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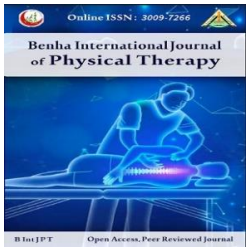

Original research

NMES as an Adjunct to Conventional Rehabilitation for Phrenic Nerve Recovery After Cardiac Surgery: A Randomized Controlled Trial

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Abstract:

Background: This study investigated the effects of transcutaneous electrical diaphragmatic stimulation (TEDS) on phrenic nerve regeneration following cardiac surgery, aiming to reduce respiratory dysfunction and improve recovery outcomes. **Methods:** Fifty patients aged 25–45 years who underwent cardiac surgery were randomly assigned to two groups 25 participants for each group. The TEDS group received conventional physiotherapy combined with transcutaneous electrical diaphragmatic stimulation (TEDS), while the conventional group received Conventional physiotherapy alone. Interventions were administered three times per week for four weeks. Nerve conduction studies assessed phrenic nerve regeneration through latency, amplitude, and area measurements pre and post treatment. **Results:** The TEDS group demonstrated statistically significant increase in latency mean increase 54.94% and improvement amplitude mean increase: 75.45% compared to the conventional group 6.01% and 11.83%, respectively. No significant difference was observed in the area parameter between the two groups. **Conclusion:** Adding TEDS to conventional rehabilitation significantly enhances phrenic nerve regeneration, as evidenced by improved and increase amplitude. This noninvasive adjunct may optimize postoperative recovery in cardiac surgery patients.

Keywords: Cardiac surgeries, Nerve conduction study, Phrenic nerve injury, TENS.

Introduction

The surgical repair of problems affecting the heart and the thoracic aorta is the focus of cardiac surgery, a subspecialty of general surgery [1, 2]. From its beginnings at the end of the nineteenth century, current cardiac surgery has progressed thanks to the efforts of many dedicated surgeons who have expanded the range of heart pathologies that may be treated. This progress is occurring even now [3-5]. Major surgery like coronary artery bypass grafting (CABG) removes atheromatous blocks from the coronary arteries and replaces them with conduits taken from the veins or arteries [6-8]. The most frequent major surgical treatment, with about 400,000 operations performed annually, is CABG[9,10].

Phrenic nerve (PN) injury post-cardiac surgery is a serious problem closely related to frequent respiratory complications [11]. The frequency of Diaphragm dysfunction (DD) owing to PN damage post-cardiac surgery may approach 75%, and it has been linked to pneumonia, DD, as well as difficulties weaning critically sick patients [12].

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Respiratory problems following heart surgery can arise for a variety of reasons, including but not limited to invasive mechanical ventilation, general anesthesia, surfactant damage, sternotomy, as well as cardiopulmonary bypass [13, 14].

Physical therapists frequently employ neuromuscular electrical stimulation (NMES) to encourage muscle development and strength training [15]. To produce muscular contractions, NMES involves applying an electric current to the membranes of alpha-motor neurons, which depolarizes them and sets off an action potential. This physical therapy procedure is low-cost and carries little risk [16]. The use of NMES to induce involuntary muscle contractions offers the dual benefit of preserving muscle thickness and strength without necessitating cooperation [17, 18]. Recently, there has been a rise in research using transcutaneous electrical stimulation of the diaphragm (TEDS). Electrodes put on the skin of the patient's chest, one on each side, over the area where the diaphragm attaches, allow TEDS to deliver non-invasive stimulation [19]. TEDS reduced the incidence of ventilator weaning failure while increasing the number of type II fibers, maximum expiratory pressure, and mean inspiratory pressure (MIP) [20]. Therefore, we hypothesize that TEDS and conventional treatment have gained better benefits than conventional treatment only in improving amplitude and latency; however, no significant statistical difference in area.

