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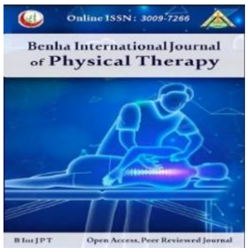

Original research

Effect of Intercostal Stretch on Respiratory Function in Mechanically Ventilated Patients: A Randomized Controlled Trial

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Abstract

Background: As an adjuvant treatment to help clear the airways and encourage productive coughing, chest physical therapy, or CPT, has been used extensively. Proprioceptive neuromuscular facilitation (PNF) techniques use large-scale, three-dimensional spiral resistive exercises to increase the strength of the respiratory muscles. **Purpose:** This study aimed to look into how diaphragmatic proprioceptive neuromuscular facilitation (DPNF) of the intercostal stretch type affected the respiratory function of patients on mechanical ventilation. **Methods:** Forty male patients, aged 50–60, with acute exacerbation of chronic obstructive pulmonary disease (AECOPD) were included in this randomized controlled trial. They were placed in pressure support mode on a mechanical ventilator and divided into two equal groups (n = 20) at random. The study group (A) received the DPNF technique in addition to regular medical care and chest physical therapy (percussion, shaking, and mobilization), while the control group (B) only received regular medical care and chest physical therapy, which includes percussion, shaking, and mobilization. Study variables included arterial blood gases (ABGs), such as PaO2 and PaCO2, which were measured before and after treatment over a period of five to seven days. **Results:** Within-group statistical analysis, both groups (A) and (B) showed significant increase of PaO2 and significant decrease of PaCO2 post-treatment compared to pretreatment mean values. While, between-group statistical analysis showed a significant difference in posttreatment mean values of PaCO2 only between groups (A) and (B) in favor of group (A). with a post-study confidence interval for PaO2 of -2.7 (-8.1, 2.7) and an effect size of 0.026, and for the post-study confidence interval for PaCO2 of -3.4 (-6.1, -0.7) and an effect size of 0.146. **Conclusion:** In mechanically ventilated patients experiencing an AECOPD, intercostal stretch-type diaphragmatic proprioceptive neuromuscular facilitation (DPNF) was an effective strategy to improve respiratory function as an adjunctive technique to routine medical treatment and chest physiotherapy.

Keywords: Diaphragmatic proprioceptive neuromuscular facilitation, Intercostal stretch, Arterial blood gases, AECOPD.

Introduction

While traditional chest physiotherapy techniques, such as percussion and vibration, have been widely used to improve respiratory function, recent evidence suggests that diaphragmatic proprioceptive neuromuscular facilitation (DPNF) may offer additional benefits. By targeting the primary muscle of respiration, DPNF has the potential to enhance diaphragmatic strength and function, leading to improved gas exchange, as reflected by increased PaO2 and decreased PaCO2. However, there is a paucity of research directly comparing the efficacy of DPNF and traditional chest physiotherapy in achieving these outcomes. This study aims to fill this gap by investigating the comparative effects of DPNF and traditional chest physiotherapy on PaO2 and PaCO2 in mechanically ventilated patients.

Complication from prolonged mechanical ventilation can include diaphragm disuse atrophy, oxygen toxicity, pneumonia, alveolar damage, airway injury, and decreased cardiac output.Additionally, prolonged mechanical ventilation may cause volutrauma, barotrauma, and biotrauma, all of which can damage the lungs and initiate the process of ventilator-induced lung injury. [1,2]

Mechanically ventilated-ICU patients usually require additional physical therapy care with their main goals always to keep patients` chest clear and sustain such bed ridden mechanically ventilated patients` joints` mobility as possible therefore permit easier weaning patients` off ventilator [3].Therefore, ICU management require active multidisciplinary team involving physical therapist in line to prevent functional impairments in whom on mechanical ventilation[4]. Studies have shown that the main cause of decreased functional status after an intensive care unit stay is deconditioning, particularly muscular weakness, rather than pulmonary function. Therefore, physiotherapists are in charge of managing the respiratory system in critically ill patients as well as preventing and treating deconditioning. [5,6]

