A Randomized Controlled Trial of The Diaphragmatic Manual Therapy on Respiratory and Cardiovascular Functions in Severe Pneumonia Patients

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Abstract

Background: Pneumonia is the leading cause of ICU admissions and a common secondary infection in critically ill patients, often leading to septic shock and requiring respiratory support. The role of diaphragmatic and right ventricular (RV) function evaluation in pneumonia prognosis is not well understood. Diaphragmatic manual therapy, including diaphragmatic stretch and manual diaphragm release, aims to improve respiratory function by enhancing diaphragm mobility and flexibility. Methods: This randomized controlled trial included hospitalized adults with severe pneumonia at Tanta Faculty of Medicine, Beni-Suef Faculty of Medicine, and Zhraa Hospital, Faculty of Medicine for Girls. Participants were randomly assigned to a control group receiving standard medical treatment or an interventional group receiving additional diaphragmatic manual therapy. The interventional group was further divided into two subgroups: one receiving the diaphragmatic stretch technique (DST) and the other the manual diaphragm release technique (MDST). Diaphragmatic excursion (Dex), RV and pulmonary functions were evaluated using ultrasonography and echocardiography before and after the interventions. Results: Thirty cases were included, with ten patients in each group. There were significant improvements in pulmonary function tests (FEV1/FVC), arterial blood gases, and diaphragmatic mobility in the interventional groups compared to the control group. Both DST and MDST showed significant improvements in diaphragmatic excursion and RV functions. However, there were no significant differences between the two techniques. Conclusion: Both DST and MDST can be safely recommended for patients with severe pneumonia to improve diaphragmatic excursion, chest expansion, and RV functions. These findings suggest that diaphragmatic manual therapy could be an effective adjunctive treatment in the management of severe pneumonia, warranting further research to explore its long-term benefits and applications.

Keywords: Severe pneumonia, Diaphragmatic manual therapy, Diaphragmatic excursion, Respiratory function, Pulmonary function tests

Significance | This study demonstrated diaphragmatic manual therapy significantly improves diaphragmatic excursion and respiratory function in severe pneumonia patients, enhancing overall prognosis.

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Editor Md Shamsuddin Sultan Khan, And accepted by the Editorial Board May 23, 2024 (received for review Mar 26, 2024)

Introduction

Pneumonia is the primary cause of admissions to intensive care

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Please cite this article.
Mai M. Saleh et al. (2024). A Randomized Controlled Trial of The Diaphragmatic Manual Therapy on Respiratory and Cardiovascular Functions in Severe Pneumonia Patients, Journal of Angiotherapy, 8(5), 1-18, 9680

units (ICUs) globally. Furthermore, it is the predominant secondary infection contracted by people who are critically unwell. Pneumonia of a severe kind is the prevailing factor leading to septic shock, typically necessitating medication for respiratory support, and is linked to a significant fatality rate (Shebl E et al., 2023).

Hence, timely identification of serious illness is vital for enhanced prognosis. Several scoring methods have been developed to evaluate the severity of the condition. (Mittal R et al., 2022).

Diaphragmatic manual therapy approaches encompass tactile interventions to evaluate and rectify malfunctions in the diaphragm, a crucial muscle responsible for respiration and core stabilization (Roberts, A., et al., 2022).

Practitioners employ techniques like as diaphragmatic release, myofascial release, and breath work in conjunction with manual treatments (Duncan, R., 2021). The purpose of these exercises is to improve the mobility, flexibility, and coordination of the diaphragm, ultimately leading to better respiratory function (Moon, H., et al., 2023).

The techniques employed may encompass the application of mild force, myofascial release to address connective tissues, mobilization of the diaphragm along with stretching, and trigger point therapy to alleviate tension (Atchison, J. W., et al., 2021). Therapists additionally evaluate body position and rectify irregularities that may affect the functioning of the diaphragm (Fernandez-Lopez, I., et al., 2021). Incorporating other therapies, such as physical therapy or chiropractic care, might be utilized to achieve a comprehensive approach.

Thoracic ultrasound has become increasingly popular due to its ability to easily see the lung, pleura, and diaphragm in a highly efficient, cost-effective, and safe manner. It is commonly employed for the diagnosis of pleural fluid, atelectasis, pneumonia, and pneumothorax, exhibiting high sensitivity and specificity (Demi L et al, 2023).

Diaphragmatic ultrasonography is a useful tool for assessing the function and motion of the diaphragm. Additionally, it furnishes data on vital capacity, labour of breathing, and diaphragm contractile activity (Saad M et al, 2023).

Diaphragm ultrasonography has been employed to anticipate the outcome of discontinuing mechanical ventilation and evaluate respiratory exertion. In addition, sonographic diaphragm assessment can be used to identify diaphragmatic fatigue following surgery (Turton P et al, 2019).

Transthoracic echocardiography (echo) was used to assess cardiac chamber size and function, valvular function and pulmonary artery pressure. The chief abnormalities were RV dilation, (41%), and RV dysfunction at a level of British Society (Hani Elsayed et al, 2020)

The aim of the study is to elucidate the impact of both diaphragmatic stretch and manual diaphragm release procedures, on diaphragmatic excursion (Dex), RV and pulmonary functions in patients suffering from severe pneumonia.

Materials and Methods

Hospitalized adults with severe pneumonia were the subjects of a randomized controlled trial conducted between Tanta Faculty of Medicine, Egypt and Beni-Suef Faculty of Medicine, Egypt and Zhraa hospital, Faculty of Medicine for girls.

The AST Guidelines for Diagnosis and Treatment of Community-Acquired Pneumonia in Adults (2019 Version) serve as the basis for the diagnostic inclusion criteria. The paper was released in 2019 and was written by Metlay JP et al.

Using a randomization technique, the patients were assigned to different groups.

The two groups under consideration here are the diseased group (I) and the control group (II). Both sets of patients were treated for severe pneumonia using standard medical procedures. On the other hand, diaphragmatic manual procedures were administered to the observational group as an extra treatment. Two subgroups were created from this group: IA, which underwent diaphragmatic doming method treatment, and IB, which underwent diaphragmatic release technique treatment.

In order to avoid participating, patients must not have any of the following medical conditions: acute coronary syndrome, chronic heart failure, severe pulmonary arterial hypertension, serious osteoarthrosis or fracture, chronic lung disease (COPD and chronic asthma), neuromuscular disorder, diaphragmatic hernia, clinical evidence of phrenic nerve injury, recent surgery on the abdomen or chest, or a history of traumatic lesion that could impact the diaphragm.

All patients gave their verbal informed consent, and the study was approved by the Ethics Committee under Approval code 36264PR416/11/23.

Diagnostic data:

All Patients were subjected to:

Complete history: disease duration, history of mechanical ventilation its duration and type, history of comorbidities.

Anthropometric measurements: body weight, height, with calculation of body mass index (kg/m^2)

Complete physical examination, Pulmonary function tests including PEF and **arterial blood gas analysis.**

Chest ultrasound: for evaluation of diaphragmatic excursion (Dex) before and after both diaphragmatic manual techniques.

- **Echocardiography:** Before and after two weeks from both diaphragmatic manual techniques for evaluating the effect of both techniques in restoring the normal features of RV functions including pulmonary artery pressure. Measurements were performed in accordance with 2015 joint guidelines from American

Society of Echocardiography and European Association of Cardiovascular Imaging. The right ventricle was assessed in focused view. The RV was defined as dilated if the RV was defined as dilated if the RV basal diameter measured> 41 mm: RV systolic dysfunction was defined as a tricuspid annular plan systolic excursion (TAPSE)< 17 mm, systolic velocity by tissue Doppler (Sa) at RV lateral annulus>9.5 cm/sec and right ventricular systolic pressure> 36 mmHg.

Pharmacologic and Therapeutic methods: For conventional therapy, conventional anti-infection and antibiotic Beta-lactam + Macrolide, or Beta-lactam + fluoroquinolone, anti-MRSA if prior MRSA infection in the past year, or other validated risk

Factors, Anti-pseudomonal if prior P. aeruginosa infection in past year, or other validated risk factors (Jones, Herman et al. 2020)

In regards to diaphragmatic manual techniques, the participants in both groups received six treatments, separated by1to2 days, during a 2-week period

Group (IA): Diaphragmatic Stretch Technique: The participants are positioned in an upright posture for this intervention. The therapist should position oneself posteriorly to the subject and encircle the thoracic cage, putting their fingertips beneath the subcostal borders. The subject's trunk exhibits a little curvature to alleviate tension in the rectus abdominis muscle. During exhalation, the therapist delicately holds the lower ribs near the subcostal border, exerting a firm but gentle pulling force as the patient inhales (Chaitow, 2002).

