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ELECTRICAL NEUROMUSCULAR STIMULATION (EENM) EFFECTS ON RESPIRATORY AND MOTOR FUNCTION IN CRITICALLY ILL INDIVIDUALS

EFEITOS DA ESTIMULAÇÃO ELÉTRICA NEUROMUSCULAR (EENM) NA FUNÇÃO RESPIRATÓRIA E MOTORA DE INDIVÍDUOS CRÍTICOS

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ABSTRACT: Physiotherapeutic care planning for critically ill patients in Intensive Care Units progresses daily. Considering this fact, this study reported the effects of Neuromuscular Electrical Stimulation (NMES) on the respiratory and motor function of hospitalized patients using invasive ventilatory support. Based on an integrative review in the PubMed and PEDro databases, between November 2023 and February 2024, randomized clinical trials related to the topic were filtered and evaluated as well as their methodological quality. Initially, 128 articles were collected, with a final sample of 6 studies after assessing the inclusion criteria. It was possible to conclude that NMES in critically ill patients affects muscle strength gain, reduced hospitalization time, and shorter duration of Invasive Mechanical Ventilation (IMV), both in isolation and combination with conventional physiotherapy. Further studies on the subject are essential to better understand the potential of NMES in these patients.
KEYWORDS: Electrical Stimulation Therapy. Intensive Care Unit. Physiotherapy.

RESUMO: O planejamento de cuidados fisioterapêuticos de pacientes críticos em Unidades de Terapia Intensiva evolui a cada dia. Considerando esse fato, este estudo relatou os efeitos da Estimulação Elétrica Neuromuscular (EENM) na função respiratória e motora de pacientes internados com uso de suporte ventilatório invasivo. A partir de uma revisão integrativa nas bases de dados PubMed e PEDro, entre novembro de 2023 e fevereiro de 2024, foram filtrados e avaliados ensaios clínicos randomizados relacionados ao tema e sua qualidade metodológica. Foram coletados 128 artigos, com uma amostra final de 6 estudos após avaliação dos critérios de inclusão. Foi possível concluir que a EENM em pacientes críticos possui efeitos no ganho de força muscular, menor tempo de internação hospitalar e na duração da ventilação mecânica invasiva (VMI), tanto de forma isolada quanto combinada a fisioterapia convencional. Mais estudos relacionados ao tema são essenciais para melhor compreender o potencial da EENM nesses pacientes.
PALAVRAS-CHAVE: Fisioterapia. Terapia por Estimulação Elétrica. Unidade de Terapia Intensiva.

INTRODUCTION

The care offered in the Intensive Care Unit (ICU) is essential to the population's health. It was established on the Brazilian health scene in the 1970s to provide intensive care for people with serious illnesses[1,2]. With modern equipment and specialized health professionals, the intensive care setting of this service can offer prolonged life support to individuals in acute or chronic clinical conditions, which increases the survival rate of the population[2].

Despite the obvious benefits of intensive care for individuals with many serious clinical conditions, functional declines are often observed after a long period of hospitalization in an intensive care environment[5,6]. In the first 24 hours of ICU care, significant changes can occur in the gastrointestinal, cardiovascular, respiratory, urinary, and musculoskeletal systems[5,7,8]. Such conditions not only prolong the length of hospitalization but can also worsen the individual's clinical condition, resulting in impacts on morbidity and deterioration in quality of life after discharge[5,7,8].

Research indicates that patients admitted to ICUs without early mobilization practices can suffer muscle loss of 10% to 15% in just one week and up to 50% in a period of three to five weeks[5,7,8,9]. These studies also point out that between 30% and 60% of hospitalized individuals develop muscle weakness due to inactivity in bed, the use of mechanical ventilation, as well as the use of sedatives and neuromuscular blockers[5,7,8,9]. ICU-acquired muscle weakness is a serious secondary impairment, often occurring symmetrically and diffusely in the skeletal muscles, as well as potentially affecting muscle innervation[10,11,12].