It has been demonstrated that CPT is beneficial for enhancing long-term respiratory physical function. Early mobilization and rehabilitation could improve physical function and outcomes, prevent or lessen bed rest-related sequelae, and shorten hospital stays by increasing ventilator-free days. [7]

Proprioceptive neuromuscular facilitation (PNF) strategies use three-dimensional spiral large-scale resistance workouts to strengthen respiratory muscles. The PNF exercise pattern causes large-scale spiral motions in the lower rib cage and improves pulmonary function in young people. [8]. The intercostal stretch technique of respiratory PNF has a significant impact on enhancing oxygen saturation and lowering respiratory and heart rate in mechanically ventilated patients. The PNF offers a facilitatory signal, causing reflex respiratory action in response. This affects the rate and depth of breathing.[10]. The proprioceptive and tactile stimuli delivered during respiratory PNF cause reflex respiratory movement. Furthermore, intercostal stretch restores the normal breathing rhythm and enhances chest wall movement, therefore promoting chest expansion.[11]. Proprioceptive neuromuscular facilitation is a facilitator technique that can be employed to enhance the mobility of the thoracic wall. Intercostal stretch is the most effective proprioceptive facilitator technique for restoring a functional respiratory pattern.[12]

Examining the effects of intercostal stretch type diaphragmatic PNF on respiratory function in patients on mechanical ventilation experiencing an AECOPD was the aim of this study. Patients with AECOPD may experience a shorter ICU stay, a faster recovery and weaning process, and a decreased rate of morbidity and mortality as a result.

Patients and Methods

From November 2023 to May 2024, forty men who were mechanically ventilated due to AECOPD were recruited from the intensive care unit (ICU) of Gamal Abdel Nasser Hospital, Health Insurance Organization, Alexandria, Egypt. The study was presented to and approved by the Cairo University research Ethics Committee of Physical Therapy. Before participating in the study, all patients or their relatives gave their informed consent.

Forty male mechanically ventilated patients with ages ranging from 50 to 60 and BMIs between 25 and 34 points 9 kg/m2 were eligible to participate. They were on pressure support (PS) mode of mechanical ventilation (MV) with the following settings: Positive end-expiratory pressure (PEEP) less than 8 cm H2O. They were ventilated due to AECOPD, Their Glasgow Coma Scale (GCS) scores ranged from 13 to 15, and they were categorized with moderate (GOLD 2) and severe (GOLD 3) stages of COPD based on the global initiative for chronic obstructive lung disease (GOLD) grading system for the severity of COPD. They also had oxygen saturation (SpO_2) greater than 90 percent. and fraction of inspired oxygen (FiO_2) 0.4 or less. They could obey orders and were cooperative.

Patients could not participate if they met the following criteria: fever exceeding 38.3 °C, unstable hemodynamics, prior thoracic or abdominal surgery that prohibits PNF exercises, history of chest trauma (e.g., rib fracture, flail chest, thoracic vertebra fracture, or chest burns), diseases affecting the peripheral or central nervous system, active infection of the lungs (e.g., tuberculosis), active bleeding (e.g., alveolar hemorrhage, hemoptysis), spinal cord injuries involving the phrenic nerve, chronic renal or hepatic diseases, and severe cardiac complications caused by chronic obstructive pulmonary disease (COPD).

Grouping:

Forty mechanically ventilated patients were divided into two equal groups (n = 20) at random; the study group (A) received the intercostal stretch DPNF technique in addition to their regular medical care and chest physical therapy, while the control group (B) only received these treatments. From the first day the patient was placed on the mechanical ventilator until five or seven days later, the treatment regimen was administered once daily to both groups per the advice of the physician. [13].

Instruments:

Blood gases analyzer (GEM Premier 3000, Werfen Co., 2020, USA) was used to measure arterial blood gases (ABGs) which included PaO_2, $PaCO_2$ as a part of pulmonary function tests [14].

All patients were subjected to history and physical examination and blood gases analysis pre and post the treatment program duration.