Significance of study: There is a noticeable gap in the literature regarding this topic, indicating a need for further investigation. a Previous investigation conducted by SHAZA et al. [21]., who observed very significant improvement in PaO2 / FiO2 ratio and SaO2 ($p > 0.05$) was noted. The mean values of PaO2 showed significant increase pre and post study in both groups in favor to TEDS group. The percentage of change were 27% and 13%. The TEDS group showed tendency toward decreased PaCO2. Also, previous study conducted by Hsin YF et al. 2022. [22], After TEDS, there was a significant increase in Pemax (10 [8–20] vs. 20 [10–22] cmH2O, $P = 0.034$) in the intervention group. At the end of the study, the improvement of minute volume in the TEDS group (0.64 (−0.67) was significantly higher than the control group (−0.64 (−2.5–0.78) ($P = 0.008$). In the control group, there was a significant difference between groups in the weaning rate, with a higher rate in the TEDS group (90%) when compared with that in the control group (66.7%) ($P = 0.021$). Accordingly, we aim to investigate the effect of TEDS on phrenic nerve amplitude, latency and area post-cardiac surgeries due to lack of sufficient studies. It has been estimated that somewhere between 30–75% of patients undergoing cardiac surgery have some radiological evidence of unilateral phrenic nerve injury post-operatively and Diaphragm dysfunction is a common complication following cardiac surgery [23] , increased flow of patients after cardiac surgeries in kasr Aini hospital who suffers from respiratory complication due to phrenic nerve injury so the hospitalization period of them increased which make economic burden in health insurance services with decreased level of quality of life that is the most concern as to improve patient status and relief this burden. So, this study aims to decrease respiratory complication and improve phrenic nerve regeneration by using TEDS as a safe, non-invasive, inexpensive and virtually risk-free method.

Methods:

Patients and Study Design:

Individuals were screened for potential inclusion in a randomized control study. They had been recruited from Kasr Al Aniey (cardiothoracic surgeries ICU and 24 department), and assigned at random into two equal groups by simple Randomization numbers in the envelope to take part in this study over a ten-month period (May 2024–February 2025). The treatment program's techniques and measuring devices were thoroughly explained to all patients, and they signed an informed consent form. An ethical review board from Cairo University's Faculty of Physical Therapy gave its approval to this research (P.T.REC/012/005299). The study was registered in the Clinical Trials Registry (registration no: NCT06621693) and followed the Helsinki Declaration.

Articles will be eligible for inclusion if they meet the following criteria:

Inclusion criteria:

Fifty male and female patients post cardiac operations (CABG, valve repair or replacement) referred by a physician, medically stable patients (normal range of heart rate, blood pressure in addition to oxygen saturation on room air), both genders, age 25-45 years old, BMI 25-29.9 kg/m2, overweight It is as well supposed to be a hazard

reason for preoperative morbidity and mortality with cardiac surgery [24] , Conscious patient who can follow verbal instructions and comprehend study needs. The exclusion criteria included: Patients with rib fractures, Patients developing lung cancer, or Patients who have dementia., Patients on mechanical ventilators after 24 hours, metabolically unstable, and with chronic illness were randomized into two groups equivalent in number by simple Randomization. The TESD group received TENS and conventional treatment, and the Conventional group received conventional treatment, including diaphragmatic breathing exercises, percussion, postural drainage, cardiac rehab phase one, and balance training. The treatment was done three sessions a week for 4 weeks, and nerve regeneration was evaluated by nerve conduction study **(Figure 1).**

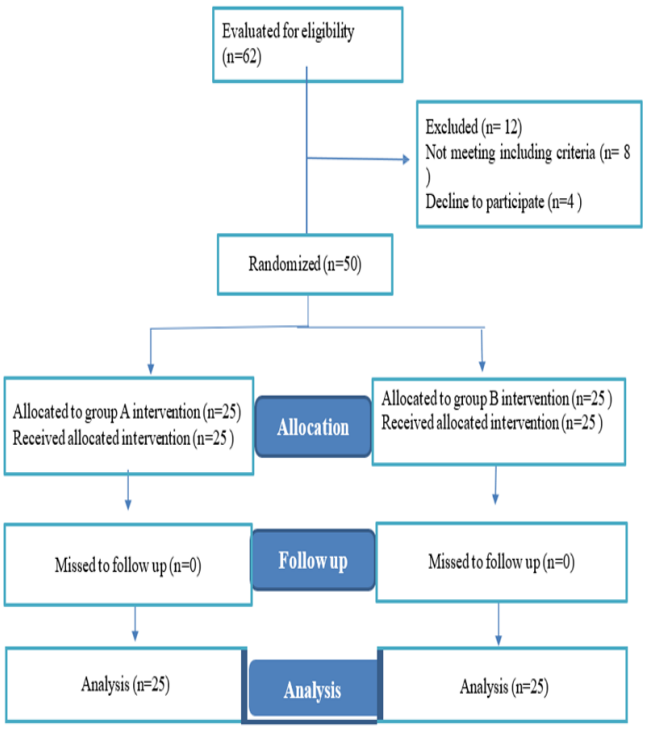

Fig. 1. Study Flowchart

Outcome Measures

Nerve conduction studies (NCSs): All outcome measures (latency, amplitude, and area) were evaluated before the start of the intervention and immediately following the completion of treatment by nerve conduction study. NCSs are a key component of peripheral nervous system evaluation. Compound muscle action potentials (CMAPs) assess the entire motor nerve fiber pathway, from the anterior horn cell to the muscle fibers. During PN conduction studies, participants were positioned supine while a bipolar stimulating electrode (Neurosoft, Ivanovo, Russia) was placed between the sternal and clavicular heads of the sternocleidomastoid muscle, just superior to the clavicle. Two reusable disc electrodes (Viasys Healthcare, Madison, WI) were used for recording. The active electrode (G1) was placed 5 cm above the xiphoid process, and the reference electrode (G2) was positioned 16 cm ipsilateral to the stimulated PN. Normative values for expiratory CMAP were as follows: amplitude (0.47–0.83 mV), latency (5.74–7.10 ms), and duration (18.30–20.96 ms). For inspiratory CMAP, normative data included amplitude (0.67–1.11 mV), latency (5.90–6.34 ms), and duration (13.77–15.37 ms) [25].

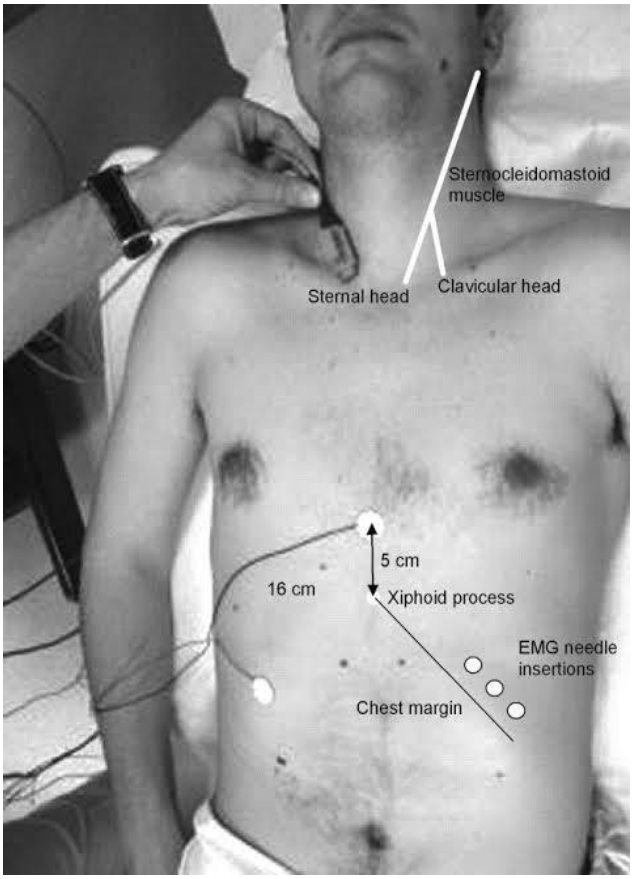

Fig.2. Nerve conduction study for phrenic nerve

Therapeutic procedures:

Conventional Group subjects underwent postural drainage, percussion, diaphragmatic breathing exercises, phase 1 cardiac rehab, and balance training**.**

Postural drainage:

1. patient position the patient was tilted or propped at an angle required and chest percussion is performed to loosen the secretions. Frames, tilt tables, and pillows may be used to support patients in these positions**.**

2 **.**the upper lobe segments have the advantage of gravity drainage both in erect as well as in semi recumbent position, so postural drainage can be facilitated in sitting or lying posture**.**

3 **.**The middle and lower lobes do not have the advantage of gravity drainage in erect, semi-recumbent or recumbent postures. A foot end elevation of 14-18 inches is requires for the drainage of middle and lower lobes [26].

4 **.**Each position consists of placing the target lung segment(s) superior to the carina. Positions should generally be held for 15 minutes (longer in special situations)**.**

The percussion technique: involved using cupped hands to trap air between the patient's chest and the therapist's palm in a rhythmic, alternating pattern over the sections of the lungs that needed to expel secretions from bottom to top. When coupled with the corresponding gravity placement. It was executed during the inspiratory and expiratory stages of breathing. Percussion rate, 400 repetitions per minute [27].

