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Effect of Transcutaneous Electrical Co-Activation of Diaphragm and Abdominal Muscles on Weaning Time in Mechanically Ventilated Patients

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ABSTRACT

Background: In intensive care units (ICUs), around one-third of severely sick patients need mechanical ventilation (MV) to maintain their breathing; some require it for just hours, while others need it for months. The diaphragm, abdominal, and intercostal muscles—the three main breathing muscles—may experience atrophy due to lack of usage during this period.

Objective: We aimed to determine the effect of transcutaneous electrical co-activation of diaphragm and abdominal muscles on weaning time in MV patients.

Patients and Methods: A total of 52 mechanically ventilated patients of both sexes participated in the study with age range from 40 to 55 years old. They were recruited from ICU Department in New Cairo Generalized Hospital; referred by physicians. They were assigned randomly into 2 Groups. Group A consisted of 26 patients; received co-activation of both diaphragmatic electrical stimulation and abdominal functional stimulation in addition to conventional physical program for one session per day for 7 days a week till discharge, 60 minutes per session. Group B consisted of 26 patients; received conventional physical therapy program for 30 minutes per session for one session a day for 7 sessions a week till discharge. Outcome measure weaning time was assessed.

Results: Both groups showed significant improvements in the weaning time. However, Group A demonstrated greater improvements compared to Group B.

Conclusion: Application of transcutaneous diaphragmatic stimulation and abdominal functional electrical stimulation is safe way for critically ill patients for decreasing length of duration in ICU for mechanically ventilated patient thus improve weaning.

Keywords: TEDS, FES, MV, Weaning.

INTRODUCTION

MV is the most often used short-term life support treatment globally, and it is utilized on a daily basis for a wide range of causes, including acute organ failure and planned surgical operations [(1-3)].

MV treats critically sick people globally for a variety of causes. It has recently been demonstrated that MV may have negative effects [(4)].

Patients on MV are susceptible to respiratory muscle weakening. It is well known that ICU acquired muscular weakness is a common disease that is linked to a poor prognosis, challenging ventilator liberation, and longer ventilator stays [(5)]. Diaphragm dysfunction patients had greater ICU and hospital mortality rates than non-diaphragm dysfunction patients [(6)].

Weaning difficulties and prolonged MV have been linked to acquired diaphragm dysfunction and atrophy in patients on MV in ICUs [(7)]. This lowers respiratory function and causes a host of problems, such as difficulties weaning off of MV, elevated mortality, cardiac and respiratory issues, hospital readmissions, reduced QOL, and ICU stays [(8)].

Reducing the level of ventilator support and empowering the patient to take on more of their own breathing (e.g., spontaneous breathing trials or a progressive reduction in ventilator assistance) is known as weaning. Extubation is the last stage of being freed from MV assistance. It involves removing the endotracheal tube. When the patient successfully weans and all airway protective measures and patency are in place, extubation is done [(9)]. Reducing respiratory muscle atrophy or strengthening respiratory muscle is expected to shorten the time of MV, which will have an effect on QOL, morbidity and mortality, and healthcare provider costs [(10)].

A crucial component of the interdisciplinary care given to patients in ICUs is respiratory physiotherapy [(11)]. Improving maximum expiratory strength was also linked to respiratory muscle training, even if it was solely inspiratory muscle training. By maximizing the diaphragm's length-tension relationship prior to inspiration, the abdominal muscles contribute significantly to the cough reflex and improve the neuromuscular coupling of the diaphragm, hence strengthening the muscle's load-capacity balance [(12)].

Training of the respiratory muscles is an essential part of physical therapy treatment. One specific tactic to strengthen the diaphragm muscle would be to use transcutaneous electrical diaphragmatic stimulation (TEDS), which would enhance ventilatory work and benefit patients with respiratory muscle weakness or those who have had MV [(13)].

It has been demonstrated that neuromuscular electrical stimulation (NMES), a method of producing visible muscle contractions with portable devices

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attached to surface electrodes, is beneficial in treating impaired muscles because it may maintain muscle-protein synthesis and prevent muscle atrophy during extended periods of immobilization. If muscle protein production and breakdown rates are out of equilibrium, this will lead to disuse atrophy [14].

By strengthening their muscles and reducing the duration of MV, length of stay in the ICU, and overall length of hospital stay, early use of the NEMS intervention in ICU patients can avoid ICU-AW and enhance the quality of life for mechanically ventilated patients [15].

TEDS may be a specific tactic used to enhance ventilatory function, which will benefit individuals with respiratory muscle weakness or those who have had MV [16].

Since the muscles in the abdomen are involved in cough production and breathing during respiratory distress, and FES is a useful method of enhancing cough function, abdominal FES may offer a straightforward, useful, and efficient means of minimizing MV time in critical illness [17].

Given these interventions efficiency, our aim was to determine the effect of co-activation of transcutaneous diaphragmatic electrical stimulation and abdominal FES on weaning time in mechanically ventilated patient. We hypothesized that there is no significant effect of co-activation of diaphragm and abdominal muscles on weaning time in mechanically ventilated patients.

PATIENTS AND METHODS

A total of 52 mechanically ventilated patients of both sexes participated in the study. They were between the ages of 40 and 55 years. They were assigned randomly into two groups (A and b). **Group (A):** consisted of 26 mechanically ventilated patients who received transcutaneous electrical diaphragm stimulation and abdominal functional electrical stimulation and conventional physical therapy for 60 minutes each session, one session daily for 7 days a week till discharge. **Group (B):** consisted of 26 mechanically ventilated patients who received conventional physical therapy program that consisted of percussion, vibration and passive range of motion for 30 minutes each session for one session daily for 7 days a week till discharge.

Sample size calculation:

The study was on mechanically ventilated patients Using G*power version 3.1.9.7. The sample was determined. A total of 52 patients was the minimum sample size for the investigation. $\alpha = 0.05$, power $=1-\beta$ error probability, and effect size = 0.95 were calculated.

Inclusion criteria

Fifty-two patients from ICU, New Cairo Generalized Hospitals. Their ages ranged from 40:55 years old, Their BMI ranged from 25-34.9 kg/m^2, Level of consciousness according to Glasgow coma scale was from 3:8, duration of ventilation ranged from 24 hours up to 14 days, medical stability was defined as $PaO_2 \geq 60$ mmHg at 40% FiO_2 and the lack of infection signs and symptoms.

Exclusion criteria

Proliferative lesion that may obstruct probes; neurological disease resulting in paralyzing muscular weakness, hemodynamic instability, patients with rib fractures, patients with pacemaker, tachycardia, uncontrolled hypertension, spinal injuries, severe COPD (FEV1 < 30%), unwillingness to initiate MV, and the choice to refuse life-sustaining care.

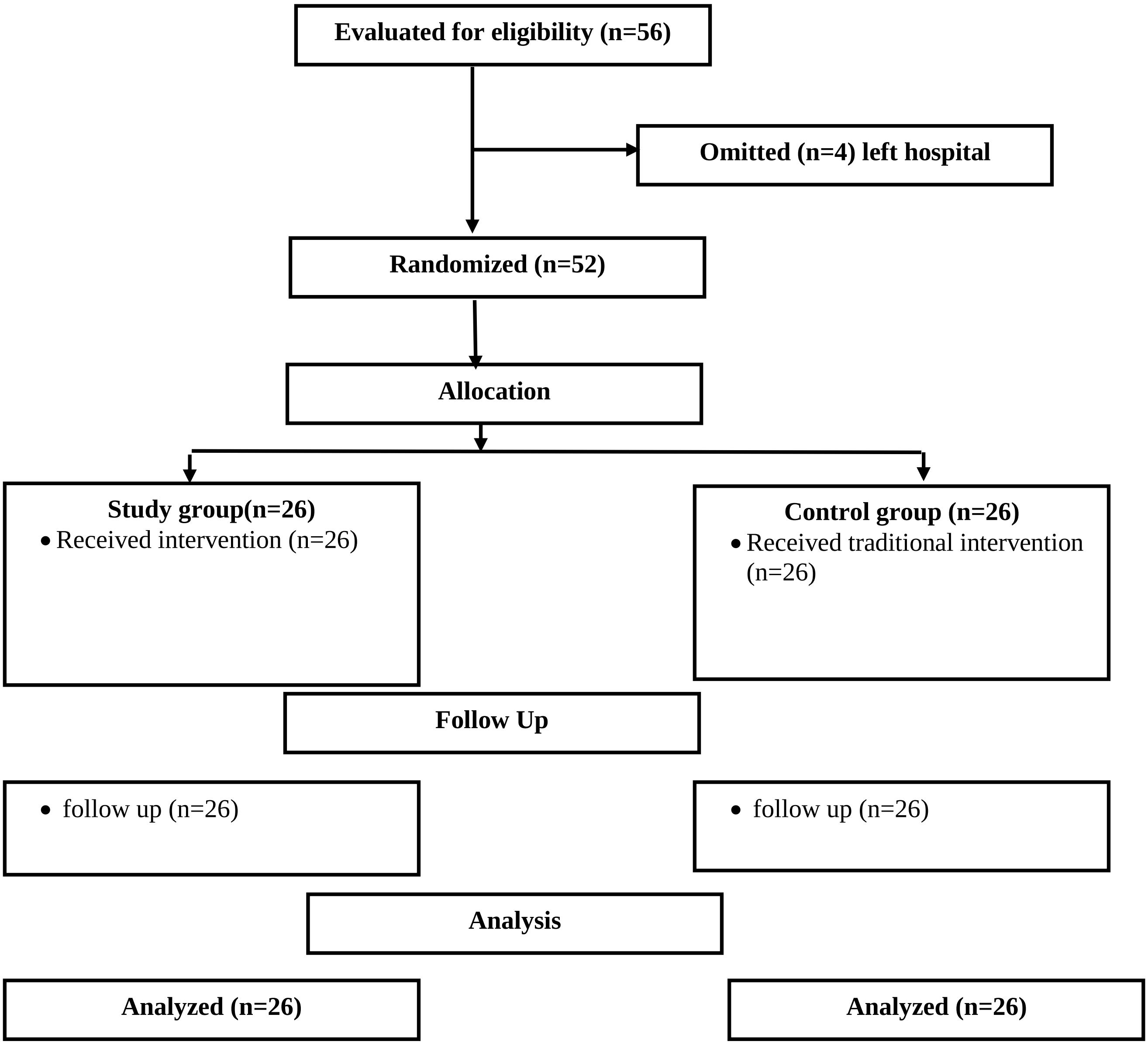

Fig. (1): Study flow chart.

Evaluating procedure:
All the following evaluations have been done for all patients enrolled in the study.
Including: name, address, age, sex, history and cause of admission were recorded in the recording data sheet.
-Detailed history was acquired to identify more medical disorders that might influence the research.

The rapid shallow breathing index (RSBI):
It was used to evaluate the success of the weaning attempt. The researcher monitored the RR and TV from the screen of the MV and calculated as the ratio of tidal volume (TV) in liters to respiratory rate (RR) in breaths/minute: RSBI = TV/RR [18].

Weaning time:
Reducing ventilatory assistance is the process of weaning off MV, which ends with the patient extubated and breathing on their own. In around 80% of patients, this process may be completed quickly after the underlying reason of the respiratory failure has improved. My computation had determined how long the patient would remain in the ICU [19].

Treatment procedure:
Diaphragmatic and abdominal stimulation for group (A)* [17]*:
All patients in this group received 60 minutes electrical stimulation administrated by the researcher for one session per day 7 days a week according to the following principle.

Intensity: aimed to cause the muscles beneath the probes to contract palpably. Frequency: 50 Hz bidirectional current with a 300 ms pulse width, two-second on time, and three-second off time.

Size of electrode: 5x5 cm. Electrode placements for diaphragmatic stimulation: were placed in the 8^{th} to 11^{th} anterior intercostal spaces. Electrodes placement for abdominal stimulation: were placed bilaterally over the abdominal wall to activate the abdominal muscles.

Conventional physiotherapy program for group A and group B:

All patients of the two groups received conventional program which included: percussion was done with cupped hand for 1:3 minute over affected lung, vibration was applied at the end of expiration as the patient exhales, it continued for 3 exhalation, postural drainage was done by placing of the patient in a certain position according to the affected segment of the lung and every position was done for 3:15 minutes, and passive limb exercise for both upper limb and lower limb was done passively for each joint with repetition 10 times each for 30 minute each session, for 7 consecutive days till discharge.

Ethical Considerations:

This work received approval by Cairo University's 2023 Faculty of Physical Therapy's Ethical Committee (No. P.T.REC/012/ 005025). Individual and group explanations of the study aims were given to the families of the participants. The family of each person who engaged in the study gave their informed written agreement. Every stage of the investigation involved respecting individual privacy and confidentiality. Throughout the course of the work, the Helsinki Declaration was adhered to.

Statistical analysis

We performed statistical analysis using SPSS program for Windows version 25.0. Utilizing mean±SD and an unpaired t-test, the subject characteristics among the groups were compared. The X^2-test was utilized for the examination of categorical data, which were presented as frequency and percentage, between groups. The data's normal distribution was investigated using the Shapiro-Wilk test. Levene's test for homogeneity of variances was run to see whether the groups were homogenous. The criterion for significance in the statistical tests was set at $p < 0.05$.

RESULTS

Table (1) shows the subject characteristics of group A and B. There was no significant difference between groups in age and sex distribution.

Table (1): Comparison of subject characteristics between the group A and B:

	Group A	**Group B**			
	Mean± SD	**Mean± SD**	**Mean difference**	**t-value**	**p-value**
Age (years)	49.35 ± 3.66	48.42 ± 4.56	0.93	0.81	0.43
Sex,	n (%)				
Females	12 (46%)	11 (42%)		(χ^2 = 00.78	
Males	14 (54%)	15 (58%)			

There was a significant decrease in RSBI of both groups A and B post treatment compared with pretreatment. There was a significant decrease in group A regarding post treatment RSBI compared to group B (Table 2).

Table (2): Mean RSBI pre and post treatment of group A and B:

	Pre treatment	**Post treatment**			
	Mean± SD	**Mean± SD**	**Mean difference**	**% of change**	**p-value**
RSBI (breaths/min/L)					
Group A	151.15 27.87	63.46 15.92	87.69	58.02	0.001
Group B	144.19 33.82	101.92 18.55	42.27	29.31	0.001
MD	6.96	-38.46			
	p = 0.42	p = 0.001			

Effect of treatment on weaning time:

There was a significant decrease in weaning time of group A compared with that of group B (Table 3).

Table (3): Comparison of weaning time between group A and B.

	Group A	**Group B**				
	Mean± SD	**Mean± SD**	**Mean difference**	**t-value**	**p-value**	**Sig**
Weaning time (days)	11.88 ±2.25	13.50± 2.45	-1.62	-2.47	0.01	**S**

DISCUSSION

This study was conducted to study the effect of co-activation of TEDS and FES of abdomen on mechanically ventilated patients.

This study provides robust evidence supporting the efficacy of co-activation of transcutaneous diaphragmatic electrical stimulation and abdominal functional electrical stimulation in weaning on mechanically ventilated patient and enhancing the ventilator function. The intervention used in this study, which included both co-activation muscle stimulation and conventional physical therapy program, resulted in significant improvements in measures of arterial blood gases, ventilator function, rapid shallow breathing index and weaning time, particularly in the study group (Group A).