In this context, there are already developed clinical trials and reviews to report the effects of early mobilization as a strategy to combat the negative effects of immobility in ICU patients[5,6,13,14]. According to the findings already available in the literature, early mobilization is a viable intervention well tolerated by intensive care patients, making it possible to reduce the length of ICU stay and improve functionality after discharge[5,6,13,14]. However, it is essential to emphasize that the active collaboration of the individual plays a crucial role in the success of early mobilization, which is not always possible, especially in the most serious clinical conditions that require orotracheal intubation. The Neuromuscular Electrical Stimulation (NMES) use in intensive care patients can be used as a therapeutic strategy to overcome the poor cooperation of intensive care patients[6,13,15].

NMES is a therapeutic intervention that uses electric currents to recruit motor units, inducing muscle contractions that help maintain muscle mass and prevent atrophy due to prolonged immobilization. It is noteworthy that NMES improves blood circulation, favoring tissue oxygenation, which is often deficient in critically ill patients, as well as preventing complications such as deep vein thrombosis. This technique has been progressively applied to promote the health of ICU patients, consolidating itself as an effective tool in the critically ill individuals care, especially in the post-discharge period, when the aim is to recover muscle function and minimize complications related to immobilization[9,16,34.]

In this context, the benefits provided by NMES have aroused the interest of researchers who seek to understand its broader impacts in the intensive care environment. Although important gaps still need to be explored, reviews have already shown the benefits of using NMES in intensive care patients, such as greater success in extubation and increased muscle strength at the time of ICU discharge[18,19]. One review study focused exclusively on gaining muscle strength and improving functionality[18]. Another review highlighted results such as reduced mechanical ventilation time and an increase in extubation success rates[19]. It is interesting to note that the few available reviews on the effects of using NMES as an early mobilization strategy in the intensive care setting do not simultaneously address outcomes related to respiratory and motor function. However, it is known that these functions are often deficient in this context, directly impacting the functionality of patients.

This review aims to report the effects of using NMES on the individual's respiratory and motor function under invasive ventilatory support admitted to the ICU.

METHODOLOGY

This study is an integrative review that reports the effects of using NMES on ICU patients' respiratory and motor function. The search for articles was carried out in the PubMed and PEDro databases from November 2023 to February 2024, with publications between 2019 and 2024. The terms used for the search were selected from the Medical Subject Headings (MeSH), including Electrical Stimulation Therapy, Intensive Care Unit, Physiotherapy, Electrical stimulation, and Randomized controlled trial, combined with Boolean operators ("AND" and "OR").

The inclusion criteria established were that the studies selected should be randomized clinical trials (RCTs), with participants over the age of 18, of both sexes, who were using Invasive Mechanical Ventilation (IMV). The intervention offered to the experimental group in the studies should have been a treatment protocol using NMES, while the control group should have received conventional physiotherapy care in the ICU. Pilot randomized clinical trials, studies without a control group, studies that did not describe NMES parameters in the intervention protocol, and articles whose full text was not available were excluded from this review.

To assess the methodological quality of the randomized clinical trials, we used the Jadad Scale. Created by Alejandro Jadad in 1996, this tool analyzes three criteria: randomization, which verifies whether the study was randomized adequately or inadequately; blinding, which assesses whether the method used was appropriate to ensure the blinding of participants and evaluators; and reporting of all subjects, which examines the complete description of the study sample, including losses and exclusions. Each criterion can receive 1 point for a positive response and 0 points for a negative response, and you can add or subtract 1 point based on the quality of the additional information provided. The Jadad Scale scores up to 5 points and studies with a score of 3 or more are considered to be of high methodological quality, while those with a score of less than 3 are classified as low quality[22].

RESULTS

Initially, 128 articles were identified from the search for the selected descriptors. Of these, 109 articles were excluded, of which 9 were duplicates, 32 did not use NMES as an intervention, 18 studies were aimed at investigating the effects on reducing pain, 24 were carried out outside the ICU, 10 used another type of electric current and 16 compared NMES with another approach. After analyzing and excluding the studies, 19 articles remained to be read; 1 article was excluded due to the authors not returning the request. After thoroughly analyzing the remaining 18 articles, 12 were excluded for addressing NMES combined with another intervention, being pilot studies, or involving non-intubated individuals. The final sample for the integrative review consisted of 6 studies. To optimize the composition of the included studies, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart was developed, which is described in Figure 1. Table 1 also shows the characteristics of the clinical trials analyzed.

