suggest that the effects of respiratory and core-postural stabilisation breathing on diaphragmatic movement and pulmonary function were superior to those of abdominal breathing in patients with chronic obstructive pulmonary disease.

Keywords: Chronic obstructive pulmonary disease, dyspnea, breathing training, core stabilisation, pulmonary function

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1. Introduction

Diaphragmatic dysfunction is a common respiratory and core-postural stabilisation (RCS) impairment, which affects 251 million people with chronic obstructive pulmonary disease (COPD) worldwide [1]. In COPD, with an increase in airflow resistance, air trapping, and hyperinflation in this disease, the inspiratory muscles are passively shortened and are at a mechanical disadvantage [2]. While contemporary pulmonary rehabilitation exercise (PRE) includes the pursed-lip breathing combined with abdominal breathing (AB) technique, inspiratory (external intercostals) strengthening and increased exercise endurance regimens, and has been shown to be effective, the potential importance of the coordinated RCS in the COPD pulmonary rehabilitation, to date, only one clinical trial is available which demonstrated positive effects of the RCS on forced vital capacity (FVC) in stroke patients [3]. RCS is an integrated, coordinated RCS approach which combines a diaphragm-TrA-IO-EO-pelvic floor muscle chain breathing and postural stabilisation during daily living activities and movement [4,5]. A motion magnetic resonance imaging (MRI) study showed that the diaphragm plays an important role in regulation of the breathing and postural stabilisation when coordinated or orchestrated with other RCS chain muscles including diaphragm, transverse abdominis (TrA) and internal oblique (IO) [6,7]. Despite However, the therapeutic effects and rationale underlying RCS for the management of patients with COPD have not been investigated. Hence, the present study aimed to compare the therapeutic effects of AB and RCS on mMRC (Modified Medical Research Council) Dyspnea Scale, diaphragm excursion movement and FVC pulmonary function as measured by quantitative fluoroscopy and spirometry tests, respectively. We hypothesised that the RCS technique would produce superior changes in the outcome measures than the AB technique in patients with COPD.

2. Materials and methods

2.1. Patient database

Fourteen patients with acute COPD (6 women, mean age, 69.4 $\pm$ 13.34 years) were recruited from the University Hospital. All patients provided informed consent prior to participation in the study. The experimental protocol was approved by the University Hospital Institutional Review Board (WMCSB201703-39) and Korea Center for Disease Control and Prevention ([on]-17-CRI-00003025). The inclusion criteria were as follows: diagnosis of acute COPD; age between 50 years and 80 years; and absence of current medical complications. Exclusion criteria were as follows: presence of 1) a history of surgery for unstable cardiovascular disease (unstable angina, acute myocardial infarction, and severe aortic stenosis) or severe pulmonary hypertension without treatment; 2) critical medical conditions (ischaemic heart disease and intermittent claudication); 3) congenital chest deformity or rib fracture; 4) chest pain; and 5) cognitive impairment [8].

2.2. Experimental procedure

The present study is a randomized, single blinded experimental design where the patients were randomly assigned to either control or experimental group by a random allocation sequence method. To reduce or eliminate experimental biases associated with patients' expectations, experimental information which may affect the patients of the experiment is masked until after the experiment is completed. A consistent experimental procedure was followed using the intervention and standardised tests, including the mMRC

dyspnoea scale, fluoroscopy, and spirometric measurements; these tests were used throughout the pre-test and post-test conditions. All test and intervention were consistently conducted by the same investigators to improve internal validity of the measurements.

2.3. mMRC (Modified Medical Research Council) dyspnea measurement

The mMRC dyspnoea scale is a subjective questionnaire, which is designed to examine the degree of severity of shortness of breath associated with COPD conditions including emphysema and chronic bronchitis. The scale ranges from grade 0 (dyspnoea only with strenuous exercise) to 4 (too dyspnoeic to leave house or breathless when dressing); the higher is the grade, the greater is the dyspnoea. The reliability and validity of the mMRC dyspnoea scale has been well established in a previous study (dyspnoea score ($r = 0.59$ to 0.66) in mMRC) [9].

2.4. Fluoroscopy radiographic measurement of diaphragmatic movement

The advanced fluoroscopy imaging technique (Siemens, Munich, Germany) was the standardised, quantitative radiographic measurement to determine diaphragmatic movement. The radiographic imaging data was acquired with individual baseline data point for the diaphragm motion to normalize the measurement of the diaphragm motion volume. Markers were placed on the rib cage and vertebral bodies in each patient and were used as the base points in the PA chest radiographs for imaging analysis. Patients were instructed to breathe deeply in a standing position, and fluoroscopy was performed while patients took 3 deep breaths. Three consecutive chest radiographs were collected at both maximum inspiratory and expiratory phases using a guided fluoroscopy [10]. Fluoroscopy was performed for 5 seconds at 0.3 mGy per second with a 25 cm square filed. Radiographic imaging data analysis was implemented using a software. The anatomical origin of the diaphragm was drawn at the costophrenic angle where the diaphragm meets the chest wall. The outline of the diaphragm dome was traced by using a mouse; a line was drawn along the silhouette on the radiograph. Vertebral columns at the same level of costal insertion were identified, and transverse lines were drawn from the spinal process of the vertebral columns to the costal insertion of the diaphragm, which is also called the horizontal line. The area of diaphragm motion displacement was assessed according to the area defined by the vertical line of the vertebral column, the horizontal line, and the shadow of the diaphragm dome according to the PA chest radiograph method [11]. A relatively short duration of fluoroscopy was used to assess the change in the diaphragm motion displacement to minimise radiation exposure to patients [12].

2.5. Spirometry volume measurement of pulmonary function

The spirometry (Elite Dx 83001-28, Minnesota, USA) was used to determine the pulmonary function including $\text{FVC}(\%)_{\text{predicted}}$ and $\text{FEV1}(\%)_{\text{predicted}}$. Normal $\text{FVC}(\%)_{\text{predicted}}$ and $\text{FEV1}(\%)_{\text{predicted}}$ are represented as $\text{FEV1} \geqslant 80\%$ predicted and $\text{FEV1}(\%)_{\text{predicted}}/\text{FVC}(\%)_{\text{predicted}} \geqslant 0.7$ [13]. A certified medical technologist who was blinded to the experimental study placed a nose clipper on the nose and a respirator in the mouth. The patients were then asked to perform deep inspiration and then, maximal exhalation; repeated three times. Three consecutive lung functions were collected at both maximum inspiratory and expiratory phases using a spirometry. The expiratory and inspiratory volumes were normalized by obtaining maximal inhalation and exhalation. The volume data analysis about the $\text{FVC}(\%)_{\text{predicted}}$ and $\text{FEV1}(\%)_{\text{predicted}}$ were displayed in the computer monitor and the three best values among the measurements were obtained and saved for the further analysis. $\text{FVC}(\%)_{\text{predicted}}$ is the amount of air that can be forcibly exhaled from the lungs after taking the deepest breath possible, while $\text{FEV1}(\%)_{\text{predicted}}$ is the amount of air that can be forcibly exhaled from the lungs in the first second of a forced exhalation [14].

Table 1
Demographic and clinical characteristics of the patients ($N = 14$)

Characteristic	AB	RCS
Age (years ± SD)	66.14 ± 8.64	69.14 ± 11.61
Sex (male/female)	4/3	4/3
Height (cm)	158.14 ± 7.10	163.28 ± 3.45
Weight (Kg)	55.00 ± 7.43	59.14 ± 10.33
BMI (kg/m^2)	21.84 ± 1.33	22.14 ± 3.88
GOLD* stage (N)	A:2 B:1 C:0 D:5	A:1 B:2 C:0 D:4

GOLD, The Global Initiative for Obstructive Lung Disease; AB, Abdominal Breathing; RCS, respiratory and core-postural stabilisation.

