Clinical Uses of Transcutaneous Electrical Diaphragmatic Stimulation: A Mini-Review

Ahmad Mahdi Ahmad[1]| Maali Mohamed Hassan[1] | Nagwan Adel Ismail[2] | Shymaa Mohamed Ali[1]

[1] Department of Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Egypt.

[2] Department of Chest Diseases, Faculty of Medicine, Zagazig University, Egypt

ABSTRACT

Inspiratory muscle weakness occurs as a consequence of aging, neuromuscular disease, after cardiothoracic or abdominal surgery, and prolonged mechanical ventilation. In such a case, patients' respiratory status could be too fragile to withstand inspiratory muscle training. Transcutaneous electrical diaphragmatic stimulation (TEDS) is a passive modality that requires no effort from patients and aims at recruiting the highest number of intact muscle fibers to generate muscle contraction and strengthen the muscle. TEDS involves the usage of two pairs of electrodes: one pair in the parasternal region beside the xiphoid process, and the other pair are located between the sixth and seventh intercostal spaces at the mid-axillary line. TEDS has recently increased respiratory muscle strength and enhanced weaning rate in ICU patients on prolonged mechanical ventilation. TEDS also led to positive changes in selected cardiovascular parameters such as systolic blood pressure and heart rate in healthy subjects. Further, TEDS through Russian currents increased minute ventilatory volume and induced a clinically meaningful increase in the six-minute walk distance in COPD patients. Russian currents are alternating currents at a frequency of 2.5 kHz and burst modulated at a frequency of 50 Hz. The stimulus lasts for 10 seconds, followed by 50 seconds of rest, with an optimal duration of 10 minutes per session, applied once daily or every other day over a period of weeks. The theoretical basis for the use of Russian currents is that maximum stimulation of almost all muscle motor units may produce more muscle contraction than can't be achieved by voluntary contraction. TEDS through Russian current is a good therapeutic modality for promoting diaphragmatic contraction in different patient populations suffering from diaphragmatic weakness.

Keywords: Transcutaneous electrical diaphragmatic stimulation, Russian Current, muscle strength

INTRODUCTION

Inspiratory muscle weakness is observed in chest diseases and contributes to hyper-capnia, dyspnea, nocturnal oxygen desaturation, and reduced walking distance. **(Hamilton et al, 2021).** During exercise, it has been shown that diaphragm work is increased and patients use a larger proportion of the maximal inspiratory pressure (PImax) than healthy subjects. This pattern of breathing is closely related to the dyspnea sensation during exercise and might potentially induce respiratory muscle fatigue **(Sinderby et al, 2001).** The diaphragm is a large muscle that lies below the lungs and heart. It is the primary muscle that facilitates breathing. Patients with diaphragmatic weakness have reduced breathing capabilities or are unable to control their voluntary breathing. They also have difficulty maintaining adequate gas exchange **(Meznaric et al, 2016).** Symptoms of diaphragmatic weakness include difficulty of breathing, both at rest and when active. Transcutaneous electrical diaphragmatic stimulation (TEDS) has been used to improve respiratory muscle strength in patients with respiratory muscle weakness **(Cancelliero et al, 2012).** Pulmonary rehabilitation has also been shown to increase exercise endurance, decrease dyspnea, improve health-related quality of life, and reduce healthcare costs **(Nici et al, 2006).** However, in patients with more severe COPD, the benefits of rehabilitation may be limited; there are new approaches to PR, such as electrical stimulation, a technique that externally stimulates contractions of peripheral muscles to improve their function in patients with severe COPD (Wijkstra et al, 2011). Electrical diaphragmatic stimulation is a non-invasive method, which stimulates the intercostal muscles and muscle fibers. TEDS increases SpO2 and reduces HR. These results may have clinical relevance for the use of TEDS in patients with COPD **(Cancelliero et al, 2012).** TEDS through Russian current is a medium-frequency current, alternating sinusoidal waveform current, waveform delivered in bursts or series of pulses known as Burst Modulated Alternating Current (BMAC).