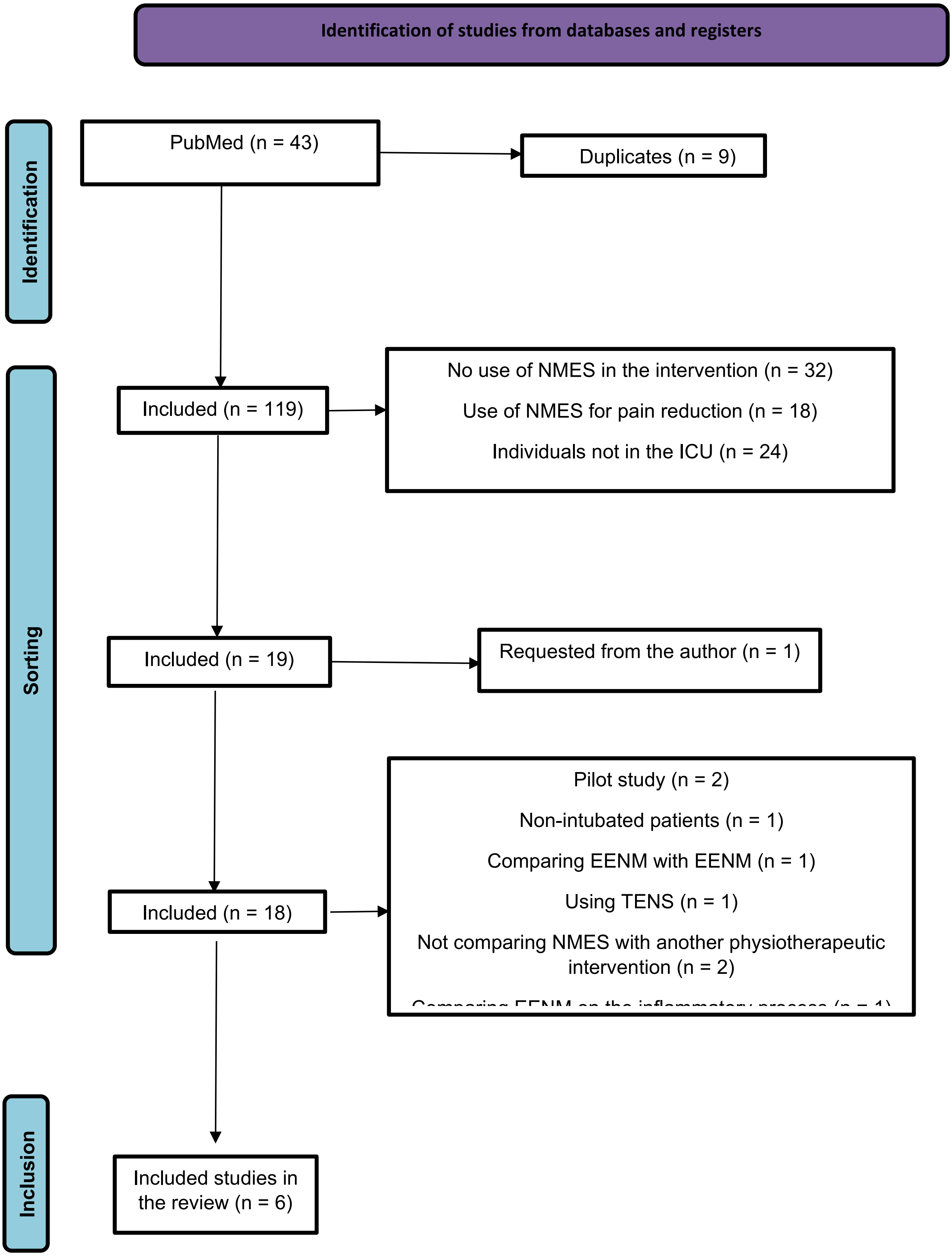

Figure 1. PRISMA flowchart.

Table 1- Description of results

AUTHOR/ YEAR	**SAMPLE**	**DIAGNOSIS**	**CONDUCT/ DURATION/ CURRENT**	**RESULTS**
Campos et al. (2022)	106 46 women 60 men	Stroke, TBI[+], PO [++], Respiratory arrest, Sepsis.	Control: EM[¶] - kinesiotherapy and respiratory physiotherapy. Intervention: EM[¶] + EENM[§] + