RESEARCH PAPER

EFFECTS OF DIAPHRAGMATIC STRETCHING TECHNIQUE ON PULMONARY FUNCTIONS IN ICU PATIENTS

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ABSTRACT

Background

During the ICU stay there is development of muscle weakness that is referred to as "intensive care unit acquired weakness" (ICUAW), also reduces force generating capacity of muscle. Normal function of skeletal muscle depends on the strength of the muscle which gets detoriated either by muscle wasting or impaired contractility (muscle-specific force), which ultimately leads to weakness. Diaphragm is the primary muscle which gets impaired contractility during ICU stay. Stretching has traditionally been included among the therapeutic approaches to respiratory pathologies that increases force generation significantly, which is referred as "residual force enhancement".

Objective

The aim of this study is to find effectiveness of diaphragmatic stretching technique on pulmonary functions (Pulmonary function test, chest expansion, respiratory rate and oxygen saturation) in ICU patients.

Methods

Total number of 12 patients was taken having hemodynamic stable admitted in ICU. Further patients were selected based on inclusion and exclusion criteria. After taking the demographic data and baseline values of the outcome measures [Pulmonary function test includes (FEV1, FVC, PEFR, MVV), chest expansion, respiratory rate and oxygen saturation], diaphragmatic stretching technique was performed one time for 5-7 minutes. All the outcome variables were recorded immediately after the intervention. The t-test for paired samples was used to compare the results of the outcome measures before and after treatment.

Results

There was statistically significant improvements ($p<0.05$) in FEV1 and FVC with highly significant improvements ($p<0.001$) in PEFR and MVV, along with a highly significant reduction in respiratory rate with significant increase in oxygen saturation and chest expansion (middle and lower) following the intervention.

Conclusion

Diaphragmatic stretching technique showed improvement in pulmonary functions in ICU subjects.

Keywords: Diaphragmatic stretching, Pulmonary functions, ICU patients, ICUAW, FEV1, FVC, PEFR, MVV, Respiratory rehabilitation.

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Introduction:-

The term 'ICU' known as intensive care unit, is a special department in hospital that provides intensive treatment. There are many evidences which suggest that during the ICU stay there is development of muscle weakness that is referred to as "intensive care unit acquired weakness" (ICUAW). ICUAW majorly affects to respiratory muscle and also affects peripheral muscle [1]. Critical illness polyneuropathy (CIP) [2] and critical illness myopathy (CIM) [3] or both [4] evokes ICUAW during period of critical illness also reduces force generating capacity of muscle. Normal function of skeletal muscle depends on the strength of the muscle which gets deteriorate either by muscle wasting or impaired contractility (muscle-specific force), which ultimately leads to weakness. The rate varies from 11%, at 24 hours of ICU stay, to as high as 67%, if the stay is ≥10 days [5]. It is well defined that muscle unloading/inactivity leads to a loss of contractile proteins will leads to loss in muscle size, which further results in reduced myocyte-specific force [6]. Even in the absence of these phenomena, contractile function is directly impeded due to cellular signaling within the intact muscle fibers of critically ill patients, with or without concurrent induction of changes in muscle size/mass, at least in the short term [6].