The good function of the respiratory system depends on the respiratory muscles' adequate force and resistance. Any dysfunction affecting the diaphragm will reduce the pulmonary volume and affect adequate gas exchange. The physiological aging process promotes a reduction in the number of motor units and muscle fibers type I and II volume, resulting in muscle force reduction which also affects the respiratory musculature **(Meznaric et al, 2016).** Inspiratory muscle strength training is superior to endurance training for improving inspiratory muscle strength, functional exercise performance, and dyspnoea. Patients with

inspiratory muscle weakness and lower PaO2 or higher PaCO2 show better response to IMT on inspiratory muscle strength and functional exercise capacity than those patients with better preserved respiratory muscle function. The improvement in inspiratory muscle endurance capacity is supported by a study in COPD patients showing significant increases in the proportion of type I fiber and size of type II fiber in the external intercostal after IMT **(Cancelliero et al, 2012).**

Transcutaneous electrical diaphragmatic stimulation (TEDS) is a modality help to increase muscle contraction and strengthen the muscle. Physiological effects of Russian Current are (1) Medium frequency modulated sinusoidal currents (2) High level electrically evoked muscular contraction (3) Contraction against external load (4) Muscle strengthening. Russian current is thought as a therapeutic resource for being beneficial to musculature, which promotes increase in resistance and strength of skeletal muscles **(Bruno et al, 2016).**

Conclusion

Transcutaneous electrical diaphragmatic stimulation through Russian current is a good therapeutic modality for promoting powerful muscular contraction in different patient populations suffering from diaphragmatic weakness.

References

1. Cancelliero KM, Ike D, Sampaio LMM, Santos VLA, Stirbulov R, Costa D. Estimulação diafragmática elétrica transcutânea (EDET) para fortalecimento muscular respiratório: estudo clínico controlado e randomizado. Fisioter Pesqui. 2012(4):303-8. doi: dx.doi.org/10.1590/ S1809-29502012000400002

2. Hamilton N, Killian KJ, Summers E, et al. Muscle strength, symptom intensity, and exercise capacity in patients with cardiorespiratory disorders. Am J Respir Crit Care Med 1995; 152: 2021–2031.

3. Hurd SS, Agustí AG, Jones PW, Vogelmeier C, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med. 201 (4):347-65. doi: 10.1164/ rccm.201204-0596PP.

4. McKenzie DK, Butler JE, Gandevia SC. Respiratory muscle function and activation in chronic obstructive pulmonary disease. J Appl Physiol. 2009(2):6219. http://dx.doi.org/10.1152/ japplphysiol.00163.2009

5. Meznaric M, Cvetko E. Size and Proportions of Slow-Twitch and Fast-Twitch Muscle Fibers in Human Costal Diaphragm. Biomed Res Int. 2016Doi: https://doi.org/10.1155/2016/5946520

6. Nici L, Donner C, Wouters E, Zuwallack R, Ambrosino N, Bourbeau J, et al. American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation. Am J Resp Crit Care Med. 2006(12):13901413.http://dx.doi.org/10.1164/ rccm.200508-1211ST

7. Sampaio LMM, Santos VLA, Stirbulov R, Costa D. Estimulação diafragmática elétrica transcutânea (EDET) para fortalecimento muscular respiratório: estudo clínico controlado e randomizado. Fisioter Pesqui. 2012(4):303-8. doi: dx.doi.org/10.1590/ S1809-29502012000400002
8. Sinderby C, Spahija J, Beck J, et al. Diaphragm activation during exercise in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2001; 163: 1637–1641.

9. Vestbo J, Hurd SS, Agustí AG, Jones PW, Vogelmeier C, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med. 2013(4): doi: 10.1164/ rccm.201204-0596PP.

10. Wijkstra PJ, Wempe JB. New tools in pulmonary rehabilitation. Eur Respir J. 2011 (6):146874. http://dx.doi. org/10.1183/09031936.00111911