Group (IB): MDST Technique:

The individual was lying flat on their back with their limbs in a relaxed state. The therapist should place themselves at the participant's head and establish physical contact with the pisiform, hypothenar region, and the last three fingers on both sides, beneath the seventh to tenth rib costal cartilages. The therapist's forearms should be positioned parallel to the participant's shoulders. During the inhalation phase, the therapist delicately exerted force on the points of contact using both hands, moving them towards the head and slightly to the side, while simultaneously raising the ribs. During exhale, the therapist intensifies their touch towards the inner costal margin while sustaining resistance. During the ongoing respiratory cycles, the therapist gradually intensifies the level of their contact within the costal margin (Rocha et al., 2015).

Both manoeuvres were executed in two sets of 10 deep breaths, with a 1-minute break between each set.

Observation indexes:

The primary outcome is the mobility and excursion of the diaphragm, which were assessed by ultrasonography.

The secondary outcomes include the pulmonary function test (PFT), blood gas indexes, Dyspnea Borg index, 6-min walk distance (6MWD), and chest wall expansion and normal features of RV functions including pulmonary artery pressure.

Measurements were taken in both groups at four specific times: before and immediately after the first treatment session (Pre1 and Post1), and immediately before and after the sixth treatment session (Pre 6 and Post 6), except echo at two specific time before intervention and after 2 weeks.

Statistical analysis of the data

The data were inputted into the computer and analyzed using IBM SPSS software package version 20.0, developed by IBM Corp in Armonk, NY. Quantitative data were represented using numerical values and percentages. The Shapiro-Wilk test was employed to confirm the normality of the distribution. The quantitative data were characterized using various statistical measures, including the range (minimum and maximum values), mean, standard deviation, median, and interquartile range (IQR). The significance of the acquired results was assessed using a significance level of 5%.

The tests utilized were as follows:

1- ***Chi-square test***

To compare between various groups for categorical variables

2- ***Monte Carlo correction***

Adjustment for chi-square is necessary when the predicted count in more than 20% of the cells is less than 5. Another statistical test that can be used is the

3- ***F-test (ANOVA)***

To compare between more than two groups for normally distributed quantitative variables, use a Post Hoc test (specifically Tukey's test) for pairwise comparisons.

Results

10 cases were included in each group with insignificant differences between them as regard demographic data as shown in table 1. As regard pulmonary function test there was significant higher in FEV1/FVC in cases in two groups than control as shown in table 2. As regard MIP there was insignificant differences between study groups as shown in table 3.

There was significant differences between two groups and control regarding arterial blood gases as shown in table 4

As regard 6 MWD was insignificant differ between two technique but between cases and control there was significant higher in control than cases , regarding dyspnea Borg index there was insignificant differ between two technique as shown in table 5

As regard Diaphragmatic mobility there was insignificant differ in pre1 ,post 1 but there n pre 6 and post 6 there was significant higher among cases versus control as shown in table 6

As regard maximal inspiratory pressure I significant differ in pre 1 but in post 1 ,pre 6 and post 6 there was significant higher in cases than control as shown in table 7

Regarding maximal expiratory pressure there was insignificant differ in pre 1, 6 and post 6 but in post 1 there was significant higher in cases than control as shown in table 8

Regard sniff nasal inspiratory pressure there was insignificant differ in pre 1,post 1 ,pre 6 but in post 6 there was significant higher in cases than control as shown in table 9

As regard Vcw there was significant higher in pre1 and post 6 in cases than control as shown in table10

Regarding Vrcp there was significant higher in pre and post 1 in cases versus control but there was insignificant differ in pre and post 6 as shown in table11

Regarding Vrca there was significant higher in pre and post 1 in cases than control but in pre and post 6 there was insignificant differ as shown in table12

Regarding Vab there was significant higher cases groups than control in pre and post 1 ,6 as shown in table 13

The findings indicate that both diaphragmatic stretch and manual diaphragm release procedures have a comparable and statistically insignificant effect on cardiac output and LV ejection fraction when compared to the control group. The proximity of the mean values and the absence of statistical significance suggest that these therapies may not result in significant changes in the evaluated cardiovascular parameters. Additional research with bigger sample sizes or more diverse populations may be necessary to validate these findings and investigate potential subtleties in the impacts of the methodologies.

The findings emphasize the impact of diaphragmatic stretching and manual release techniques on some measures of left ventricular diastolic function, specifically LV(E/A) and RV (E/A). The considerable disparities seen in these metrics underscore the capacity of these approaches to influence cardiac dynamics. These findings enhance our comprehension of the impact of manual therapy on heart function and justify the need for more research to explore their therapeutic significance.

The study suggests that diaphragmatic stretch and manual diaphragm release procedures consistently affect the dimensions of the right ventricle (RV), indicating their potential to maintain or alter the structure of the RV. Moreover, these therapies demonstrate an influence on arterial pressure, highlighting their wider cardiovascular consequences. The lack of substantial changes observed after the intervention indicates the necessity of conducting additional research to comprehensively comprehend the long-term effects of these manual therapies on the dimensions of the right ventricle and arterial pressure.

Discussion

Diaphragmatic manual treatment seeks to restore optimal diaphragmatic function, (Bordoni, B., 2016). improve breathing efficiency, and reduce symptoms linked to diaphragm dysfunction. It is often used as a component of a holistic therapeutic strategy for ailments such as chronic respiratory problems, musculoskeletal discomfort, and stress-related illnesses. The aim of the study is to elucidate the impact of both diaphragmatic stretch and manual diaphragm release procedures, on diaphragmatic excursion (Dex), RV and pulmonary functions in patients suffering from severe pneumonia.

The DST exhibited a statistically significant disparity among the group. This phenomenon may be explained by the prompt activation of the muscle spindle caused by muscular stretching. This activation results in heightened sensory input, hence amplifying the neuromotor response. In the end, this process results in heightened muscular tension, enhanced muscle viscoelasticity, reduced muscle stiffness, and improved thoracic mobility (Minoguchi H et al., 2002; Mukherjee A et al., 2010). When muscles are stretched, it may stimulate the receptors in the muscle-tendon region, particularly the Golgi tendon organs. This leads to an inhibitory reaction (Siatras T. A et al, 2008).

In a study conducted by Noll DR et al (2008), it was shown that a solitary session of manual therapy, namely the redoming of diaphragm method, led to improved lung function in individuals diagnosed with chronic obstructive pulmonary disease (COPD).

Yilmaz Yelvar and his colleagues found that a single session of Manual Therapy, which included the diaphragmatic release technique, improved the strength of the muscles involved in breathing in and the overall lung function in patients with severe COPD (Yilmaz Yelvar G. D et al.,2016).

In a research done by Gonzalez-Alvarez FJ, the diaphragm stretch method was used to people who did not have any pre-existing health conditions. The findings demonstrated a significant increase in the mobility of the ribcage at the xiphoid level, together with an amelioration in the movement patterns of the posterior chain (González-Álvarez F. J et al.,2016).

The MDST Technique showed a statistically significant disparity among the group. One might speculate that this approach increases the adaptability of the respiratory muscles and the thoracic cavity, while also enhancing the link between muscle length and stress. As a result, it has a beneficial effect on the functioning of the respiratory system. This approach may improve proprioception and boost the flexibility of connected fibers. It does this by alleviating tension in the soft tissues via deliberate and gradual motions. When administered to the region, it activates the sensory system by specifically targeting the Golgi tendon organs.

However, there is a lack of scientific evidence that supports the efficacy of these techniques. There is a dearth of research on the impact of stretching on the respiratory muscles, maybe because of the complex nature of their functioning and the absence of specific protocols (Braga D. K et al, 2016).