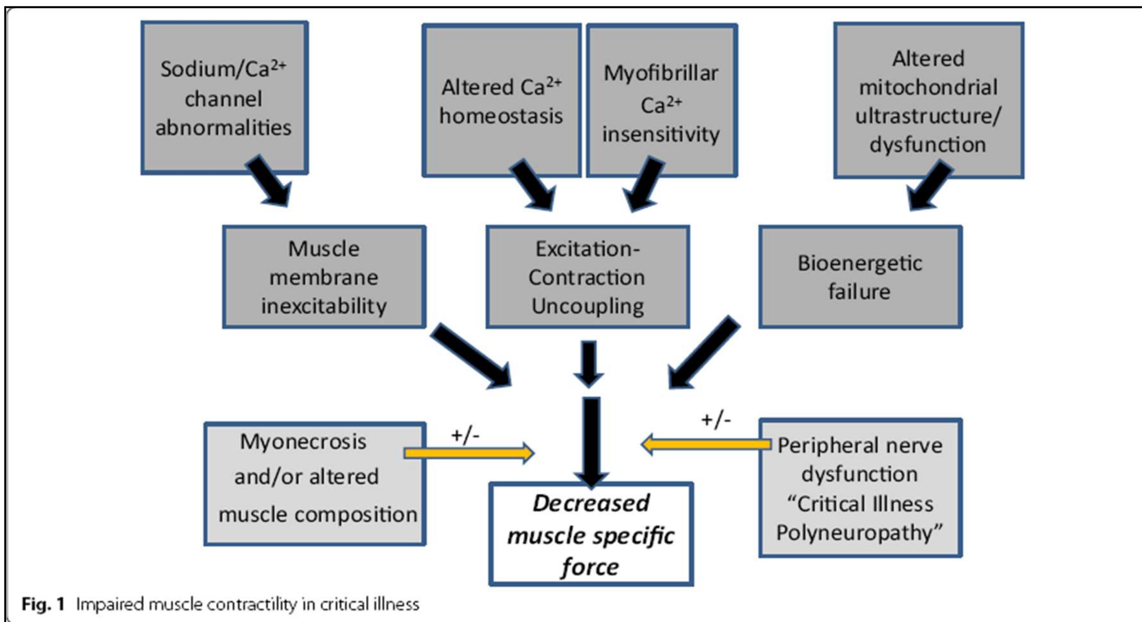

Fig.1 Impaired muscle contractility in critical illness [6]

Although mechanical ventilator is commonly used as supportive therapy for acute lung injury, evidence suggests that it may itself contribute to and perpetuate lung damage paradoxically. A term called as ventilator-induced lung injury (VILI) is used when ventilator itself creates dysfunction in diaphragm muscle fiber due to atrophy of its fibers [7]. This phenomenon is known as ventilator-induced diaphragmatic dysfunction (VIDD)[8], although it may affect other respiratory muscles as well. Diaphragm is a distinctive muscle that normally function in a negative pressure environment along its pleural surface providing a stretch-induced hypertrophic stimuli, which gets reduce or lost during the application of positive pressure ventilation [9].

The diaphragm is both the primary muscle of ventilation and the physical barrier that separates the thorax from the abdomen. Costal fibers of diaphragm originate from sternum and rib; the Crural fibers originate from vertebral bodies. It is inserted in central tendon [10]. Diaphragm gets contracted during inspiration which pulls lung downwards and gets relaxed during expiration. The vertically travelling coastal fibers of the diaphragm, lie close to the inner wall of the lower rib and makes a functional unit known as zone of apposition [11]. During inspiration, pressure increases in the abdomen and decreases in the thorax and vice versa during expiration [11]. The muscle is unique as they consist of fatigue resistant muscle fibers; they are controlled by both voluntary and involuntary mechanisms [12].

To measure lung volume and capacity, a test is used called 'Pulmonary Function Test or Lung Function Test'. This test is used to assess the functional status of the respiratory system both in physiological and pathological condition. It measures the volume of the air breath in and out in quite breathing as well as forced breathing [13]. The Maximum Voluntary Ventilation test (MVV) or Maximum Breathing Capacity (MBC) measures the maximum ventilation of a patient. It depends on a patient's lung volume, muscular strength and endurance responsible for breathing and airway resistance including overall integrity of the thoracic cage [14].

Manual therapy includes skilled hand movements and passive movements of joints and soft tissue which shows improvement in tissue extensibility, induces relaxation, modulates pain, increases range of motion, and reduce soft tissue swelling [15]. Thoracic manual therapy mainly includes stretching of respiratory muscle, soft tissue massage and myofascial release [16]. These techniques are used to improve movements of chest and spine, to improve circulation, and to improve pulmonary functions [17]. One of the studies shows that stretching of the respiratory muscles improves vital capacity, improves chest wall movement, and reduces dyspnoea thereby counteracting the effects of COPD [18]. There are very few quality research in this area and no evidence is found for the application of stretching of diaphragm in ICU patients.

