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Original Article

Effect of Proprioceptive Neuromuscular Facilitation on Lung Function in Chronic Obstructive Pulmonary Disease Patients: A Pretest- Posttest Feasibility Study

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What is already known on this topic?

- *Musculoskeletal dysfunction is a major issue in patients with COPD that is linked to the increased use of accessory muscles for respiration. The over-activation of accessory muscles results in tightness and shortening of the muscles. This prevents the patients from doing their functional activity due to poor chest compliances and altered chest biomechanics.*

What does this study add on this topic?

- *The current study depicts the importance of neuromuscular facilitation techniques in addressing the respiratory function through improved recruitment of the inspiratory and expiratory muscles.*
- *In case of altered biomechanics or inactive inspiratory and expiratory muscles, the irradiation principle is used to recruit/reinforce it (e.g., retraction of the scapula while breathing in). Moreover, the symmetrical bilateral and reciprocal arm patterns, torso, and shoulder girdle movements are indirectly used to recruit respiratory muscles, thus encouraging breathing capacity. The PNF training is safe and feasible to administer among patients with COPD.*

ABSTRACT

Objective: Chronic obstructive pulmonary disease (COPD) is considered a global burden with its pulmonary and extra-pulmonary symptoms. The soft tissues surrounding the chest wall are less commonly addressed in planning the treatment for this condition. Therefore, the proprioceptive neuromuscular facilitation (PNF) techniques applied to the chest wall and upper limb and their impact on the respiratory and quality of life outcomes can be studied. The objective of the study is to evaluate the effect of PNF techniques on pulmonary function and health impairment in stable COPD patients.

Methods: This feasibility study based pretest posttest was conducted with 14 participants with COPD Manipal Hospital, Bangalore between April to August, 2018. Participants were assessed at baseline and at the end of 4 weeks of PNF intervention. The outcomes were forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), FEV1/FVC, maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), and St. George respiratory questionnaire (SGRQ).

Results: The FEV1 mean (SD) change of 0.5 ± 0.02 (liter) after 4 weeks of PNF training, thus but FVC and FEV1/FVC did not show statistical significance. Moreover, the respiratory pressures in these patients increased by 0.93 and 0.71 cmH_2O in MIP ($P < .04$) and MEP ($P < .01$), respectively. St. George respiratory questionnaire components showed improvements post-intervention but were not statistically significant.

Conclusion: Proprioceptive neuromuscular facilitation training seems beneficial on FEV1 and the inspiratory and expiratory muscle strength but health impairment among patients with COPD.

Keywords: Proprioceptive neuromuscular facilitation, lung function test, quality of life, chronic obstructive pulmonary disease

Introduction

Chronic obstructive pulmonary disease (COPD) is a complex respiratory condition involving pulmonary and extra-pulmonary manifestations.[1] It is estimated that the disease's global burden in 2019 was 10.3%, or approximately 391.9 million individuals in the 30- to 79-year-old age range.[2] In India, the prevalence is approximately 11.1%.[3] Globally, COPD is the third most common cause of mortality.[4] The pulmonary manifestations of COPD comprise dyspnea, elevated sputum production, decreased exercise tolerance, persistent cough, and ultimately, a decline in overall quality of life.[4] The extrapulmonary manifestations include pain, abnormal posture, decreased bone mineral density, musculoskeletal dysfunction, and a high incidence of vertebral deformities.[5]

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Furthermore, pulmonary hyperinflation contributes chest tightness, decreased ability to generate inspiratory pressures and volumes and increased amount of effort required to breathe among COPD patients.[6] Consequently, the work of accessory muscles of respiration increases. This causes thoracoabdominal desynchrony as the muscles primarily prioritize the arm task over breathing. It leads to exacerbation of dyspnea and limited tidal volume, which further affects chest wall impedance to maintain the trunk and upper arm movement.[7,8]