Table 1. Comparison between the three studied groups according to demographic data

	Diaphragmatic stretch technique (n = 10)		**MDST technique (n = 10)**		**Control (n = 10)**		**Test of Sig.**	**p**
	No.	**%**	**No.**	**%**	**No.**	**%**		
Sex								
Male	6	60.0	7	70.0	6	60.0	χ^2= 0.406	^{MC}p= 1.000
Female	4	40.0	3	30.0	4	40.0		
Age (years)								
Min. – Max.	45.0 – 76.0		45.0 – 78.0		44.0 – 75.0		F= 0.001	0.999
Mean ± SD.	59.40 ± 10.20		59.60 ± 10.92		59.60 ± 10.54			
Median (IQR)	60.50 (50.0 – 66.0)		60.0 (52.0 – 67.0)		63.50 (50.0 – 66.0)			
BMI (kg/m^2)								
Min. – Max.	25.0 – 29.0		25.0 – 29.0		25.0 – 29.0		F= 0.404	0.671
Mean ± SD.	26.50 ± 1.65		26.90 ± 1.52		27.10 ± 1.37			
Median (IQR)	26.0 (25.0 – 28.0)		26.50 (26.0 – 28.0)		27.0 (26.0 – 28.0)			

IQR: **Inter quartile range** SD: **Standard deviation** **F: F for One way ANOVA test**
χ^2: **Chi square test** MC: **Monte Carlo** p: p value for comparing between the three studied groups

Table 2. Comparison between the three studied groups according to pulmonary functions

Pulmonary functions	**Diaphragmatic stretch technique (n = 10)**	**MDST technique (n = 10)**	**Control (n = 10)**	**F**	**p**
FEV1					
Min. – Max.	28.0 – 42.0	29.0 – 42.0	27.0 – 42.0	1.049	0.364
Mean ± SD.	37.10 ± 4.72	37.80 ± 4.29	34.90 ± 4.98		
Median (IQR)	39.0 (33.0 – 40.0)	38.50 (35.0 – 41.0)	35.0 (30.0 – 38.0)		
FVC					
Min. – Max.	42.0 – 58.0	43.0 – 59.0	40.0 – 52.0	1.877	0.172
Mean ± SD.	50.90 ± 5.36	51.10 ± 5.15	47.30 ± 4.22		
Median (IQR)	51.50(48.0–55.0)	51.50 (49.0 – 55.0)	48.50 (45.0 – 51.0)		
FEV1/FVC					
Min. – Max.	47.0 – 57.0	48.0 – 56.0	43.0 – 52.0	3.689*	0.038*
Mean ± SD.	52.60 ± 3.47	52.40 ± 2.59	49.20 ± 3.29		
Median (IQR)	53.0(50.0 – 56.0)	52.50 (51.0 – 55.0)	50.50 (46.0 – 52.0)		
Sig. bet. Grps.	p_1=0.989, p_2=0.023*, p_3=0.076				

IQR: **Inter quartile range** SD: **Standard deviation**
F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**
p: p value for comparing between the three studied groups
p_1: p value for comparing between **DST**and **MDST technique**
p_2: p value for comparing between **DST**and **Control**
p_3: p value for comparing between **MDST technique** and **Control**
*: Statistically significant at $p \le 0.05$

Table 3. Comparison between the three studied groups according to MIP

	MIP (cmH$_2$O)	**Diaphragmatic stretch technique (n = 10)**	**MDST technique (n = 10)**	**Control (n = 10)**	**F**	**p**
Pre	Min. – Max.	59.80 – 64.60	59.90 – 66.30	59.70 – 69.0	1.029	0.371
	Mean ± SD.	62.51 ± 1.78	63.58 ± 2.08	63.84 ± 2.65		
	Median (IQR)	63.10 (60.70– 64.0)	64.10(62.30–65.20)	64.0 (62.0 – 65.50)		
Post	Min. – Max.	60.50 – 67.50	60.50 – 67.20	59.70 – 69.0	0.444	0.646
	Mean ± SD.	64.77 ± 2.04	64.25 ± 1.87	63.84 ± 2.65		
	Median (IQR)	65.05(63.60–66.50)	64.70(63.50–65.30)	64.0 (62.0 – 65.50)		
	t(p_0)	6.705* (<0.001*)	0.873 (0.405)	–		

IQR: **Inter quartile range** SD: **Standard deviation**
F: F for One way ANOVA test **t: Paired t-test**
p: p value for comparing between the three studied groups
p_0: p value for comparing between **Pre** and **Post**
*: Statistically significant at $p \le 0.05$

Table 4. Comparison between the three studied groups according to arterial blood gas

		Arterial blood gas	Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
$PaCO_2$ (mmHg)	Pre	Min. – Max.	62.0 – 85.0	63.0 – 83.0	75.0 – 100.0	15.369*	<0.001*
		Mean ± SD.	70.50 ± 6.67	70.10 ± 6.03	85.70 ± 8.58		
		Median (IQR)	69.50 (66.0 – 72.0)	69.50 (65.0– 72.0)	85.0 (79.0 – 94.0)		
		Sig. bet. Grps.	p_1=0.991, p_2<0.001*, p_3<0.001*				
	Post	Min. – Max.	68.0 – 98.0	69.0 – 98.0	76.0 – 100.0	1.469	0.248
		Mean ± SD.	81.60 ± 8.66	81.10 ± 7.92	86.90 ± 8.56		
		Median (IQR)	80.0 (75.0 – 89.0)	81.50 (76.0 – 85.0)	86.0 (80.0 – 95.0)		
		t(p_0)	6.217* (<0.001*)	4.930* (0.001*)	4.811* (0.001*)		
	Pre	Min. – Max.	33.0 – 40.0	33.0 – 40.0	35.0 – 42.0	2.613	0.092
		Mean ± SD.	37.10 ± 2.23	36.70 ± 2.26	38.90 ± 2.38		
		Median (IQR)	38.0 (35.0 – 39.0)	37.0 (35.0 – 38.0)	38.50 (38.0 – 41.0)		
	Post	Min. – Max.	30.0 – 40.0	30.0 – 41.0	36.0 – 41.0	13.892*	<0.001*
		Mean ± SD.	32.60 ± 3.20	33.0 ± 3.62	38.80 ± 1.62		
		Median (IQR)	31.50 (30.0 – 35.0)	31.50 (30.0 – 36.0)	39.0 (38.0 – 40.0)		
		Sig. bet. Grps.	p_1=0.950, p_2<0.001*, p_3<0.001*				
		t(p_0)	5.679* (<0.001*)	3.874* (0.004*)	0.361 (0.726)		
HCO_3 (mmol/l)	Pre	Min. – Max.	22.50 – 29.50	22.60 – 29.80	23.0 – 28.0	0.838	0.443
		Mean ± SD.	26.26 ± 2.17	26.21 ± 2.34	25.20 ± 1.62		
		Median (IQR)	26.60 (24.50 – 27.50)	26.60 (24.20 – 27.60)	25.0 (24.0 – 26.0)		
	Post	Min. – Max.	22.40 – 28.50	22.50 – 28.60	24.0 – 28.0	0.232	0.795
		Mean ± SD.	25.60 ± 1.87	25.69 ± 1.89	26.10 ± 1.45		
		Median (IQR)	25.80 (24.20 – 26.80)	26.05 (24.20 – 26.70)	26.0 (25.0 – 27.0)		
		t(p_0)	4.611* (0.001*)	2.661* (0.026*)	9.0* (<0.001*)		
pH (mole/l)	Pre	Min. – Max.	7.39 – 7.47	7.38 – 7.46	7.31 – 7.41	15.679*	<0.001*
		Mean ± SD.	7.42 ± 0.02	7.41 ± 0.02	7.36 ± 0.03		
		Median (IQR)	7.42 (7.41 – 7.43)	7.41 (7.40 – 7.42)	7.36 (7.32 – 7.38)		
		Sig. bet. Grps.	p_1=0.690, p_2<0.001*, p_3<0.001*				
	Post	Min. – Max.	7.38 – 7.45	7.30 – 7.43	7.32 – 7.40	7.228*	0.003*
		Mean ± SD.	7.41 ± 0.02	7.38 ± 0.04	7.36 ± 0.03		
		Median (IQR)	7.40 (7.40 – 7.41)	7.39 (7.38 – 7.41)	7.36 (7.33 – 7.39)		
		Sig. bet. Grps.	p_1=0.181, p_2=0.002*, p_3=0.137				
		t(p_0)	8.510* (<0.001*)	3.360* (0.008*)	0.000 (1.000)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups comparing between **MDST technique** and **Control**

*: Statistically significant at $p \leq 0.05$

p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique**

p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control**

*: Statistically significant at $p \leq 0.05$

Table 5. Comparison between the three studied groups according to Dyspnea Borg index and 6-min walk distance (6MWD)