Stretching is one of the techniques in physical exercise which elongates the muscle to its fullest length. Stretching is used to improve flexibility, to improve range of motion, to improve muscle control, to improve performance, to improve posture, and to reduce muscular stress. There are evidence that when activated skeletal muscles are stretched, the force increases significantly, which is referred as "residual force enhancement" [19]. One study shows that stretching technique of the diaphragm can improve contractile properties whereby improving pulmonary function [20]. This study aims to test hypothesis by

utilising direct diaphragm stretching technique effectiveness on pulmonary functions and chest excursion.

Materials and Methods:-

Study Design: One-Group Pretest- Posttest Design.

Inclusion criteria:

- The subjects admitted in ICU.
- The adult subjects of any age / genders.
- The subjects breathing: on air / on simple O_2 mask, with low oxygen requirement.

Exclusion criteria:

- Subjects in ICU, who are psychologically imbalance, not oriented and are unconscious.
- The subjects with large ascites.
- The subjects on ventilator and high O_2 mask.
- The subjects having any recent incision on technique vicinity.
- Severe unstable hemodynamic.
- Patients having recent history of chest wall or abdominal trauma
- Patients having chest wall deformity.

Intervention/Procedure:

Study procedure:

The study was approved by the Ethics Committee. Based on inclusion and exclusion criteria patients were selected in the part of research. The purpose of study was explained to each patient and a written informed consent were taken before including them in the study. After taking all anthropometric measures; pre test respiratory rate, oxygen saturation, chest expansion and spirometry measures were taken. After that, diaphragm stretching technique was performed on patients in ICU as described previously by Chaitow et al [24]. After completion of the technique, post test respiratory rate, oxygen saturation, chest expansion and spirometry measures were taken immediately.

Diaphragmatic Stretch Technique: - Each patient is seated in erect position. The therapist stood behind the patient and passed his hands around the thoracic cage, carefully introducing fingers under the costal margins. The patient slightly rounded the trunk in order to relax rectus abdominis. As the patient exhaled the therapist grasped the lower ribs and costal margin and eases their hands caudally. This traction was maintained as the patient inhales, causing the doming effect of diaphragm for 5-7 min. The pull towards the floor is maintained for several subsequent cycles of exhalation and inhalation, even if the finger/hand contact on lower ribs and costal margin is lost, leaving only soft tissue hold on the tissue as shown in Fig.2. This caudal traction on soft tissue is sufficient to maintain effect on diaphragm [24].

Fig.2 Diaphragmatic stretching technique

Outcome Measures:

1] Pulmonary Function Test

Spirometry is used to assess severity of individual patient's respiratory disease and their response after diaphragm stretching technique and is regarded as the gold standard measure of respiratory function [25]. Pulmonary function test was reported as per 'new ATS/ERS pulmonary function test interpretation guidelines'[23]. Pre test and immediate post test spirometric values were recorded of the following variables: forced vital capacity (FVC):- defined as the maximal volume of airthat can be forcefully exhaled with maximal effort , forced expiratory volume in the first second (FEV1), peak expiratory flow rate (PEFR):- indicate only the greatest expiratory flow

rate, and maximum voluntary ventilation (MVV):- reflects patient cooperation and effort, the ability of the diaphragm and thoracic muscles to expand the thorax and lungs, and airway patency.

2] Chest excursion

The chest expansion is measured by placing tape around the chest at three different levels (1) Under the axillae for apical thoracic expansion, (2) At the nipple line or xiphisternal junction for mid thoracic expansion, and (3) At the T10 rib level for lower thoracic expansion. Once patient perform full exhalation as much as possible, the first chest measurement was taken, after that second measurement was taken once patient performed full inhalation as much as possible [26]. The difference of the two measurements was recorded as chest excursion. The chest excursion was measured before and immediately after diaphragmatic stretching technique.