Interventions targeting thoracic joints and the soft tissues, addressing pain, joint stiffness, and postural and muscular changes have shown positive clinical impact in COPD.[9] Engel et al[10] reported through a study that application of soft tissue manual therapy to the muscles of posterior chestwall showed significant improvement in the respiratory parameters, when combined with the aerobic exercise in patients with COPD. In a similar study by Cruz-Montecinos et al,[11] soft tissue manipulations in the form of myofascial release and muscle energy techniques to respiratory muscles resulted in an immediate improvement in the respiratory outcomes of COPD patients. Additionally, Uysal et al[12] applied muscle energy techniques to the accessory respiratory muscles in fibromyalgia patients that consequently improved the maximal inspiratory and expiratory pressures among them.

Soft tissue therapy of the chest wall can potentially be approached by using proprioceptive neuromuscular facilitation (PNF) that uses the body's proprioceptive system to facilitate or inhibit muscle contraction and also address the motor control of the muscle fibers.[13] We believed that PNF techniques such as rhythmic initiation, combination of isotonics and dynamic reversal applied at chest wall and upper extremities can act on the respiratory muscles of people with COPD. Therefore, we conducted a feasibility study to evaluate the benefits of PNF techniques on pulmonary function and respiratory muscles strength that can further assist in the implementation of a future clinical trial.

The objective of the present study is to determine the feasibility and effects of PNF on pulmonary function, inspiratory and expiratory muscles strength, and health-related quality of life (HRQOL) on stable COPD patients.

Research Question

1. Is proprioceptive neuromuscular facilitation feasible and effective on lung function in patients with COPD?

Methods

Study Design

This feasibility study based pretest posttest was conducted with 14 participants with COPD at Manipal Hospital, Bangalore between April and August, 2018. This feasibility study was approved by the Institutional Research Committee of Manipal College of Health Professions, Manipal Academy of Higher Education and Ethical Committee of Manipal Hospital, Bangalore Hospital. The subjects were recruited from the pulmonary OPD of Manipal Hospital, Bangalore. Hospital.

Sample

Patients with COPD were recruited using convenient sampling. The inclusion criteria were people with stable COPD according to the GOLD criteria[1] and those with 50–75 years of age. The exclusion criteria were people with acute exacerbation of COPD in last 2 months, with a history of abdominal, lung, or spine surgery, and with a history of neurological disorders and those unable to perform pulmonary function testing (cognitive and/or physical impairment).

Procedure

The participants were screened according to the study eligibility criteria and informed consent form was taken seeking their active participation. Demographic and baseline clinical assessment was taken for the participants, following which they received 4 weeks of PNF intervention. Outcomes were assessed at baseline and at the end of fourth week of intervention by a qualified physiotherapist.

Intervention

The PNF techniques were applied at thoracic wall and upper limb to activate the respiratory muscles. The therapist began with rhythmic initiation technique and progressed to a combination of isometrics and then dynamic reversal. All the techniques were given in supine position initially, followed by side lying and sitting.

Rhythmic initiation:[13,14] This technique was performed with the patient in the supine position. In the direct approach to sternum, an oblique downward pressure was applied by the therapist's hand at the sternum. Furthermore, for the costal areas, the hand placement of the therapist was directed at the middle, lower and lateral areas of ribcage. The technique used a quick stretch principle at the end of expiration for each treatment area and reinforced with stretch throughout inspiration.

Combination of isotonics:[13,15] This technique was performed with the patient in side-lying position. The postero-lateral and antero-medial areas of the chest were treated. With the patient in left side-lying position, the therapist placed her hands on the lateral aspects of the right lower ribcage. The pressure was applied in a diagonally caudal direction such that the motion of left side of the chest was resisted by the plinth. Same was repeated in the right side-lying position.