			Diaphragmatic stretch technique (n = 10)	**MDST technique (n = 10)**	**Control (n = 10)**	**F**	**p**
Dyspnea Borg index	**Pre**	Min. – Max.	4.30 – 8.50	4.30 – 8.70	–	0.003	0.959
		Mean ± SD.	6.10 ± 1.26	6.13 ± 1.30	–		
		Median (IQR)	6.0 (5.40 – 6.50)	6.05 (5.50 – 6.80)	–		
	Post	Min. – Max.	2.60 – 5.40	3.10 – 5.30	–	0.012	0.914
		Mean ± SD.	3.85 ± 0.88	3.89 ± 0.76	–		
		Median (IQR)	3.70 (3.20 – 4.60)	3.65 (3.20 – 4.50)	–		
		t(p_0)	8.447* (<0.001*)	7.559* (<0.001*)	–		
6-min walk distance (6MWD)	**Pre**	Min. – Max.	386.0 – 428.0	368.0 – 420.0	390.0 – 499.0	2.096	0.143
		Mean ± SD.	408.70 ± 14.47	403.80 ± 16.54	422.50 ± 29.38		
		Median (IQR)	411.0(399.0 – 421.0)	410.0(394.0–416.0)	420.0(411.0–422.0)		
	Post	Min. – Max.	389.0 – 425.0	321.0 – 413.0	398.0 – 429.0	3.918*	0.032*
		Mean ± SD.	408.30 ± 11.71	390.60 ± 29.39	413.90 ± 11.46		
		Median (IQR)	406.50(398.0-418.0)	400.0(390.0–412.0)	417.50(399.0-421.0)		
		Sig. bet. Grps.	p_1=0.123, p_2=0.797, p_3=0.032*				
		t(p_0)	0.211 (0.838)	1.451 (0.181)	0.828 (0.429)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups

p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique**

p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control**

*: Statistically significant at p ≤ 0.05

Table 6. Comparison between the three studied groups according to diaphragm mobility

	Diaphragm mobility (mm)	**Diaphragmatic stretch technique (n = 10)**	**MDST technique (n = 10)**	**Control (n = 10)**	**F**	**p**
1	**Pre**					
	Min. – Max.	65.0 – 82.0	65.0 – 81.0	60.0 – 75.0	2.727	0.083
	Mean ± SD.	73.10 ± 5.20	73.0 ± 4.94	68.50 ± 4.95		
	Median (IQR)	73.50 (70.0 – 76.0)	73.50 (70.0 – 76.0)	69.0 (65.0 – 72.0)		
	Post					
	Min. – Max.	66.0 – 82.0	66.0 – 81.0	66.0 – 77.0	0.544	0.587
	Mean ± SD.	73.80 ± 4.73	73.20 ± 4.69	71.80 ± 3.71		
	Median (IQR)	74.50 (71.0 – 76.0)	73.50 (70.0 – 76.0)	71.50 (69.0 – 75.0)		
	t(p_0)	3.280* (0.010*)	0.612 (0.555)	5.706* (<0.001*)		
6	**Pre**					
	Min. – Max.	73.0 – 87.0	72.0 – 86.0	57.0 – 70.0	53.151*	<0.001*
	Mean ± SD.	81.0 ± 4.52	80.10 ± 4.65	62.30 ± 4.55		
	Median (IQR)	81.0 (79.0 – 85.0)	80.0 (76.0 – 85.0)	61.50 (59.0 – 65.0)		
	Sig. bet. Grps.	p_1=0.899,p_2<0.001*,p_3<0.001*				
	Post					
	Min. – Max.	72.0 – 87.0	70.0 – 88.0	58.0 – 71.0	27.654*	<0.001*
	Mean ± SD.	78.90 ± 4.41	78.10 ± 6.69	63.20 ± 4.54		
	Median (IQR)	80.0 (75.0 – 80.0)	75.0 (73.0 – 86.0)	62.0 (60.0 – 66.0)		
	Sig. bet. Grps.	p_1=0.940, p_2<0.001*,p_3<0.001*				
	t(p_0)	0.876 (0.404)	0.815 (0.436)	9.0* (<0.001*)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique** p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control**

*: Statistically significant at p ≤ 0.05

Table 7. Comparison between the three studied groups according to maximal inspiratory pressure

		Maximal inspiratory pressure (cm H_2O)	**Diaphragmatic stretch technique (n = 10)**	**MDST technique (n = 10)**	**Control (n = 10)**	**F**	**p**
1	**Pre**	Min. – Max.	59.0 – 66.0	59.0 – 66.0	58.0 – 66.0	0.977	0.389
		Mean ± SD.	62.90 ± 2.42	63.20 ± 2.30	61.80 ± 2.35		
		Median (IQR)	63.0 (61.0 – 65.0)	63.50 (62.0 – 65.0)	61.50 (60.0 – 64.0)		
	Post	Min. – Max.	60.0 – 70.0	60.0 – 71.0	52.0 – 62.0	12.858*	<0.001*
		Mean ± SD.	64.30 ± 3.23	64.60 ± 3.53	57.60 ± 3.69		
		Median (IQR)	64.50 (62.0 – 66.0)	64.50 (62.0 – 66.0)	59.50 (54.0 – 60.0)		
		Sig. bet. Grps.	p_1=0.980, p_2=0.001*, p_3<0.001*				
		t(p_0)	1.121 (0.291)	1.055 (0.319)	3.953* (0.003*)		
6	**Pre**	Min. – Max.	60.0 – 66.0	60.0 – 67.0	59.0 – 66.0	3.412*	0.048*
		Mean ± SD.	62.80 ± 2.15	64.30 ± 2.21	61.80 ± 2.10		
		Median (IQR)	62.50 (61.0 – 65.0)	65.0 (63.0 – 66.0)	61.50 (60.0 – 63.0)		
		Sig. bet. Grps.	p_1=0.281, p_2=0.560, p_3=0.039*				
	Post	Min. – Max.	65.0 – 74.0	63.0 – 76.0	59.0 – 66.0	14.410*	<0.001*
		Mean ± SD.	68.0 ± 2.83	68.50 ± 68.50	62.10 ± 2.08		
		Median (IQR)	67.50 (66.0 – 70.0)	68.0 (66.0 – 71.0)	62.0 (60.0 – 63.0)		
		Sig. bet. Grps.	p_1=0.925, p_2<0.001*, p_3<0.001*				
		t(p_0)	4.088* (0.003*)	2.689* (0.025*)	1.964 (0.081)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**
F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**
p: p value for comparing between the three studied groups
p_0: p value for comparing between **Pre** and **Post**
p_1: p value for comparing between **DST**and **MDST technique**
p_2: p value for comparing between **DST**and **Control**
p_3: p value for comparing between **MDST technique** and **Control**
*: Statistically significant at p ≤ 0.05

Table 8. Comparison between the three studied groups according to maximal expiratory pressure

		Maximal expiratory pressure (cm H_2O)	**Diaphragmatic stretch technique (n = 10)**	**MDST technique (n = 10)**	**Control (n = 10)**	**F**	**p**
1	**Pre**	Min. – Max.	80.0 – 100.0	82.0 – 100.0	88.0 – 106.0	0.649	0.531
		Mean ± SD.	94.30 ± 6.25	95.20 ± 5.69	97.10 ± 4.79		
		Median (IQR)	96.50 (90.0 – 99.0)	97.50 (96.0 – 98.0)	97.50 (96.0 – 99.0)		
	Post	Min. – Max.	95.0 – 107.0	96.0 – 106.0	88.0 – 103.0	6.213*	0.006*
		Mean ± SD.	100.60 ± 3.86	101.0 ± 3.53	95.20 ± 4.83		
		Median (IQR)	99.50 (98.0 – 103.0)	100.0 (98.0 – 105.0)	94.50 (92.0 – 100.0)		
		Sig. bet. Grps.	p_1=0.974, p_2=0.018*, p_3=0.011*				
		t(p_0)	4.290* (0.002*)	3.570* (0.006*)	0.926 (0.379)		
6	**Pre**	Min. – Max.	99.0 – 110.0	98.0 – 110.0	98.0 – 109.0	0.090	0.914
		Mean ± SD.	104.70 ± 4.03	104.10 ± 3.45	104.10 ± 3.45		
		Median (IQR)	104.5(100.0 – 108.0)	105.0(102.0 – 106.0)	104.5(102.0 – 106.0)		
	Post	Min. – Max.	100.0 – 113.0	103.0 – 115.0	103.0 – 119.0	0.815	0.453
		Mean ± SD.	106.20 ± 4.52	108.20 ± 4.49	108.60 ± 4.50		
		Median (IQR)	105.5(102.0 – 110.0)	107.0(105.0 – 112.0)	107.5(107.0 – 110.0)		
		t(p_0)	4.025* (0.003*)	4.984* (0.001*)	3.527* (0.006*)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**
F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**
p: p value for comparing between the three studied groups; p_0: p value for comparing between **Pre** and **Post**
p_1: p value for comparing between **DST**and **MDST technique.** p_2: p value for comparing between **DST**and **Control**
p_3: p value for comparing between **MDST technique** and **Control**
*: Statistically significant at p ≤ 0.05