The results in group (A), where the patients received co-activation of both TEDS and abdominal FES, on MV patient showed that the mean difference between pre and post treatment was 87.69 breaths/min/L and the percent of change was 58.02%. There was a significant decrease in RSBI of group A post treatment compared with pretreatment. The mean difference between groups was -1.62 years. That was a significant decrease in weaning time of group A compared with that of group B.

The current study's findings corroborated those of **Hsin *et al.*** [13] who reported that TEDS on patients receiving 30-minute sessions of muscle electrical stimulation per day while on a prolonged MV showed a tendency toward decreased RSBI, however, this increase was not statistically significant (P = 0.08).

The current study's findings corroborated those of **Duarte *et al.*** [20] who reported that using TEDS to measure the duration of spinal cord patients on MV produced the conclusion that TEDS influences both the length of stay in the ICU and the duration of MV, making it a potentially useful tool for treating ICU patients.

The study's findings were in line with those of **Cancellierio *et al.*** [21] who proposed that electrical current may also cause contractions in the abdominal muscles, which make up the majority of the expiratory muscles. Since the diaphragm and abdominal muscles are stimulated by a large electric field created by the high strength of the current, the abdominal muscles may also be implicated during TEDS due to the overlap of the stimulation zone.

The results of group A come in support with **McCaughey *et al.*** [8] who studied how abdominal FES, administered twice daily for five days a week, for 30 minutes, affected respiratory muscle atrophy, and ended the patient's stay in the ICU. In comparison to the control group, the intervention group's ICU length of stay (p = 0.011) and ventilation time (p = 0.039) seemed to be shorter.

Contrary to **Medrinal *et al.*** [22] whose study investigated TEDS's impact on ventilated critically sick patients' diaphragm function and compared it to a sham intervention. The chance of diaphragm malfunction was not considerably reduced with TEDS. During breathing, the diaphragmatic thickness decreased similarly in both groups. TEDS would not maximize the success rate of extubation and weaning off MV, nor would it provide a statistically significant increase in peak expiratory flow or inspiratory muscular strength during coughing.

Abu-Khaber *et al.* [23] claimed that although EMS could not stop the development of ICU-AMW (ICU-acquired muscle weakness) in critically ill patients on MV, it could still play a role in reducing the severity of muscular weakness and could be useful in easing the transition from a MV in the EMS group as opposed to the control group. However, the evidence in such a small population sample was not statistically significant. These findings contradict the findings of the current study.

In Group (B), the mean difference between pre and post therapy was 42.27 breaths/min/L, with a percentage change of 29.31%. There was a substantial decrease in RSBI of Group (B) after therapy compared to pretreatment.

The study findings are consistent with those of **Zeng *et al.*** [24] who showed that chest physical therapy treatment can prevent ventilator-acquired pneumonia and other complications in patients undergoing MV. This could reduce the duration of MV and the length of ICU stay, as well as aid in patient recovery. The CPT group's ICU stay duration was significantly shorter than the control group's (both P < 0.05).

This study in support with **Wang *et al.*** [25] who showed that early mobility, clearing of airway secretions, and chest wall mobilization are all components of chest physiotherapy, and that these techniques can lower the risk of extubation failure and enhance RSBI scores in MV patients. When evaluating patient extubation results during the weaning phase, the RSBI has been widely utilized. The RSBI score of the intervention group was substantially lower than that of the control group (88 vs. 121; P <.0001).

CONCLUSION

To sum up, application of transcutaneous diaphragmatic stimulation and abdominal functional electrical stimulation is easy safe way for critically ill patients for improving the diaphragmatic and abdominal muscles performance and decrease length of duration in ICU for mechanically ventilated patient thus improve weaning.

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