Outcome measures:

1- PaO_2:

The goal of the test and its execution were explained to each patient in a concise and easy-to-understand manner.

The instructions were to lie down in a comfortable position with loose clothing for each patient.

A less invasive and more easily accessible method of drawing blood was the arterial line.

In accordance with the protocol for laboratory communication of the intensive care unit at Gamal Abdel Nasser Hospital, the obtained arterial blood sample was sent for analysis.

All patients were tested both before and after the therapy procedure.

Normal range : 75 to 100 millimeters of mercury (mm Hg)

2- $PaCO_2$:

The test's objective and methodology were explained to each patient in a clear, concise manner.Every patient received instructions to dress loosely and in a comfortable, relaxed position. An arterial line, which was more accessible and less painful, was used to draw arterial blood samples. Gamal Abdel Nasser Hospital's ICU department laboratory communication protocol was followed when sending the obtained arterial blood sample for laboratory analysis. The test was administered to every patient both before and after the course of treatment

.Normal range : 35 to 45 mmHg

Intervention:

Group A: Diaphragmatic Proprioceptive Neuromuscular Facilitation (DPNF) with Intercostal Stretch

- Intercostal Stretch:
  - A PNF-based technique was performed for 20 seconds, once daily, for 5-7 consecutive days.
  - The therapist manually stimulated the diaphragm, followed by a one-minute rest period.
  - Verbal cues were used to guide the patient's breathing pattern, focusing on deep inhalation and exhalation.
  - The therapist applied gentle pressure to the costal margins to facilitate diaphragmatic elongation in a posterior-superior direction.

Group B: Routine Chest Physiotherapy

- Percussion and Mobilization:

Traditional chest physiotherapy techniques, including percussion and mobilization, were administered for 30-40 minutes, once daily, for 5-7 consecutive days.

Sample size calculation :

The patient population was determined using G*Power (version 3.1). 9.2; Franz Faul; University of Kiel, Germany. The t-test was implemented in this investigation. The type II error was at 80 percent power, while the type I error was at 95 percent (alpha level: 0.05). From the pilot study conducted on patients with AECOPD who were undergoing mechanical ventilation, it was determined that the primary dependent variable (arterial blood gases) had an effect size (Cohens d) of 0.8. A minimum of 40 patients was necessary for this analysis.[17].

- ***Assessment of eligibility***:

Out of the 73 patients who had their eligibility evaluated for this study, 26 didn't fit the criteria of inclusion , and 7 patients declined to take part. Twenty patients each were chosen at random from the remaining 40 patients to form two groups. All assigned patients underwent statistical analysis and follow-up.

Statistical analysis:

All statistical tests used the statistical package for social studies (SPSS) for Windows (IBM SPSS, Chicago, IL, USA) version 20. The mean and SD of the participants were ascertained using descriptive statistics. To determine the mean age (years), weight (kg), and height (cm) of the two groups, descriptive statistics and an unpaired t-test were used. Data normality was assessed using the Shapiro-Wilk test, which revealed that the PaO2 and PaCO2 variables were normally distributed. Variance homogeneity Levene's test was used to assess the homogeneity between groups, and the results showed that the data was normally distributed and had variance homogeneity. To investigate the effects of treatment (between groups) and time (pre versus post), a mixed 2 x 2 MANOVA was used. For all statistical analyses, the significance level is set at $p < 0.05$.

Results

In terms of participant characteristics, the mean values of age, weight, and height did not significantly differ between the two groups ($p>0.05$). **Table 1**

Table 1. *General characteristics of subjects of three groups.*

Subject characteristic	Group A	Group B	t-value	p-value
Age (years)	55.15 ± 2.89	54.2 ± 3.59	0.92	0.363
Weight (kg)	83 ± 11.77	81.95 ± 11.79	0.28	0.780
Height (cm)	173.85 ± 8.82	175.4 ± 8.52	0.565	0.575

Data was expressed as mean ± standard deviation

The mean PaO2 values in each study and control group increased statistically significantly from the pre- to post-study period (p=0.001). Additionally, the mean PaO2 values for the two groups before and after the study did not differ statistically significantly (p = 0.691 and 0.321, respectively).