Table 9. Comparison between the three studied groups according to sniff nasal inspiratory pressure

		Sniff nasal inspiratory pressure	Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
1	Pre	Min. – Max.	43.0 – 50.0	42.0 – 51.0	43.0 – 52.0	1.465	0.249
		Mean ± SD.	47.30 ± 2.31	46.30 ± 2.75	48.30 ± 2.75		
		Median (IQR)	47.50 (46.0 – 49.0)	46.0 (45.0 – 48.0)	48.50 (47.0 – 50.0)		
	Post	Min. – Max.	50.0 – 58.0	51.0 – 56.0	50.0 – 56.0	1.806	0.184
		Mean ± SD.	54.60 ± 2.55	53.80 ± 1.81	52.80 ± 1.93		
		Median (IQR)	54.50 (53.0 – 56.0)	54.0 (52.0 – 55.0)	52.50 (51.0 – 54.0)		
		t(p_0)	7.939* (<0.001*)	11.777* (<0.001*)	4.258* (0.002*)		
6	Pre	Min. – Max.	46.0 – 53.0	45.0 – 52.0	45.0 – 52.0	0.597	0.558
		Mean ± SD.	49.80 ± 2.39	49.50 ± 2.68	48.60 ± 2.59		
		Median (IQR)	50.0 (48.0 – 52.0)	51.0 (48.0 – 51.0)	48.50 (46.0 – 51.0)		
	Post	Min. – Max.	52.0 – 60.0	51.0 – 61.0	47.0 – 57.0	7.683*	0.002*
		Mean ± SD.	56.10 ± 2.64	56.30 ± 2.71	52.0 ± 2.94		
		Median (IQR)	56.0 (54.0 – 58.0)	56.0 (55.0 – 58.0)	52.0 (50.0 – 54.0)		
		Sig. bet. Grps.	p_1=0.986,p_2=0.007*,p_3=0.005*				
		t(p_0)	17.182* (<0.001*)	11.476* (<0.001*)	3.470* (0.007*)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups

p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique**

p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control**

*: Statistically significant at $p \le 0.05$

Table 10. Comparison between the three studied groups according to Vcw

	Vcw (ml)	Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
1	**Pre**					
	Min. – Max.	465.0 – 652.0	465.0 – 650.0	400.0 – 510.0	9.657*	0.001*
	Mean ± SD.	534.80 ± 51.97	533.60 ± 51.33	447.60 ± 49.31		
	Median (IQR)	536.50(489.0– 46.0)	534.50(490.0 – 543.0)	416.0 (410.0 – 500.0)		
	Sig. bet. Grps.	p_1=0.998, p_2=0.002*,p_3=0.002*				
	Post					
	Min. – Max.	477.0 – 665.0	472.0 – 661.0	398.0 – 614.0	3.040	0.064
	Mean ± SD.	540.10 ± 53.59	536.50 ± 53.02	486.0 ± 57.84		
	Median (IQR)	537.50(490.0-556.0)	535.0 (492.0 – 550.0)	480.50(468.0– 500.0)		
	t(p_0)	3.205* (0.011*)	1.602 (0.144)	1.832 (0.100)		
6	**Pre**					
	Min. – Max.	428.0 – 510.0	422.0 – 512.0	420.0 – 519.0	1.102	0.347
	Mean ± SD.	459.70 ± 26.73	457.50 ± 28.56	442.50 ± 29.25		
	Median (IQR)	453.50(435.0-487.0)	452.50(437.0– 486.0)	433.50(425.0–447.0)		
	Post					
	Min. – Max.	487.0 – 530.0	486.0 – 535.0	427.0 – 551.0	3.417*	0.048*
	Mean ± SD.	505.30 ± 15.03	503.20 ± 13.93	480.70 ± 34.82		
	Median (IQR)	503.50(489.0–518.0)	501.0 (498.0 – 503.0)	470.0 (459.0 – 500.0)		
	Sig. bet. Grps.	p_1=0.978, p_2=0.065, p_3=0.097				
	t(p_0)	4.619* (0.001*)	4.610* (0.001*)	2.581* (0.030*)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p_0: p value for comparing between **Pre** and **Post** p: p value for comparing between the three studied groups

p_1: p value for comparing between **DST**and **MDST technique** p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control***: Statistically significant at $p \le 0.05$

Table 11. Comparison between the three studied groups according to Vrcp

	Vrcp (ml)	Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
	Pre					
	Min. – Max.	123.0 – 154.0	124.0 – 154.0	96.0 – 109.0	102.634*	<0.001*
	Mean ± SD.	145.30 ± 9.14	145.10 ± 8.67	102.60 ± 4.25		
	Median (IQR)	148.50(143.0-150.0)	147.50(142.0– 149.0)	102.50(100.0–106.0)		
	Sig. bet. Grps.	p_1=0.998, p_2<0.001*, p_3<0.001*				
	Post					
	Min. – Max.	120.0 – 152.0	121.0 – 153.0	95.0 – 148.0	28.050*	<0.001*
	Mean ± SD.	143.90 ± 9.36	143.70 ± 9.19	110.40 ± 15.02		
	Median (IQR)	148.0 (142.0 – 149.0)	147.0 (141.0 – 148.0)	107.50(100.0–110.0)		
	Sig. bet. Grps.	p_1=0.999,p_2<0.001*,p_3<0.001*				
1	**t(p_0)**	3.500* (0.007*)	5.250* (0.001*)	1.882 (0.092)		
	Pre					
	Min. – Max.	99.0 – 114.0	98.0 – 116.0	99.0 – 114.0	0.466	0.633
	Mean ± SD.	104.80 ± 5.22	106.80 ± 5.59	104.80 ± 5.22		
	Median (IQR)	103.50(100.0–09.0)	108.0 (103.0 – 109.0)	103.50(100.0–109.0)		
	Post					
	Min. – Max.	123.0 – 142.0	124.0 – 143.0	123.0 – 142.0	0.082	0.922
	Mean ± SD.	133.80 ± 5.87	134.70 ± 5.48	133.80 ± 5.87		
	Median (IQR)	134.0 (130.0 – 136.0)	135.0 (132.0 – 137.0)	134.0 (130.0 – 136.0)		
6	**t(p_0)**	11.817* (<0.001*)	9.844*(<0.001*)	11.817*(<0.001*)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique** p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control** *: Statistically significant at $p \leq 0.05$

Table 12. Comparison between the three studied groups according to Vrca

	Vrca (ml)	Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
	Pre					
	Min. – Max.	59.0 – 78.0	59.0 – 75.0	42.0 – 59.0	39.382*	<0.001*
	Mean ± SD.	68.80 ± 5.59	67.70 ± 5.36	49.40 ± 5.52		
	Median (IQR)	68.0 (66.0 – 74.0)	66.50 (65.0 – 74.0)	48.50 (45.0 – 51.0)		
	Sig. bet. Grps.	p_1=0.896, p_2<0.001*, p_3<0.001*				
	Post					
	Min. – Max.	58.0 – 78.0	59.0 – 76.0	45.0 – 59.0	32.653*	<0.001*
	Mean ± SD.	68.10 ± 5.69	67.40 ± 5.74	50.60 ± 4.99		
	Median (IQR)	67.50 (65.0 – 73.0)	66.0 (64.0 – 74.0)	50.0 (47.0 – 52.0)		
	Sig. bet. Grps.	p_1=0.956, p_2<0.001*, p_3<0.001*				
1	**t(p_0)**	1.655 (0.132)	0.758 (0.468)	4.129* (0.003*)		
	Pre					
	Min. – Max.	39.0 – 50.0	38.0 – 51.0	38.0 – 50.0	1.055	0.362
	Mean ± SD.	45.0 ± 3.33	44.70 ± 3.89	42.70 ± 4.27		
	Median (IQR)	45.0 (43.0 – 48.0)	44.50 (43.0 – 47.0)	42.0 (40.0 – 46.0)		
	Post					
	Min. – Max.	42.0 – 55.0	43.0 – 53.0	40.0 – 50.0	0.277	0.760
	Mean ± SD.	47.20 ± 3.79	47.70 ± 3.09	46.60 ± 2.99		
	Median (IQR)	46.0 (45.0 – 50.0)	47.50 (45.0 – 50.0)	46.50 (45.0 – 49.0)		
6	**t(p_0)**	5.659* (<0.001*)	5.809*(<0.001*)	3.162* (0.012*)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique** p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control** *: Statistically significant at $p \leq 0.05$