3]Respiratory rate

The normal resting adult rate of breathing is 12 to 18 breaths/min. The respiratory rate was counted by observing out and in movement of the abdomen or chest wall. The patient was unaware of the respiratory rate that was being counted [27]. The respiratory rate was measured before and immediately after diaphragmatic stretching technique.

4] Oxygen saturation

Pulse oximeter is a portable noninvasive monitor that is used to estimate arterial blood oxyhemoglobin saturation levels [27]. Oxygen saturation was measured before and after diaphragmatic stretching technique.

Statistical Analysis:

The t-test for paired samples was used to compare the results of the outcome measures before and after treatment. The collected data were analysed using statistically package of social sciences (SPSS) version 26.0. It was analysed for 12 subjects. The data was analysed by setting confidence interval (CI) to 95%. A p-value less than 0.05 were considered as statistically significant.

Results:-

Baseline characteristics of the patients such as Age, Gender, BMI, Smoker, Mode of oxygen requirement, Patient weaned from ventilator, and Primary diagnosis of patients are shown in (Table 1).

Table 1: Baseline characteristics of the patients included in the study.

Variables	**Percentage**	**Number of patient (n)**
Age 48.66 ± 18.46 (Mean ± SD)	100%	12
BMI 24.9 ± 5.18 (Mean ± SD)	100%	12
Gender Male Female	 66.67% 33.33%	 8 4
Smoker Yes No	 0% 100%	 0 12
Mode of oxygen requirement On air With low O_2 requirement (On O_2 mask / Nasal cannula)	 41.6% 58.3%	 5 7
Patients weaned from ventilator Yes No	 33.33%	 4

	66.67%	8
Primary diagnosis of patients Post renal transplant Pneumonia Diabetes mellitus Post covid status Post mastectomy	 33.33% 25% 33.33% 25% 8.33%	 4 3 4 3 1

Diaphragmatic stretching technique showed a significant result (p<0.05) in spirometric measures of FVC (p=0.04) and FEV1 (p=0.049), and showed highly significant result (p<0.001) in PEFR (p=0.00085) and MVV (p=0.00086) (Table 2).

Table 2: Comparison of spirometric values between pre and immediate post diaphragmatic stretching technique.

Spirometric values (liters).			
Variables	Pre-intervention (Mean ± SD)	Post- intervention (Mean ± SD)	p<0.05
FVC	1.64 ± 0.81	1.77 ± 0.75	0.04*
FEV1	1.53 ± 0.68	1.63 ± 0.63	0.049*
PEFR	220.16 ± 89.80	273.91 ± 96.06	0.00085**
MVV	61.08 ± 30.07	73.66 ± 30.07	0.00086**

***p < 0.05 (significant); **p < 0.001(highly significant); FVC: forced vital capacity; FEV1: forced expiratory volume in the first second; PEFR: peak expiratory flow rate; MVV: maximum voluntary ventilation; SD: standard deviation.**

Diaphragmatic stretching technique showed a significant result (p<0.05) in chest excursion at middle thoracic expansion (p=0.026), and showed highly significant result (p<0.001) in lower thoracic expansion (p<0.001). But there was no significant result in apical thoracic expansion (Table 3).

Table 3: Comparison of different levels of chest excursion between pre and immediate post diaphragmatic stretching technique.

Chest excursion (Difference between inspiratory and expiratory chest expansion in centimetres).			
Variables	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	p<0.05
Apical thoracic expansion	3.08 ± 0.9	3.33 ± 1.15	0.081
Middle thoracic expansion	2.83 ± 1.33	3.33 ± 1.15	0.026*
Lower thoracic expansion	3.41 ± 1.31	5.16 ± 1.46	<0.001**

***p < 0.05 (significant); **p < 0.001(highly significant); SD: standard deviation.**

A significant result (p<0.05) was obtained in oxygen saturation (p=0.015) and a highly significant result (p<0.001) was obtained in respiratory rate (p<0.001) after completing diaphragmatic stretching technique showed in (Table 4).

Table 4: Comparison of respiratory rate and oxygen saturation pre and immediate post diaphragmatic stretching technique.

Respiratory rate (breaths per minute).
SpO_2 (percentage).