Diaphragmatic breathing exercise: The patient was instructed to lie on their back on a level surface, such as a bed, with their knees flexed. One hand is placed on top of the chest while the other is placed on the belly, slightly below the rib cage. Patients take a few deep breaths through their nose. The abdominal muscles should contract and draw in during exhalation through pursed lips. Get in 5 or 10 minutes of practice [28]

Phase 1 cardiac Rehabilitation: Intensity table of perceived effort below 13 (scale 6-20) 6: No exertion, 7: Extremely light, 8-9: Very light, 11: Light exertion, 12-13: Moderate exertion (somewhat hard), 14-16: Hard to very hard exertion, 17-19: Extremely hard exertion ,20: Maximal exertion, Post-surgery HR of pateints during exercise= Resting heart rate + 30 beats per minute (Arbitrary upper limit). Duration: Intermittent sessions lasting from 3 to 5 min, resting periods from 1 to 2 min Shorter than the time of the exercise sessions Total duration of 20 min., Progression: Initially increase the duration by up to 10 to 15 min of exercise time and then increase the intensity [29] **.**

Balance training: minimum for four weeks, with three sessions weekly. Assume a standing position with one leg up and the other bent or behind you. Positioning your heel directly behind your toes, often known as a tandem stance, getting out of a chair and back into it without using your hands [30]**.**

TEDS Group subjects underwent TEDS and conventional treatment for 30 min per session, 3 days/week/4 weeks. Rectangular electrodes (A electrodes) were positioned on the parasternal region adjacent to the xiphoid process in each session. (B electrodes) placement in the sixth and seventh intercostal spaces along the mid-axillary line. TEDS intensity was incrementally increased until visible muscle. TEDS was administered at a frequency of 2–5 Hz with a pulse width of 200–250 μs [31].

Fig. 3. Electrode placement of TEDS

Figure 5: Transcutaneous Electrical Stimulation (TENS made in china)

Statistical analysis

Software developed by SPSS, Inc. of Chicago, IL, USA, v25 for Windows, was employed for the statistical analysis. To compare between both groups for patients' clinical general characteristics, numerical variables were used for the independent t-test, and the categorical variable (gender) was described as frequency and percentage and compared by the Chi-square test. The mixed design 2 x 2 MANOVA was employed, with the first independent variable (between-subject factor) consisting of two levels: the TEDS group and the conventional group. The second independent variable (within-subject factor) involved two levels of measurement periods: baseline and post-treatment. This design was utilized to compare the main outcome measures of interest, namely latency, amplitude, and area. The Bonferroni test was employed to conduct pairwise comparisons within and among groups, where F was significant according to the MANOVA test. Statistical analyses reached significance at $P \leq 0.05$.

Results

The present study involved 50 patients who received post-cardiac surgery, comprising 26 males and 24 females. These participants were randomly assigned to two equivalent groups, with 25 individuals in each group. The analysis of the clinical, demographic characteristics of patients (Table 1) indicated no significant disptrities ($P>0.05$) in the mean values for age ($P=0.892$), weight ($P=0.343$), height ($P=0.614$), BMI ($P=0.465$), along with sex ($P=1.000$) among the TEDS group and the conventional group.

Table 1. Patients' clinical general characteristics

Item	TEDS group (n=25)	Conventional group (n=25)	p-value
Age (years)	35.12 ± 6.02	35.36 ± 6.37	0.892
Weight (kg)	74.12 ± 5.93	72.36 ± 7.02	0.343
Height (cm)	164.92 ± 7.57	163.84 ± 7.47	0.614
BMI (kg/m^2)	27.22 ± 1.48	26.92 ± 1.44	0.465
Gender Males Females	13 (52.00%) 12 (48.00%)	13 (52.00%) 12 (48.00%)	1.000

Quantitative data (age, weight, height, and BMI) are reported as mean ± standard deviation; t-independent test. Qualitative data (gender) are reported as a frequency (percentage); Chi-square test. P > 0.05: non-significant.

Statistical multiple pairwise comparison tests for main outcome variables (latency, amplitude, and area) in post-cardiac surgery patients within each group showcased a significant (P<0.05) increases in latency (P=0.0001; Table 2) and amplitude (P=0.0001; Table 2) at post-treatment in comparison with baseline values within TEDS group, but insignificantly (P>0.05) increased at post-treatment for latency (P=0.693) and amplitude (P=0.831) within conventional group. Moreover, the post-cardiac surgery patients who received TENS stimulation (TEDS group) increase latency (ms) increasing percentage (54.94 %) and amplitude (µV) increasing percentage (75.45%, respectively) ,than patients with post-cardiac surgery (6.01 % and 11. 83%, respectively) who received conventional physical therapy. Table 2 shows that both TEDS (P=0.853) and conventional groups (P=0.840) had no statistically significant reduction in area after treatment compared to baseline values (P>0.05).

Table 2. Within and between groups comparison for outcome variables

Variable	Item	TEDS group (n=25)	Conventional group (n=25)	Change	95% CI	Effect size (ɳ2)	p-value
Latency	Pre-treatment	6.17 ±1.40	5.82 ±1.70	0.35	-1.50 – 2.19	0.002	0.709
	Post-treatment	9.56 ±4.88	6.17 ±2.29	3.39	1.67 – 5.10	0.151	0.0001*
	Change (MD)	3.39	0.35				
	95% CI	1.62 – 5.17	-1.43 – 2.14				
	Improvement %	54.94%	6.01%				
	Effect size (ɳ2)	0.143	0.002				
	p-value	0.0001*	0.693				
Amplitude	Pre-treatment	79.88 ±38.48	67.63 ±15.43	12.25	-64.44 – 88.94	0.001	0.752
	Post-treatment	140.15 ±32.83	75.63 ±32.71	64.52	39.48 – 89.56	0.324	0.0001*
	Change (MD)	60.27	8.22				

	95% CI	32.69 – 87.85	-66.26 – 82.25				
	Improvement %	75.45%	11.83%				
	Effect size (ɳ2)	0.300	0.001				
	p-value	0.0001*	0.831				
Area	Pre-treatment	7.13 ±2.25	6.35 ±1.79	0.78	-0.40 – 1.96	0.019	0.0193
	Post-treatment	7.02 ±2.12	6.23 ±1.47	0.79	-0.30 – 1.88	0.023	0.155
	Change (MD)	0.11	0.12				
	95% CI	-1.02 – 1.24	-1.02 – 1.26				
	Improvement %	1.54%	1.89%				
	Effect size (ɳ2)	0.00	0.00				
	p-value	0.853	0.840				

Data interpretation: Mean ± standard deviation (SD); 2x2 MANOVA test.
*MD: Mean difference, CI: confidence interval, * P < 0.05*

1) Latency (Mean ±SD)			
Mixed MANOVA (Overall effect)			
MANOVA Overall effect	F-value	P-value	Significance
Group effect	8.691	0.004*	S
Time effect	8.771	0.004*	S
Interaction (Group x Time) effect	5.758	0.015*	S

2) Amplitude (Mean ±SD)			
Mixed MANOVA (Overall effect)			
MANOVA Overall effect	F-value	P-value	Significance
Group effect	21.310	0.0001 *	S
Time effect	19.841	0.0001 *	S
Interaction (Group x Time) effect	17.225	0.0001 *	S

3) Area (Mean ±SD)			
Mixed MANOVA (Overall effect)			
MANOVA Overall effect	F-valu	P-value	Significance
Group effect	3.753	0.056	NS
Time effect	0.076	0.784	NS
Interaction (Group x Time) effect	0.000	0.989	NS

In our study, we analyzed three dependent variables of interest (latency, amplitude, and area), which are related physiological measures and may be correlated. For this reason, we initially employed a mixed-design MANOVA (2 × 2) rather than a mixed-design ANOVA. The MANOVA approach allows simultaneous testing of the combined effect of group (between-subject factor) and time (within-subject factor) on the dependent variables, while also controlling for Type I error inflation that may occur when running multiple separate ANOVAs.

After finding significant multivariate effects in the MANOVA, we performed follow-up univariate ANOVAs (with Bonferroni adjustment) to explore effects on each variable individually. In other words, MANOVA was used as an omnibus test for the three outcome variables together, and then mixed ANOVA was effectively applied to each dependent variable in the post-hoc analysis.