Table 13. Comparison between the three studied groups according to Vab

	Vab (ml)	**Diaphragmatic stretch technique (n = 10)**	**MDST technique (n = 10)**	**Control (n = 10)**	**F**	**p**
1	**Pre**					
	Min. – Max.	328.0 – 354.0	329.0 – 352.0	259.0 – 289.0	215.865*	<0.001*
	Mean ± SD.	343.50 ± 9.01	344.0 ± 7.30	273.80 ± 9.60		
	Median (IQR)	343.0(340.0–353.0)	345.5(341.0– 50.0)	272.5(268.0– 81.0)		
	Sig. bet. Grps.	p_1=0.991, p_2<0.001*, p_3<0.001*				
	Post					
	Min. – Max.	330.0 – 368.0	335.0 – 365.0	289.0 – 359.0	31.924*	<0.001*
	Mean ± SD.	353.20 ± 11.73	352.0 ± 9.87	309.20 ± 18.86		
	Median (IQR)	356.0(349.0–59.0)	353.5(348.0–360.0)	306.5(300.0–310.0)		
	Sig. bet. Grps.	p_1=0.980, p_2<0.001*, p_3<0.001*				
	t(p_0)	6.319* (<0.001*)	5.821* (<0.001*)	5.028* (0.001*)		
6	**Pre**					
	Min. – Max.	298.0 – 320.0	299.0 – 312.0	248.0 – 305.0	12.531*	<0.001*
	Mean ± SD.	305.30 ± 6.55	307.10 ± 4.61	279.50 ± 22.51		
	Median (IQR)	303.5(300.0– 09.0)	308.5(305.0–310.0)	287.5(258.0–300.0)		
	Sig. bet. Grps.	p_1=0.954, p_2=0.001*, p_3<0.001*				
	Post					
	Min. – Max.	319.0 – 345.0	317.0 – 342.0	276.0 – 317.0	38.030*	<0.001*
	Mean ± SD.	329.70 ± 8.42	329.70 ± 8.69	297.10 ± 11.53		
	Median (IQR)	329.0(323.0–337.0)	330.5(321.0–336.0)	298.0(289.0– 01.0)		
	Sig. bet. Grps.	p_1=1.000, p_2<0.001*, p_3<0.001*				
	t(p_0)	6.313* (<0.001*)	6.178*(<0.001*)	2.376* (0.041*)		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique** p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control** *: Statistically significant at $p \leq 0.05$

Table 14. Comparison between the three studied groups according to Dyspnea Borg index and Stationary bike exercise

		Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
Dyspnea Borg index	Pre					
	Min. – Max.	4.30 – 8.50	4.30 – 8.70	–	0.003	0.959
	Mean ± SD.	6.10 ± 1.26	6.13 ± 1.30	–		
	Median (IQR)	6.0 (5.40 – 6.50)	6.05 (5.50 – 6.80)	–		
	Post					
	Min. – Max.	2.60 – 5.40	3.10 – 5.30	–	0.012	0.914
	Mean ± SD.	3.85 ± 0.88	3.89 ± 0.76	–		
	Median (IQR)	3.70 (3.20 – 4.60)	3.65 (3.20 – 4.50)	–		
	t(p0)	-8.2	-7.559	–		
Stationary bike exercise	Pre					
	Min. – Max.	220.0 – .2780	.2220 –280.0	225.0 – 300.0	6.32	0.0056
	Mean ± SD.	252 ± 12.3	252.2± 12.3	279.1 ± 23.32.		
	Median (IQR)	252.5 (27.5)	249.5 (21.5)	282.5 (17.5)		
	Post					
	Min. – Max.	222.0 – .2750	218.0 – 276.0	220 – 280	3.918*	0.032*
	Mean ± SD.	252.2± 12.3	252± 12.3	304.9 ± 28.98		
	Median (IQR)	257.5 (28)	250 (19.750)	310.0 (30.5)		
	Sig. bet. Grps.	p1=0.6511,p2=0.0044.,p3=0.0116				
	t(p0)	-12	-12	-13.9		

IQR: Inter quartile range SD: Standard deviation t: Paired t-test

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey)

p: p value for comparing between the three studied groups p0: p value for comparing between Pre and Post

p1: p value for comparing between DSTand MDST technique

Table 15. Comparison between the three studied groups according to Heart rate rate and Stationary bike exercise

		Maximal Heart rate%	Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
During Exercise	Pre	Min. – Max.	85 .0– 98.0	68.0 – 99.0	68.0 – 99.0	6.231	0.0054
		Mean ± SD.	93.5± 2.56	97.125± 2.53	94.2± 5.46		
		Median (IQR)	92.5(2.5)	94.89 (13)	95.8 (8)		
	Post	Min. – Max.	85.0 – 97	83 – 97	82.0 – 97	0.4	0.636
		Mean ± SD.	92.0. ± 4.88	95.3± 1.55	93± 4.32		
		Median (IQR)	94(6)	95(4)	95.5(5)		
		Sig. bet. Grps.	p_1= 1, p_2= 0.7762283*,p_3 0.7762283				
		t(p0)	-18.2	-13.7	-12.6		
During Rest	Pre	Min. – Max.	87.0 – 97.0	85.0 – 99.0	81.0 – 98.0	0.042	0.524
		Mean ± SD.	93± 6.13	95± 3.97	92.4. %± 5.63		
		Median (IQR)	92 (13)	92 (6)	90 (7)		
		Sig. bet. Grps.	p_1=0.281, p_2=0.560, p_3=0.039*				
	Post	Min. – Max.	83.0 – 98.0	82.0 – 98.0	82.0 – 99.0	0.0119	0.991
		Mean ± SD.	93.0 ± 4.22	90.8 ± 4.01	92.5± 4.50		
		Median (IQR)	93.5 (2.5)	94.0(6)	94.5 (10)		
		Sig. bet. Grps.	p1= 0.001, p2=0.003*, p3 0.001				
		t(p0)	-8.8	-24.6	-18.68		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups, p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique,** p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control,** *: Statistically significant at $p \le 0.05$

Table 16. Comparison between the three studied groups according to Respiratory rate and Stationary bike exercise

		Maximal Respiratory rate %	Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
During exercise	Pre	Min. – Max.	83.0– 98.0	84.0 – 99.0	82.0 – 99.0	6.231	0.0054
		Mean ± SD.	9.2.2± 5.2	93.4± 6.06	912.± 6.94		
		Median (IQR)	92(6)	96(12)	94.5(14)		
	Post	Min. – Max.	82.0 – 96	84.0 – 99.0	82.0 – 99.0	0.4	0.636
		Mean ± SD.	90.9 ± .491	91.4± 7.3	89.9± 7.08		
		Median (IQR)	94(6)	93(14)	90(4)		
		Sig. bet. Grps.	p_1= 1, p_2= 0.7762283*,p_3 0.7762283				
		t(p0)	-16.51	-11.16	-11.28		
During exercise	Pre	Min. – Max.	83.0 – 98.0	83.0 – 98.0	82.0 – 98.0	0.042	0.524
		Mean ± SD.	93.2± 5.31	92.4± 5.24	92.4. %± 5.63		
		Median (IQR)	92 (13)	92 (6)	90 (7)		
		Sig. bet. Grps.	p_1=0.281, p_2=0.560, p_3=0.039*				
	Post	Min. – Max.	82.0 – 96.0	85.0 – 98.0	81.0 – 98.0	0.0119	0.991
		Mean ± SD.	92.2 ± 9.3	91.5 ± 3.3	.922± 4.77		
		Median (IQR)	92.5 (6)	.945(8)	93 (7)		
		Sig. bet. Grps.	p_1= 0.001, $p_2$0.003=*, p_3 0.001				
		t(p0)	-8.83	-24.6	-17.23		