Variables	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	$p<0.05$
Respiratory rate	25.25 ± 3.41	21.83 ± 3.21	<0.001**
SpO_2	98.08 ± 1.67	99.08 ± 0.9	0.015*

***$p < 0.05$ (significant); **$p < 0.001$(highly significant); SpO_2: oxygen saturation; SD: standard deviation.**

Discussion

Due to critical illness, stay in ICU reduces force generating capacity of muscle, sarcopenia and dynapenia (loss of strength and power not necessarily associated with loss of muscle mass) which ultimately leads to respiratory muscle weakness [6]. Thus to improve or to retard decrease in muscle contractility and to improve force generation of diaphragm muscle, stretching technique was applied. Due to the anatomical access to the diaphragm, an anterior approach was performed and only the costal portion of the diaphragm was stretched.

The result showed statistically significant ($p<0.05$) increase in spirometric measures of forced vital capacity (FVC) and forced expiratory volume in the first second (FEV_1). These short-term changes following a single stretching session may be related to temporary alteration in the elastic properties of the muscle, which, although not permanent, can be therapeutically beneficial for immediate effects such as enhanced sports performance [20]. A similar result was found by Gonza´lez-A´lvarez FJ, et al. applied diaphragmatic stretching technique in healthy individuals showed a significant improvement in FEV1 and FVC values [20].

PEFR indicate only the greatest expiratory flow rate and MVV mainly indicates endurance of respiratory muscle. This increase in PEFR and MVV after stretching can be explained as 'residual force enhancement'[19]. Skeletal muscles subjected to stretch during activation demonstrates a marked increase in force production, along with reduced energy consumption [19]. Following the stretching, the generated force gradually declines and reaches at a level greater than the force produced at the corresponding length at a time of isometric contractions at same muscle length [19]. None of the previous studies have evaluated the effects of diaphragmatic stretching technique on PEFR and MVV measures. But Gonza´lez-A´lvarez FJ, et al. applied diaphragmatic stretching technique in healthy individuals and had got a significant improvement in maximal inspiratory pressure (MIP) and the maximal expiratory pressure (MEP) [20].

There was no significant result ($p>0.05$) found at upper thoracic expansion. There was significant result ($p<0.05$) at middle thoracic expansion and a highly significant result ($p<0.001$) at the lower thoracic expansion, this can be justified as the nearest area to the diaphragm, where the stretching was performed. Maybe the reason behind the above findings is due to reduce diaphragm muscle stiffness, resulting in enhanced rib cage motion and improved the length-tension relationship [11].

There is a highly significant ($p<0.001$) reduction in respiratory rate after diaphragmatic stretching. This decrease in respiratory rate can be explained by decreases in the passive tension in the muscle after stretching, and it is due to stress relaxation. Stress relaxation can be corelated with reduction in stress (force per unit area) in a material elongated and kept at a constant length. When a static stretch is hold, reduction in muscle tension is felt by the patients. Holding passive stretches even for 20 to 30 seconds induces the stress relaxation and provides an acute 10 – 30% reduction in passive tension [21]. But Yelvar GDY found that a single session of Manual Therapy including the Diaphragmatic Release improved pulmonary function, and reduced dyspnoea, fatigue, heart rate and respiratory rates in patients with severe COPD [28]. In their study, they have discussed that diaphragmatic release caused stimulation of the parasympathetic system, which would have decreased dyspnoea, fatigue, and rate of respiration which enhanced pulmonary function and oxygen saturation [28]. This can be correlated with diaphragm stretching as this technique may have activated parasympathetic system and had regulated the relaxation of muscle, thus the force of contraction of diaphragm muscle would had increased during inspiration and more amount of oxygen would have consumed.

Thus, in this study, improvement in pulmonary functions can be hypothesized that because of acute stimulation of the muscle spindle during muscle stretching enhanced sensory afferent stimulus and increased neuromotor response which ultimately lead to greater muscle tension, improving viscoelastic property, reduced muscle stiffness and enhanced thoracic mobility [22].

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