In each group study and control, there was statistically significant decrease of mean values of PaCo2 between pre and post study (p=0.001). Also, there was no statistically significant difference of mean value of PaCO2 between both groups pre study (p = 0.958), while there was statistically significant difference post study (p = 0.015). **Table 2**

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Table (2): *Comparison between pre and post-study mean values of PaO_2 and $PaCo_2$ between and within groups*

Measured variables	Study group (n=20)	Control group (n=20)	MD(95% CI)	P value	η^2
PaO_2					
Pre-study	62.95 ± 4.7	62.4 ± 3.97	0.55 (-2.2, 3.3)	0.691	0.004
Post-study	69.85± 11.4	72.55 ± 3.76	-2.7 (-8.1, 2.7)	0.320	0.**026**
MD (95% CI) P-value[1]	-6.9 (-10, -3.7) 0.001*	-10.2(-13.3, -7) 0.001*			
$PaCo_2$					
Pre-study	57.5 ± 6.41	57.4 ± 5.61	0.1 (-3.8, 4)	0.958	0.001
Post-study	47.8 ± 3.83	51.2 ± 4.58	-3.4 (-6.1, -0.7)	0.015 *	**0.146**
MD (95% CI) P-value[1]	9.7 (8.4, 10.8) 0.001*	6.2 (4.9, 7.5) 0.001*			

*Data is represented as mean ±SD, *: significant, η^2: partial eta square, MD: mean difference, CI: confidence interval*

Discussion

Aim of This study is to investigate the impact of intercostal stretch-based diaphragmatic proprioceptive neuromuscular facilitation (DPNF) on the respiratory function of mechanically ventilated patients.

AECOPD could be expressed by worsening of bronchial obstruction and its mucosal edema, plus sputum production. Therefore, reduced pulmonary ventilation would lead to pulmonary gas exchanges disturbances, requiring ICU to be kept on mechanical ventilation (MV), and continuous monitored their vital signs thus permits continuous vigilant medical care [18,19]

Extended mechanical ventilation for AECOPD patients was associated with numerous serious and threating complications including ventilator induced lung injury that refers to both pulmonary and extrapulmonary injuries such as barotrauma due to excess pressure, volutrauma because of extra volume delivered, atelectrauma as a result of repetitive alveoli opening and closure, and biotrauma based on systemic dysfunction that leads to release of multiple inflammatory mediators, as well oxygen toxicity [20.]

Increased chest wall mobility and, by extension, chest expansion, can be achieved with the use of proprioceptive neuromuscular facilitation (PNF), a facilitator technique. When it comes to re-establishing a regular breathing pattern, the most effective proprioceptive facilitator technique is the intercostal stretch. Additional techniques include abdominal co-contraction, moderate manual pressure, perioral pressure, rear basal area stretching, and higher and lower thoracic spine vertebral pressure. In order to restore function, PNF improves muscular strength and endurance while also easing mobility, stability, control, and coordinated movement.

To the best of our knowledge, this is the first study to evaluate how the intercostal stretch DPNF technique affects the level of ABGs in patients on mechanical ventilation. Therefore, the purpose of this study was to examine how the intercostal stretch DPNF technique affected respiratory function in patients with AECOPD who were on *mechanical ventilation as an adjunct to a regular chest physical therapy program. According to the study's findings, both the study (A) and control (B) groups experienced a significant rise in PaO2 and a significant fall in PaCO2. Additionally, there was a significant difference. only between groups in favor of the research group (A) in terms of posttreatment mean values of PaCO2 and group study (A) had a superior imporvment in statistical results with post study confidence interval for PaO2 -2.7 (-8.1, 2.7) and effect size for (0.026) and for post study confidence interval for PaCO2 -3.4 (-6.1, -0.7) and effect size (0.146).*