Dynamic reversal:[13,16] This technique was performed with the patient in side-lying position that was progressed to sitting position followed by guided resistance technique. Unilateral arm pattern with short and long lever was performed initially, which was further progressed to bilateral arm pattern. The flexion–abduction–external rotation pattern during inhalation and the extension–adduction and internal rotation pattern during exhalation served as the selective supports for trunk movement during breathing. Afterward, to provide selective resistance to trunk movement during respiration, the dynamic reversal of upper limb flexion–abduction and extension–adduction patterns were performed while coordinating with breath control. The patterns were then incorporated into functional activities.

Each PNF session lasted for 30-40 minutes with a frequency of 20 breaths for 4-5 sets for each position. Three therapy sessions were given per week totaling 12 times over a period of 4 weeks. A rest interval of 2-3 minutes was given after each PNF technique. The treatment sessions were provided by a qualified physiotherapist who was experienced in administering PNF techniques.

Outcome Measures

Pulmonary Function Test

The forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and the ratio of FEV1/FVC were assessed using a handheld spirometer. The procedures for testing the PFT parameters were followed as per the guidelines by American Thoracic Society and European Respiratory Society (ATS/ERS).[17]

Maximal Respiratory Pressure

Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were assessed using a digital manometer (CAREFUSION UK). The testing procedures including patient instructions and maneuver followed the guidelines by ATS/ERS.[18]

St. George's Respiratory Questionnaire

The English version of St. George respiratory questionnaire (SGRQ) was used to assess the subjective respiratory impairments among the patients with COPD. It has 50 items divided into 2 parts. First part is symptoms and second part consists of activity and impact. It is scored on a 4-point likert scale. Total score ranges from 0 to 100 with higher scores depicting more limitations.[19]

Pulmonary function test (PFT), maximal respiratory pressure, and SGRQ were assessed at baseline and at the end of fourth week.

Ethical Consideration

The study was approved by the Institutional Review Board of Manipal College of Health Professions, Manipal Academy of Higher Education. (Date: 23.08.2018, Approval no: CTRI/2018/04/0132.) Informed consent was taken from all the subjects prior to their participation in the study.

Statistical Analysis

Data were analyzed using statistical package for the social sciences (SPSS) version 16.0. Shapirowilk test was used to assess the normality of the baseline outcomes. The data were found to be normally distributed ($P > .05$). So, paired *t*-test was used to analyze the pre and post differences in outcomes within group. The statistical significance level was set at $P < .05$ and confidence interval at 95%. The descriptives were expressed as mean and SD.

Results

Of 24 participants screened for the eligibility, 14 met the inclusion criteria and were enrolled into the study. Baseline demographic and clinical parameters are projected as mean and SD as shown in Table 1. The mean age of the study participants was 68.0 ± 6.2 years. There were 9 male and 5 female subjects diagnosed with stable COPD from 5 to 7 years. The overall mean BMI was 27.58 ± 4.98 kg/m^2. The patients were also assessed for severity of COPD. Among the 14 participants, 4 were with mild COPD, 6 participants with moderate COPD, and remaining 4 participants with severe COPD according to the GOLD criteria. All the patients (N = 14) completed the PNF training and included for the analysis.

Table 2 shows the changes in the outcomes following PNF training. The FEV1 increased from baseline 56.32 ± 7.36 to 56.86 ± 7.38 (lit) after 4 weeks of PNF, resulting in a statistically significant difference ($P < .05$). Although FVC increased from 62.21 ± 8.24 to 63.14 ± 8.16, but it showed no statistical significance. The FEV1/FVC ratio decreased upto 0.6% compared to baseline scores, but no statistical changes were observed. Following 4 weeks of PNF training, the inspiratory and expiratory muscle strength parameters showed statistically significant changes with MIP increase from 57.92 ± 8.01 to 58.85 ± 7.04 mmH$_2$O ($P < .04$) and MEP from 69.14 ± 6.904 to 69.85 ± 6.92 mmH$_2$O ($P < .01$). Figure 1 graphically represents the mean changes of pulmonary outcomes after the intervention. The symptoms, activities, and impact subscores of SGRQ did not show statistical significance following PNF training.

Table 1. Descriptive Characteristic of the Participants

Baseline Characteristics	N = 14 (Mean ± SD), N (%)
Age, mean (SD), years	68.0 ± 6.2
Gender (M/F)	09/05
BMI, mean (SD), kg/m^2	27.58 ± 4.98
Duration of COPD, mean (SD), years	4.92 ± 3.38
Severity, N (%)	
Mild	4 (28.6%)
Moderate	6 (42.9%)
Severe	4 (28.6%)
Associated Chronic Conditions, N (%)	
Hypertension	11 (78.6%)
Diabetes mellitus	12 (85.7%)
Smoking	6 (42.9%)

Values are shown as mean ± SD or N (%).
M/F, Male/Female; BMI, body mass index; COPD, chronic obstructive pulmonary disease.

Discussion

The study determined the feasibility and benefits of PNF on pulmonary function, respiratory muscle strength, and HRQOL among patients with COPD. The study did not observe any adverse events and participants never experienced any discomfort during the training except mild fatigue post training. The dose and dosage of PNF techniques were administered as per the patient's exercise tolerance capacity. The strong arm patterns were used to irradiate the neural impulse and to reinforce the respiratory muscle activation and strength. The progression of exercises performed from supine to side-lying and sitting might have provided optimal thoracic wall compliance and lung ventilation to the patients. To the best of the authors' efforts, this study is one of its kind that utilized the PNF techniques and assessed the FVC, FEV1, and FEV1/FVC parameters, and the improvement in FEV1 is clinically relevant. The increase in FEV1 was approximately 500 mL in this study, which was greater than the minimal clinically important difference (MCID) of 100 mL established for COPD patients.[20] This depicts that the intervention could be helpful in enhancing the FEV1 values in clinical practice. The FEV1/FVC decreased after 4 weeks of treatment but failed to show significant difference. The possible reasons could be a limited number of samples in this study. The improvement in FVC values approximated the significance level. Thus, the intervention showed an overall enhanced pulmonary function among patients with COPD.

These findings are in line with the study by Bhatnagar and Sharma,[14] describing the effect of PNF on respiratory outcomes of male smokers. It is believed that the stretch reflex was activated during the PNF techniques which acted upon the sensory muscle spindles of the intercostal muscles and diaphragm. This improved the ability of these muscles to contract resulting in deeper breaths and improved flow of respiration. According to Malpani et al,[21] muscle spindle firing and discharge transmit a signal to the central nervous system via alpha and gamma motor neurons that further causes the respiratory muscles to contract and relax under the control of Golgi tendon organ (GTO). The PNF techniques could lengthen the intercostals muscle, which improves the direction of anterior upward movement of the upper costal muscle and lateral outward movement of the lower costal muscle, consequently improving the biomechanics of chest movement. Moreover, the flexion-abduction-external rotation pattern and the extension-adduction and internal rotation pattern were performed by the subjects in coordination with inspiration and expiration. These patterns improve the ventilation by maximally elongating and reinforcing the chest wall muscles and opening up the ribs as described in butterfly technique.[22]

The PFT parameters are directly correlated to the respiratory muscle strength among older adults.[23] In the current study, the inspiratory and expiratory respiratory muscle strength showed significant improvement following 4 weeks of intervention. However, it failed to reach the clinically significant difference of 17 cmH$_2$O. This could be addressed in detail through future randomized controlled trials.[24] Muscle weakness, which is common in advanced COPD, is responsible for the reduction in MEP, and hyperinflation is known to impair MIP because it results in the shortening of the inspiratory muscles.[25] In the current study, the strengthening of the abdominals and internal and external intercostal muscles and facilitation of the diaphragm were addressed by using different PNF techniques. After ensuring the relaxed diaphragmatic and intercostal breathing using rhythmic initiation technique,

Table 2. Comparison of Study Outcomes Pre and Posttreatment

Variables	Pretreatment (Mean ± SD)	Posttreatment (Mean ± SD)	Mean Differences	*P*
Pulmonary function				
FVC (lit)	62.21±8.24	63.14±8.16	0.93±0.08	0.05
FEV1 (lit)	56.351±7.36	56.86±7.38	0.5±0.02	0.02*
FEV1/FVC (%)	90.64±6.41	89.92±5.24	-0.62±1.17	0.33
Respiratory Muscle Strength				
MIP(cmH_2O)	57.92±8.01	58.85±7.04	0.93	0.04*
MEP(cmH_2O)	69.14±6.904	69.85±6.92	0.71	0.01*
SGRQ				
Symptoms	82.08±6.3	77.0±13.4	-5.08±7.1	0.16
Activities	39.53±8.31	42.35±20.8	2.8±12.49	0.62
Impact	37.2±6.1	42.3±13.4	5.1±7.3	0.22
SGRQ- Total score	45.0±3.5	46.4±9.1	1.4±5.6	0.57

Values are shown as mean ± SD.
FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; FEV1/FVC, ratio of FEV1 and FVC; MEP, maximal expiratory pressure; MIP, maximal inspiratory pressure; SGRQ, St. George respiratory questionnaire.

the patients with COPD performed combination of isotonic and progressed to dynamic reversal. A combination of isotonics addresses the concentric contraction followed by the eccentric lengthening of the agonist muscles, whereas the dynamic reversal emphasizes the triphasic burst of both agonist and antagonist muscles. This aspect is critical for breathing control. The indirect approach of working on strong arm diagonal patterns might have reinforced the inspiratory and expiratory muscle strength through spatial and temporal summation. This may be the rationale for improved respiratory muscle strength after PNF in COPD patients.

The significantly positive outcomes in FEV1 and inspiratory and expiratory muscles strength did not reflect on the HRQOL assessed using SGRQ among the patients. Literature suggests that health-related outcomes would change over a long time that requires robust training intensity and behavioral adaptation. In a systematic review, Mendes Xavier et al[26] analyzed the effect of pulmonary rehabilitation on COPD patients and reported that the intervention duration of less than 2 months was insufficient to bring about significant changes in HRQOL measures among these patients. Therefore, we believe the dose and dosage of PNF techniques administered in the current study is inadequate to impact the health impairments in COPD. Furthermore, the factors including severity of COPD, age, and the presence of other comorbidities play a crucial role in influencing the SGRQ outcomes.[27] The mean age of the subjects was 68 years, with the presence of hypertension and diabetes mellitus in most of the patient,s which could be imputed to the non-significant difference in HRQOL outcome. Hence the current study with 4 weeks of intervention did not have a significant effect in HRQOL. Future trials require a longer duration of treatment and detailed exploration on the role of comorbidities influencing HRQOL among patients with COPD.

Limitations and Strengths

There were certain limitations in these studies. Firstly, the sample size was small as this was a feasibility study. It limits the generalizability of the results. Future studies should perform the intervention on a larger sample to substantiate the results. Secondly, there is absence of control group in this study. It is difficult to strongly determine if the

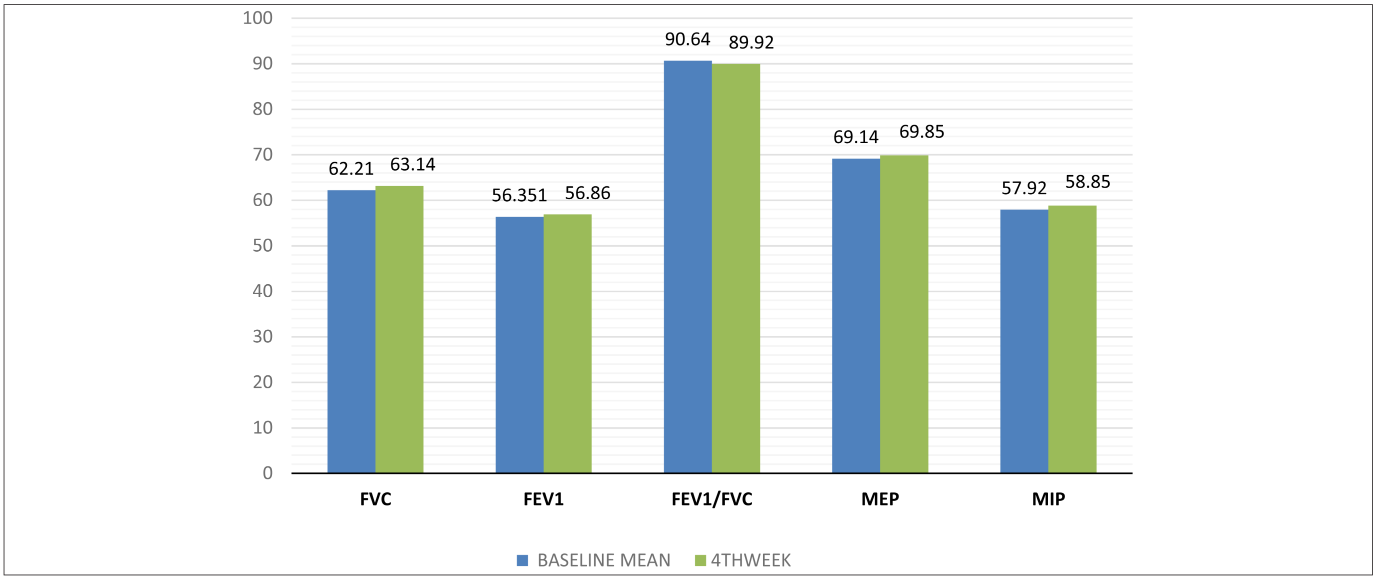

Figure 1. Graphical representations of the mean of baseline and posttreatment respiratory outcomes. Bar graph comparing the mean values of the respiratory outcomes before and after the 4-week intervention. FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; FEV1/FVC, ratio of FEV1 and FVC; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure.

observed changes in outcomes are due to the intervention or other variables. Thus, future studies should incorporate a control group to examine the effect of this intervention and compare it with the conventional treatment. The results were limited to an immediate effect. Future studies are required to study the long-term effects of the intervention. Moreover, the study was limited to a specific geographical location thus the results cannot be generalized.

Conclusion

The PNF techniques are feasible to get administered on the thoracic wall and upper limbs for lung functioning among people with COPD. The PNF training is beneficial in improving FEV1 and the inspiratory and expiratory muscle strength in COPD patients, warranting a well-structured clinical trial to affirm this statement.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: The study was approved by the Institutional Review Board of Manipal College of Health Professions, Manipal Academy of Higher Education (Date: 23.08.2018, Approval no: CTRI/2018/04/013201).

Informed Consent: Informed consent obtained from the participants who agreed to take part in the study.

Peer-review: Externally peer reviewed

Author Contributions: Concept – P.V., S.K.; Design – G.G., P.V.; Supervision – P.V., S.K.; Materials – S.K.; Data Collection – G.G.; Analysis and Interpretation – M.P., P.V.; Writing Manuscript – M.P.; Critical Review – P.V., S.K.

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Declaration of Interests: The authors declare that they have no competing interest.

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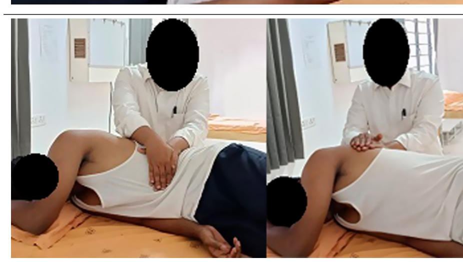
Appendix: Chest PNF Procedure and Techniques

The therapist places the hand (lumbrical grip) on the sternum and applies a slight amount of quick stretch at the end of the exhalation. He asks the person (volunteer) to breathe in (sternum goes up and out) and breathe out (sternum goes in and down). While the person inhales the air, the therapist applies repeated stretches to reinforce the inspiratory muscle activity and then assists the exhalation.