IQR: **Inter quartile range** SD: **Standard deviation** **t: Paired t-test**

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using **Post Hoc Test (Tukey)**

p: p value for comparing between the three studied groups

p_0: p value for comparing between **Pre** and **Post**

p_1: p value for comparing between **DST**and **MDST technique**

p_2: p value for comparing between **DST**and **Control**

p_3: p value for comparing between **MDST technique** and **Control**

*: Statistically significant at $p \le 0.05$

Table 17. Comparison between the three studied groups according to systolic blood pressure and stationary bike exercise

		Maximal (Systolic pressure)	Diaphragmatic stretch technique (n = 10)	MDST technique (n = 10)	Control (n = 10)	F	p
During Exercise	Pre	Min. – Max.	125– 130	126– 130	116 – 122	0.95	0.0054
		Mean (Systolic pressure)	127 ±4	127 ±5	120±2		
		Median	129	129	120		
	Post	Min. – Max.	124– 128	124-129	116 –120	0.35	0.0053.
		Mean (Systolic pressure)	126± 4	126 ±4	116 ±4		
		Median	128	128	118		
		Sig. bet. Grps.	p1:0.002(Pre), p2: 0.001 (Pre)*, p3: 0.001(Pre)				
During Rest	Pre	Min. – Max.	125– 128	125– 129	118 – 120	0.042	0.0054
		Mean systolic pressure	126 ±4	126±4.	118 ±4		
		Median	127	128	120		
		Sig. bet. Grps.	p1: 0.001 (Post) p2: 0.002* (Post), p3: 0.001 (Post)				
	Post	Min. – Max.	125 – 127	126 – 128	116 – 120	0.0119	0.005
		Mean systolic pressure	125 ±4	126 ±4	122127 ±4.5		
		Median	126	127	120		
		Sig. bet. Grps.	p_1= 0.001,$p_2$0.003=*,p_3 0.001				
		p0 (Pre vs. Post):	Diaphragmatic stretch technique: 0.291	MDST technique: 0.319	Control: 0.003*		

IQR: Inter quartile range SD: Standard deviation t: Paired t-test

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey), p: p value for comparing between the three studied groups, p_0: p value for comparing between Pre and Post

p_1: p value for comparing between DSTand MDST technique

p_2: p value for comparing between DSTand Control

p_3: p value for comparing between MDST technique and Control

*: Statistically significant at p ≤ 0.05

Table 18. Comparison between the three studied groups according to the rate of change cardiac output (CO)& ejection faction (EF) of the left ventricular

			Diaphragmatic stretch technique (n = 10)	Manual diaphragm release technique (n = 10)	Control (n = 10)	F	p
LV cardiac output (CO)	Pre	Min. – Max.	4.7 – 5.8	4.6 – 5.8	4.5– 5.5	0.07	0.788
		Mean ± SD.	5.3. ± 0.9	5.32 ± .85	5 ± 0.6		
		Median	5.35	5.36	5		
		Sig. bet. Grps.	p_1=787, p_2=0.787=p_3=788				
	Post	Min. – Max.	4.6 – 5.7	4.6 – 5.7	4.5 – 5.5	0.07	0.07
		Mean ± SD.	5.2. ± 0.88	5.24 ± 0.83	5 ± 0.6		
		Median	5.32	5.32	5 ± 0.6		
		Sig. bet. Grps.	p_1=0.788, p_2=0.788=*, p_3=788				
		t(p_0)	0	0	0		
LV ejection faction (EF)	Pre	Min. – Max.	62–74	62–75	60 – 90	0.53	0.224
		Mean ± SD.	65.2± 9.8	66.01± 8.79	75 ±1 5.22		
		Median	80.2	80	76.5		
	Post	Min. – Max.	62–72	62–74	60–90	0.63	0.21
		Mean ± SD.	63.23.5± 9.55	65.21± 8.31	75 ±1 5.22		
		Median	79	79.2	76		
		Sig. bet. Grps.	p1=0.788, p2=0.788=*, p3=0.788				
		t(p_0)	0.95	0.95	0.97		

IQR: Inter quartile range SD: Standard deviation t: Paired t-test

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey), p: p value for comparing between the three studied groups, p0: p value for comparing between Pre and Post

p1: p value for comparing between DSTand MDST technique

p2: p value for comparing between DSTand Control

p3: p value for comparing between MDST technique and Control

*: Statistically significant at p ≤ 0.05

Table 19. Comparison between the three studied groups according to the rate of change RV (E/A) &LV(E/A)

	Vab (ml)	Diaphragmatic stretch technique (n = 10)	Manual diaphragm release technique (n = 10)	Control (n = 10)	F	p
RV (E/A)	Min. – Max.	2.1 – 2.4	2.1 – 2.5	1.2–0.8	0.01	<0.001*
	Mean ± SD.	2.2 ±0.6	2.2 ± 0.6	1.0 ±0.2		
	Median (IQR)	2.3	2.3	1		
	Sig. bet. Grps.	p_1<0.001,p_2<0.001*,p_3<0.001*				
	Min. – Max.	1.8 –2	1.7– 1.4	1.2-0.8	0.01	<0.001*
	Mean ± SD.	1.7± 0.4	1.6 ± 0.6	1.00 ± 0.10		
	Median (IQR)	1.7	1.7	1		
	Sig. bet. Grps.	p_1<0.001,p_2<0.001*,p_3<0.001*				
LV (E/A)	Min. – Max.	.2 – 2.30	2.1–2.3	0.7 – 0.5		
	Mean ± SD. Median (	2 ± 0.4 2	2 ±0.4 2	0.6± 0.4 0.6	0.04	0.0056
	Sig. bet. Grps.	p_1=<0.001,p_2<0.001*,p_3<0.001*				
	Min. – Max.	1.5 –2	1.5 – 2	0.5 – 0.6	0.05	<0.001*
	Mean ± SD.	1.6 ±0.4	1.6 ±0.4	0.8 ± 0.6		
	Median	1.5	1.5	0.6		
	Sig. bet. Grps.	p_1<.001,p_2<0.001*,p_3<0.001*				

IQR: Inter quartile range SD: Standard deviation t: Paired t-test

F: F for One-way ANOVA test, pairwise comparison bet. each 2 groups were done using Post Hoc Test (Tukey), p: p value for comparing between the three studied groups, p0: p value for comparing between Pre and Post

p1: p value for comparing between DSTand MDST technique, p2: p value for comparing between DSTand Control

p3: p value for comparing between MDST technique and Control,

*: Statistically significant at p ≤ 0.05

Table 20. Comparison between the three studied groups according to rate of change of RV basal dimension(mm) & PA pressure(mmHg)

		Diaphragmatic stretch technique (n=10)	Manual diaphragm release technique (n=10)	Control (n = 10)	F	p
RV basal dimension	Min. – Max.	36-44	36-43	25-40	0.11	0.08
	Mean ± SD.	42.02±5.35	42.22±5.55	32.24±6.35		
	Median	42	42	33		
	Sig. bet. Grps.	p1=0.5, p2=0.5,p3=0.01				
	Min. – Max.	36-40	36-40	26-40	0.13	0.08
	Mean ± SD.	39.88±7.23	40.01.± 6.98	32.84±6.02		
	Median	39	40	33		
	Sig. bet. Grps.	p1=0.5,p2=0.5,p3=0.01				
	t(p0)	0.01 (0.001*)	0.01 (0.001*)	0.01* (0.001*)		
PA systolic pressure	Min. – Max.	26 – 38	25 –38	20– 30	2.78	0.06
	Mean ± SD.	33.34±6.34	32.24±6.35	26.66±4.75		
	Median	36.41	36.40	26.55		
	Sig. bet. Grps.	p1=0.02,p2=.05,p3=0.09>0.05				
	Min. – Max.	25 – 33	25 –34	20– 30	2.68	0.059
	Mean ± SD.	32.01±6.13	32.64±5.65	26.6±6.55		
	Median	32.25	32.48	25.1		
	Sig. bet. Grps.	p1=0.02,p2=0.05,p3=0.09>0.05				
	t(p0)	0.571278125	0.681478726	T(P0) = 0		