In agreement with the present study, Zhou et al.[13] *compared the effects of threshold inspiratory muscle training (TIMT) and proprioceptive neuromuscular facilitation (PNF) versus TIMT alone on respiratory function in neurocritical patients who experienced a weaning failure. This was determined through a randomized controlled trial. Of the 50 patients in the study who were intubated and on mechanical ventilation, 25 were placed in the experimental group (PNF + TIMT), and the remaining 25 were placed in the control group (TIMT).*

Consistent with the present investigation, Zwoliński et al.[11] *investigated the viability of PNF approaches in 61 mechanically ventilated ICU patients. Patients were randomly allocated to either the rhythmic initiation technique (RIT) group or the initial stretch technique (IST) group, with outcome measurements including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and oxygen saturation (SpO2), and no control group was included. No statistically significant variations were seen among these individuals concerning demographic characteristics such as age, weight, and height.*

Consistent with our findings, Ashtankar et al. conducted a comparison research to evaluate the efficacy of PNF and chest physiotherapy in conjunction with chest physiotherapy alone on SPO2, heart rate (HR), respiratory rate (RR), and lung compliance. Thirty people from the ICU were included in this study and divided into two groups: Group A received PNF and chest physiotherapy, whereas Group B received chest physiotherapy alone. Post-intervention saturation of oxygen (SPO2) improved in both groups, with group A exhibiting a more significant enhancement than group B.

Likewise, Gupta et al.[21] *The effects of the anterior basal lift and intercostal stretch techniques on the heart rates, peripheral oxygen saturation, and respiratory rates of intensive care unit patients were investigated in 21. The respiratory rate, heart rate, and SpO2 of the group using the anterior basal lift technique were 21.46± 2.38, 121.73± 6.27, and 95.13± 1.45, respectively. When intragroup differences were compared before and after treatment using the paired t-test, the results revealed a highly significant difference in both groups' heart rates (p=0.054), respiratory rates, and SpO2 (p=0.000). The independent t-test of the post-intervention scores shows a highly significant difference between the intervention groups (p<0.05). The group that employed the intercostal stretch technique was shown to have a significantly higher SpO2 (p=0.000).*

The intercostal stretch is more efficient at lowering heart rate, respiration rate, and oxygen saturation.. The significant changes in these parameters suggest that the intercostal stretch can enhance respiratory function and potentially lower $PaCO_2$ levels in critically ill patients [22].

Proprioceptive feedback from the diaphragm during PNF exercises may enhance neuromuscular coordination, allowing for more controlled and efficient breathing patterns. This improved coordination can contribute to maintaining or reducing $PaCO_2$ levels by optimizing respiratory mechanics [23]*. The diaphragmatic PNF technique can influence alveolar ventilation. Increased diaphragmatic activity can lead to more effective lung inflation and deflation, which is essential for maintaining normal $PaCO_2$ levels* [24]*. According to the previously mentioned explanations, the intercostal stretch DPNF technique could improve breathing in patients with AECOPD who are on mechanical ventilation by lowering the effort required to breathe and the energy expenditure of the working respiratory muscles.*

Conclusions:

This study aimed to evaluate the impact of intercostal stretch-based diaphragmatic proprioceptive neuromuscular facilitation (DPNF) on the respiratory function of mechanically *ventilated AECOPD patients. While both intervention and control groups showed significant improvements in PaO2 and PaCO2, the DPNF group demonstrated superior post-treatment PaCO2 levels. These findings suggest that DPNF, when added to routine chest physiotherapy, may enhance respiratory gas exchange in this patient population. Further research is needed to confirm these findings and to optimize the dosing and duration of DPNF.*

Limitations:

This study had some limitations included small sample size that lowered the statistical power of the analysis, short follow-up period, single-center study that made the results less generalizable, and sex-dependent study included only men patients.

Recommendations:

In future studies, we recommend further investigations with larger and stratified sample sizes involving both sexes, longer duration of follow-up to detect the long-term possible effects of intercostal stretch DPNF technique, multi-center studies for more generalized results, and utilizing a variety of outcome measures, including subjective assessments (e.g., quality of life, dyspnea scales) alongside the objective measures (e.g., PaO2 and PaCO2) for a more holistic understanding of this technique effects

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