The therapist places both hands on the pectoral region with the lumbrical grip. While the person exhales (blows out air), the pectorals move down and in and the therapist gives a quick stretch at the end of expiration. He asks the person to breathe in deeper (sternum goes up and out) so as to increase upper rib cage compliance.

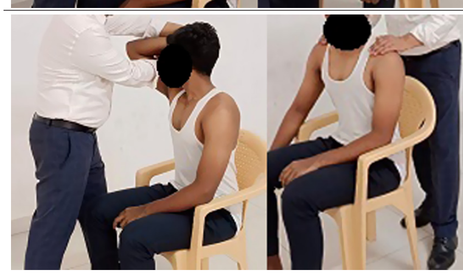
Therapist places the hands near the xiphisternum area bilaterally for lower ribcage mobility. He asks the person to breathe and facilitates the rib cage outwards and upward movement (bucket-handle movement). He assists the movement downwards and inwards towards the umbilicus during exhalation and applies a quick stretch at the end of expiration.

The therapist places their hands and thumbs bilaterally near the xiphisternum and a few centimeters above the umbilicus. They apply a quick stretch at the end of exhalation, which activates diaphragm and is reinforced with repeated stretching (inhale deeper and more). While breathing in and blowing air out, the abdominal belly goes up and down.



The therapist stands behind the person and places their hands in a lumbrical grip, one above another for mobilizing the postero-lateral (backside of the hand) and anteromedial areas of the rib cage. The therapist assists the rib cage inward and downward towards the navel region during exhalation and applies a quick stretch at the end to facilitate the inspiration.

Therapist teaches scapular anterior-depression and posterior-elevation and asks the person to replicate it. Using the rhythmical initiation technique, the person actively takes their elbow near the umbilicus (breathe out passively) and brings the girdle near the ear pinna (breathe in), coordinating with breathing. Scapular posterior-elevation and anterior-depression reinforce (Dynamic reversal) the respiratory muscle strength.

	The flexion-abduction and extension-adduction arm patterns are performed with inhalation and exhalation. The person is given commands to bring a hand from the opposite knee (breathe out), to take it upward, and externally rotate to touch the curtain (breathe in). The anteromedial chest area can also be treated using the principle of irradiation for respiratory muscle recruitment or contract-relax for pectoralis muscle tightness.
	The therapist stands behind the person and teaches postural awareness is taught for better breathing. One hand is placed on the sternum area and the other hand on the medial scapular area. The therapist asks the person to take a deep breath while applying traction from the stabilized hand for trunk extension-rotation. He applies guided resistance trunk extension-rotation, and the person inhales (goes up - extension) and exhales (comes down - flexion).
	The person touches the opposite knee and lifts it up, i.e., unilateral arm abduction-internal rotation (while taking the arm up, breathe in, breathe out when bringing it down). Along with the arm movement, the person performs neck movement as well (e.g., looking at the arm while taking it up). The combination of isotonics and dynamic reversal of the arm pattern can reinforce and strengthen respiratory muscles.
	If the long lever is difficult and the person is too breathless, ask him to take the hand behind the head. So, while taking the arm up towards the head, breathe in, and while coming down, breathe out). To progress it, the PNF strengthening (CoI and dynamic reversal) techniques are taught using arm patterns.
	The person crosses both arms and touches knees (exhale out) and lifts arms over the head (breathe in) with hands (bilateral flexion-abduction). Once the postural and motor control is better (achieve dynamic stability), and the patient is less breathless, he is encouraged to perform bilateral symmetrical arm flexion-abduction coordinated with breathing.