2.6. Intervention

All patients consistently underwent a 30-minute of AB or RCS and successfully completed 20 sessions of the intervention training. For AB technique, the patient was first asked to lie in supine with one hand placing on the upper thorax and the other hand on the abdominal area and performed the inward abdominal movement during expiration and outward abdominal movement during inspiration. If the patient was not able to perform, the therapist monitored and manually guided through the movement [15]. Pursed-lip breathing involved a combination of (slightly) active and prolonged expiration with half-opened lips [16]. This exercise was progressively performed in supine, sitting, standing, and during gait and repeated 5 times. For RCS breathing, the patient was asked to exhale and concentrate (or neutralise) on the thorax and rib cage in a caudal position. Subsequently, maintaining the neutral caudal alignment, the subject was asked to inhale to enable the diaphragm to descend and allow co-activation of the TrA and pelvic floor muscles. The therapist palpated on posterior lateral side from the 10th to 12th ribs, with symmetrical activation against the therapist's fingers while expanding from the 10th to 12th ribs, in a posterior lateral direction. This consists of caudal movement and widening of the intercostal spaces, with a relatively stable rib motion (no cranial motion) in a transverse plane [7]. This exercise was progressively performed in supine, sitting, standing, and during gait and repeated 5 times.

2.7. Statistical analysis

All statistical analyses were performed by using SPSS Statistics 21 (SPSS Inc., Chicago, IL, USA). T-tests, Wilcoxon signed-rank test and Mann-Whitney U test were used to assess the difference of the diaphragmatic movement and pulmonary function between the AB and RCS breathing groups at $\alpha = 0.05$.

3. Results

3.1. Demographic and clinical data

Table 1 summarises no significant differences in baseline data were observed between the groups, indicating homogeneity. GOLD stage was also similar between the groups.

3.2. mMRC (modified Medical Research Council) dyspnoea scale scores

Statistically significant differences were observed between the pre-test and post-test mMRC scores in the RCS breathing group ($P < 0.05$).

Table 2
Comparison of differences in mMRC scores between the two groups

Variables	AB[a]	RCS[b]	Z	P^*
mMRC	0.43 ± 0.53	0.86 ± 0.37	-1.612	0.107

[a]AB: Abdominal breathing. [b]RCS: Respiratory and core-postural stabilisation.

Table 3
Comparison of differences in AB/DNS diaphragmatic movement between the two groups

Variables	AB[a]	RCS[b]	Mean difference	t value	P^*
Diaphragmatic movement (mm^2)					
Lt.	-7807.00 ± 32263.85	62098.43 ± 39354.03	69905.42 ± 19234.25	3.63	0.003
Rt.	26781.14 ± 12362.29	60600.71 ± 23968.39	33819.57 ± 10193.20	3.31	0.006

*independent t-test was significant at $P < 0.05$. Data are mean $\pm$ standard deviation. [a]AB: Abdominal breathing. [b]RCS: Respiratory and core-postural stabilisation.

Table 4
Comparison of the differences in pulmonary function between the two groups

Variables	AB[a]	RCS[b]	t value	P^*
Pulmonary function				
$FVC(\%)_{Predicted}$	3.43 ± 4.23	19.57 ± 11.50	3.480	0.009
$FEV_1(\%)_{Predicted}$	5.00 ± 6.78	14.29 ± 7.86	3.980	0.036

*independent t-test was significant at $P < 0.05$. Data are mean $\pm$ standard deviation.
[a]AB: Abdominal breathing. [b]RCS: Respiratory and core-postural stabilisation.

3.3. Diaphragmatic movement

Paired t-test revealed a significant difference in the right diaphragmatic movement displacement (mm^2) between the pre-RCS and post-RCS ($P < 0.05$).

3.4. Pulmonary function tests

Paired t-test indicated significant differences in indicators of the pulmonary function between the pre-RCS and post-RCS ($P < 0.05$).

4. Discussion

The present study provides the first clinical evidence demonstrating the differential therapeutic effects of the AB and RCS techniques on diaphragmatic movement, pulmonary function, and mMRC dyspnoea scale scores, as determined by fluoroscopy, in patients with acute COPD. As anticipated, RCS breathing improved the diaphragmatic movement and FVC(%) and FEV1(%) better than AB, supporting the superior effect of the RCS breathing technique. However, dyspnoea was improved only in the RCS breathing group. Thus, it is difficult to compare our present findings with previous clinical data because no relevant evidence is available in literature.