IQR: Inter quartile range SD: Standard deviation t: Paired t-test

F: F for One way ANOVA test, pairwise comparison bet. each 2 groups were done using Post Hoc Test (Tukey), p: p value for comparing between the three studied groups, p0: p value for comparing between Pre and Post

p1: p value for comparing between DST and MDST technique. p2: p value for comparing between DST and control.

p3: p value for comparing between MDST technique and control. *: Statistically significant at p ≤ 0.05

Table 21. Comparison between the three studied groups according to tricuspid annular plan systolic excursion (TAPSE) and RV systolic velocity by tissue Doppler (RV-Sa)

			Diaphragmatic stretch technique (n = 10)	Manual diaphragm release technique (n = 10)	Control (n = 10)	F	p
TAPSE (mm)	Pre	Min. – Max.	14– 16	14-16	18– 22	0.06	0.077
		Mean ± SD.	15.2 ± 2.9	15.32 ± 2.32	22 ± 5.22		
		Median	16	16	23		
		Sig. bet. Grps.	p_1=0.77, p_2=0.77=p_3=.077				
	Post	Min. – Max.	16 – 18	16-18	18-28	0.07	0.077
		Mean ± SD.	17.21 ± 3.02	17.2 ± 3.83	22.5 ± 5.6		
		Median	17.9	17.8	24		
		Sig. bet. Grps.	p_1=0.77, p_2=0.77, p_3=0.77				
		t(p_0)	0.95	0.96	0.97		
RV-Sa (cm/sec) ventricular	Pre	Min. – Max.	7–9	7-9	8 – 10	0.44	0.02
		Mean ± SD.	8± 1.01	8.01± 0.99	9 ±0.98		
		Median	8.1	8.1	9.1		
	Post	Min. – Max.	7.8–9.9	7.7–9.9	8–10	0.43	0.018
		Mean ± SD.	9.7± 2.2	9.7± 2.3	9±1.22		
		Median	9.65	9.61	9.2		
		Sig. bet. Grps.	p_1=0.77, p_2=0.77, p_3=0.77				
		t(p_0)	0.95	0.96	0.97		

IQR: Inter quartile range SD: Standard deviation t: Paired t-test

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Tukey), p: p value for comparing between the three studied groups, p0: p value for comparing between Pre and Post

p1: p value for comparing between DSTand MDST technique, p2: p value for comparing between DSTand Control, p3: p value for comparing between MDST technique and Control, *: Statistically significant at p ≤ 0.05

Rocha et al. performed a research in which they used the MDST Technique on stable COPD patients and reported an improvement in diaphragm mobility (Rocha T et al., 2015).

Abdaleel A. A et al., 2015 found that employing the diaphragmatic release technique and re-doming of the diaphragm technique resulted in a notable enhancement in Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), and the distance traveled during the 6-minute walk test (6MWT).

A study conducted by Braga D. k et al., 2016, found that utilizing the "diaphragm lift" and double diaphragm led to improvements in the maximum expiratory pressure, all cytometry coefficients, and thoracic cavity mobility.

The results of this research suggest that both the DST and MDST techniques have a significant and advantageous impact on Vab in patients with severe pneumonia, in comparison to the control group. The findings indicate that the application of these manual therapy techniques results in improved diaphragmatic and pulmonary function.

Rocha et al. (2015) replicated the aforementioned results, demonstrating that the MDST Technique improves diaphragmatic mobility, exercise capacity, and inspiratory function in individuals with chronic obstructive pulmonary disease. This technique might be considered for the management of persons with chronic obstructive pulmonary disease.

Similar results were obtained by Bennett et al. (2021), who demonstrated that the MDST Technique has the capacity to significantly improve diaphragmatic mobility and reduce expansion of the lower and abdominal chest wall in children with CP. Therefore, MDST should be considered as an additional approach to physiotherapy programs designed to improve diaphragmatic function in persons with spastic cerebral palsy.

The DST and MDST groups displayed comparable systolic pressures during maximum exertion, which were significantly distinct from those of the Control group. The results suggest that both techniques may influence blood pressure during physical exercise, perhaps resulting in enhancements in cardiovascular health. The lack of significant changes at rest indicates that the therapies may not have a significant impact on systolic pressure when at rest.

Roshan, P. S. B., and Niranjan Meenar, S. S. (2021) discovered that the combination of the diaphragmatic stretch method and Jacobson's relaxation technique resulted in a substantial improvement ($P<0.001$) within the group when comparing the findings from the first day to the eighth week of interventions. Nevertheless, there was no statistically significant alteration found when comparing the group practicing diaphragmatic breathing alone with the group practicing diaphragmatic breathing in combination with Jacobson's relaxation technique ($P>0.05$).

The Control group exhibited a significant change from pre-intervention to post-intervention. As a result, the Control group showed changes in systolic pressure over the study, but the other groups did not show any statistically significant differences.

DST and the MDST groups had similar maximum respiratory rates during exercise, suggesting that they have equivalent effects on respiratory parameters. An observable disparity between the Control group and another group suggests possible advantages in the respiratory response. The Control group demonstrated a considerable gap in the percentage change from before to after exercise, in compared to both the DST and MDST groups. These data suggest that diaphragmatic manual treatment techniques might potentially influence the percentage change in breathing rate during intense physical exercise.

The research of (Chukwu, S. C., et al., 2022) demonstrated that the DBE group exhibited a considerable boost in respiratory functions when comparing the pre- and post-test results. There was a large difference between the study group and control groups. The respiratory values exhibited a robust connection with the MPT values. Specifically, the correlation coefficients (r[p]) for FVC, FEV1, and PEF were 0.416 ($p=0.011$), 0.416 ($p=0.010$), and 0.566 ($p=0.000$), respectively. However, there was no significant link between FEV1/FVC and MPT, with a correlation value of 0.248 ($p=0.138$). The voice category exhibited no association with respiratory parameters or maximum phonation time (MPT). Male singers revealed higher modifications in respiratory function, while female vocalists displayed more substantial increases in maximum phonation time (MPT).

The study gives useful insights into the influence of manual therapy on echocardiography measures, but also underscores the demand for future research to validate and corroborate these results.

The research consistently indicated that both diaphragmatic stretch and manual diaphragm release therapies had an influence on the dimensions of the right ventricle. These manual treatments possess the ability to maintain or alter the structure of the RV. This suggests that these manual operations may have broader ramifications on the circulatory system beyond the right ventricle. The research conducted by ELIMY, D. A., et al. in 2022 found similar results when the manual diaphragm release was supplemented with additional procedures.

The research revealed significant disparities in certain measures of left ventricular diastolic function, namely LV (E/A) and RV (E/A). The aforementioned study by Fernandez-Lopez et al. (2021) demonstrates the efficacy of diaphragmatic stretching and manual release methods in influencing cardiac dynamics.

Both diaphragmatic stretch and manual diaphragm release procedures had a comparable and statistically insignificant effect on cardiac output and ejection fraction when compared to the control group. The close closeness of the mean values and the lack of statistical significance suggest that these therapies are unlikely to cause significant changes in these cardiovascular parameters.

The study highlights the need for more investigation in order to comprehensively comprehend the enduring effects of these manual treatments, specifically on the dimensions of the right ventricle and the pressure in the pulmonary artery.

The findings suggest that manual intervention may have clinical significance for individuals with severe pneumonia, however more investigation is required to determine the exact therapeutic benefits and applications.

These results provide valuable insights into potential therapies for persons suffering from severe pneumonia, emphasizing the importance of diaphragmatic manual therapy in enhancing respiratory function. Further research and clinical trials are required to validate these results and explore the long-term effects of these methods on the respiratory well-being of persons with pneumonia.

Conclusion

The DST and MDST Technique can be safely recommended for patients with severe pneumonia to improve diaphragmatic excursion and chest expansion confermed by improved RV function.

Author contributions

M.M.S., M.T.S., S.B.E., Z.R.A., A.I.S., T.S.A., M.M.E.A.A., H.A.S., E.R.M.M., A.K.A.A., E.W., G.M.M.S.E., S.N.M.M., P.M.H. all contributed to the study design, data collection, analysis, interpretation, and manuscript preparation. All authors reviewed and approved the final manuscript.

Acknowledgment

Author was grateful to their department.

Competing financial interests

The authors have no conflict of interest.

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