Discussion

The current study was performed to show the impact of TEDS and conventional physiotherapy on phrenic nerve Regeneration post-major cardiac surgeries, and the results showed a latency-increasing percentage (54.94%) and an amplitude improved increasing percentage (75.45%). However, there has been a decrease in the areas of pre- and post-TEDS and conventional physical therapy.

Interpretation of finding:

Regarding Amplitude variable:

The post cardiac surgery patients received TEDS stimulation and Conventional physical therapy improved amplitude increasing percentage (75.45%) than patients with post cardiac surgery (11.83%) who received conventional physical therapy only.

The Rationale of improvement amplitude is due to ES is also found to accelerate regeneration following nerve injuries that cannot be repaired primarily and require alternative forms of reconstruction, ES application activates the intrinsic cellular mechanisms of regeneration causes calcium and sodium to flood the neuron, creating an action potential that propagates retrograde to the cell body, similar to that which occurs naturally following an injury. Inhibition of intracellular calcium influx blocks the regenerative response in injured neurons. previous study In vitro experiments in cultured spinal neurons demonstrated that following ES delivery (20 Hz, 3–5 V, 100 μsec) and subsequent calcium influx, there is an increase in mRNA expression of BDNF (brain derived neurotrophic factor) and its high-affinity receptor, tyrosine receptor kinase B (trkB). Together these molecules mediate many of the downstream effects of ES. Electrical stimulation proximal to the injury site stimulates the upregulation of RAG (Recombination-Activating Genes) through a calcium-dependent mechanism.

Increased expression of BDNF and trkB drives increased expression of cAMP (cyclic adenosine monophosphate) which activates CREB (cAMP response element binding protein) to maximize the pro-regenerative axon phenotype, stimulating axonal sprouting and neuron survival [32]

TENS are used to improve sensory feedback and adjust neural network pathways. Sensory feedback plays an important role in completing an action. When the motor nerve is damaged and unable to conduct, the sensory nerve will temporarily innervate the muscle to prevent muscle atrophy until the motor nerve recovers [33]. Some scholars believed that ES could redistribute blood flow to active muscles and meet muscle metabolic demands, which encouraged muscle contraction. another study in animal experiments, nerve ES can increase the structural changes of capillaries in rats with nerve injury, thereby increasing blood flow, providing sufficient oxygen, and accelerating peripheral nerve regeneration [34.]

Regarding latency variable:

The post cardiac surgery patients received TEDS stimulation and conventional physical therapy increase latency increasing percentage (54.94%) than patients with post cardiac surgery (6.01%) who received conventional physical therapy only. mechanism of increased peripheral nerve latency after electrical stimulation occurs due to temporary axonal conduction failure or hyperpolarization, rather than nerve damage. High-intensity or prolonged stimulation can cause sustained excitation of the neuron, leading to a prolonged silence or recovery period where nerve impulses are slowed or temporarily blocked, thus increasing latency [35].

This opinion supported by previous study conducted by Serrano-Muñoz D et al [36] has shown that compared with the sham-stimulation group, and 40 min of TENS can significantly inhibit the amplitude and lengthen the latency of the soleus H-reflex. TENS at a frequency of 10 kHz had the effect of regulating the soleus H-reflex, but there was no meaningful difference between the two groups.

Regarding Area variable:

The post cardiac surgery patients received TEDS stimulation and conventional physical therapy decreased in area percentage (1.54%) than patients with post cardiac surgery (1.89%), who received Conventional physical therapy only evidence in this point is very rare.

The rationale behind the absence the effect of conventional physical therapy on amplitude, latency and area, the direct impact and improvement on respiratory muscle strength, oxygen saturation and arterial blood gases than nerve regeneration,

Supported by prospective, single-blinded study in a general hospital intensive care unit (ICU). Patients who required mechanical ventilation longer than 48 h and who were expected to remain mechanically ventilated for at least another 48 h were randomly divided into two intervention groups: group I (n = 9) - the routine care group, received physical therapy according to our daily custom protocol; and group II (n = 9) - the intensive treatment group, were treated by the same protocol twice a day. he main outcome measures included the Medical Research Council (MRC) physical strength examination, maximal inspiratory pressure (MIP), significant strength improvement from first (T1) to second (T2) measurements was demonstrated for variables MIP and MRC physical strength examination in favor of the intensive treatment group ($P < 0.05$). The intensive treatment group also required shorter intensive care length of stay than the routine care group ($P = 0.043$). [37]

Another study on Thirty patients post MV, their age ranged from 50 to 60 years old were recruited in this study. The patients were selected from ICUs of Kasr al Ainy hospital, Faculty of Medicine, Cairo University The patients received conventional physical therapy has shown that improvement in Pao2 and SaO2 in addition to decreased incidence of chest infection and decreased ICU stay [38].

The findings of this study about the impact of using TEDS on phrenic nerve regeneration were in line with the findings of a previous study conducted by Hsin et al [39] examined the effects of transcutaneous electrical diaphragmatic stimulation (TEDS) on respiratory muscle strength and weaning outcomes in patients with PMV (prolonged mechanical ventilation) Participants on ventilation for ≥21 days were randomly assigned to TEDS (n = 29) and control (n = 30) groups. The TEDS group received muscle electrical stimulation for 30 min/session/day throughout the intervention. Pulmonary function parameters (tidal volume,

respiratory rate, and rapid shallow breathing index), and respiratory muscle strength (Pimax, Pemax) were assessed. The hospitalization outcome, including weaning rate and length of stay, was followed up until discharge. Results: show that After TEDS, there was a significant increase in Pemax (10 [8-20] vs. 20 [10-22] cmH2O, P = 0.034) in the intervention group. At the end of the study, the improvement of minute volume in the TEDS group (0.64 (-0.67) was significantly higher than the control group (-0.64 (-2.5-0.78) (P = 0.008). In the control group, there was no significant difference between pre- and post-measurement of weaning parameters. There was a significant difference between groups in the weaning rate, with a higher rate in the TEDS group (90%) when compared with that in the control group (66.7%) (P =0.021). all of outcomes improvement agrees with the results of this study aims decrease respiratory complication, improve quality of life and patient status decrease hospitalization period and economic burden in health insurance services.

Another study that matches the findings of this study rationale Nassef et al. [40], indicating a significant escalation in SaO2 and an increase in the PaO2/FiO2 ratio (p > 0.05). Compared to the control, the TEDS group's mean PaO2 readings increased significantly prior to and after the study. The change percentages were 13% and 27%, respectively. Decreases in PaCO2 were seen in the TEDS group.

Controversial study for this study conducted by Medrina et al. [41]. a controlled trial to assess the impact of daily active electrical stimulation versus sham stimulation on the prevention of diaphragm dysfunction during the weaning process from mechanical ventilation. The evaluation was based on ultrasound measurements of diaphragm thickening fraction during spontaneous breathing trials. also measured maximal inspiratory muscle pressure (MIP), peak cough flow (PEF) and extubation failure., Sixty-six patients were included and randomised using a 1:1 ratio. Results show that Diaphragm thickening fraction was > 30% at the SBT (Spontaneous Breathing Trial) for 67% of participants in the TEDS group and 54% of the Sham group (OR1.55, 95% CI 0.47-5.1; p = 0.47). MIP and PEF were similar in the TEDS and Sham groups (respectively 35.5 ± 11.9 vs 29.7 ± 11.7 cmH20; p = 0.469 and 83.2 ± 39.5 vs. 75.3 ± 34.08 L/min; p = 0.83). TEDS did not prevent diaphragm dysfunction or improve inspiratory muscle strength in mechanically ventilated patients.

Limitations:

1.The study sample was considerably less; large sample will be better representative of the population and will hence provide more accurate results increase statistical power to answer the primary research question. [42]

2-The study was limited to short time, for further studies longer time with periodical follow up should be included to improve research participant's experience and health of populations also electrical stimulation seems to only jump-start axonal regeneration, as increasing the period of stimulation from a single hour to 2 weeks did not further improve outcomes; in fact, a longer duration of stimulation was detrimental for neuron regeneration.[43]

3. using more accurate assessment tools as diaphragmatic ultrasound, ultrasonography is a promising technique for the evaluation of the structure and dynamic function of the diaphragm. It is accurate, reproducible, and relatively easy to learn. The modality is portable, which is very important for critically ill patients on mechanical ventilation, and uses no ionizing radiation Sarwal A et al.[44]

Conclusions:

The present clinical trial has concluded that treating patients' post-cardiac surgeries with TEDS and conventional treatment, including (diaphragmatic breathing exercises, percussion, postural drainage, cardiac rehab phase one, and balance training) has gained better benefits than conventional treatment only in improving and increase amplitude and increase latency, However, No significant statistical difference in area.

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Conflicting interest:

None.

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