Fluoroscopic diaphragmatic movement analysis demonstrated the superior effect of RCS (Lt. = 77%, Rt. = 82%) technique over AB (Lt. = −10%, Rt. = 54%) on diaphragmatic movement. Similarly, the RCS breathing group demonstrated six times higher diaphragmatic descending movement (Lt. =

21%, Rt. = 36%) than the AB group (Lt. = −5%, Rt. = 16%) with respect to patients with COPD. This finding was consistent with previous evidence regarding improved diaphragmatic movement in patients with COPD following a combination of AB and cycle exercises as evidenced by fluoroscopic and ultrasound imaging measurements, respectively [3,8]. Although we cannot explain the reason for the asymmetry in diaphragmatic movement, we wonder that the presence of the liver may limit the excursion of the right diaphragm. This discrepancy in the diaphragmatic movement may have resulted from the methodological difference. The AB technique, which is primarily designed to selectively activate the diaphragm muscle, emphasises on the anterior chest-abdominal excursion. This anterior chest-abdominal expansion movement creates an open scissor-like intra-abdominal pressure, which may further prevent the natural descending diaphragmatic movement. In contrast, the RCS breathing activates the entire breathing and core stabilisation muscle chain including the diaphragm, external oblique abdominis, internal oblique abdominis, TrA, multifidus muscle, and pelvic floor muscles of the cylinder-shaped IAP (intra-abdominal pressure). A possible underlying rationale for a superior descending diaphragmatic movement effect of RCS may be attributed to a coordinated activation of the diaphragm-TrA/IO/EO-pelvic floor-multifidus along with superficial abdominal and erector spinae (respiratory chain) muscles, which generates a cylinder-shaped IAP and expands the chest-abdominal wall in the anterior-posterior-inferior as well as medial-lateral directions [4]. This multi-directional abdominal wall expansion improves air-way clearance and the inspiratory and expiratory lung volume and capacity. Furthermore, patients with COPD initially presented a progressively restricted mobility of the chest-rib cage-abdominal wall structure and associated thoracoabdominal movement loss, which resulted in a compensatory recruitment of the accessory respiratory muscles of the rib cage including upper trapezius, scalene, and sternocleidomastoid muscles [5]. However, after the RCS intervention, all patients were able to activate the diaphragm-respiratory chain muscles, which expanded the abdominal wall and facilitated associated thoracoabdominal movement, and subsequently, inhibited the overactive accessory muscles and lengthened the shortened muscles, thereby improving the dyspnoea condition, which involves intense chest tightening, air hunger, difficulty in breathing, and breathlessness. In fact, spirometric pulmonary function analysis revealed greater improvements in FVC(%) (31%) and FEV1(%) (30%) after RCS breathing than after AB. Similarly, mMRC dyspnoea data showed a greater improvement as a function of RCS. Interestingly, no significant change was observed in the AB group. For assessing COPD symptoms, GOLD 2011 primarily recommended the use of the COPD Assessment Test (CAT) or the mMRC dyspnoea score. CAT is a patient-completed questionnaire used to assess and quantify the health-related quality of life and symptom burden in patients with COPD [17,18,20]. It comprises 8 questions, each of which is presented using a semantic 6-point (0–5) differential scale, respectively [21]. The mMRC dyspnoea scale is a 5-point (0–4) scale used to assess the severity of dyspnoea. CAT is revealed a sensitive tool to differentiate between patients with COPD with and without comorbidities. CAT is more sensitive than mMRC in identifying patients with COPD with comorbidities [22]. Perhaps, the dyspnoea scale represents a subjective feeling of shortness of breath or difficulty in breathing during daily life activities; in addition, mMRC is less sensitive than CAT. Hence, CAT may not be sensitive in discriminating minute changes associated with the intervention. As a result, there may not be a significant difference in the comparison between the groups. Clinically, this technique can be used for patients with pulmonary impairments secondary to neurological conditions, such as stroke or spinal cord injury and traumatic brain injury, which warrant further investigation.

Acknowledgments

This research received financial and administrative support from the Korea Health Industry Development

Institute (grant no. 2019-51-0468) and Brain Korea 21 PLUS Project (grant no. 2019-51-0018) for the Department of Physical Therapy in Graduate School, Yonsei University.

Conflict of interest

None to report.

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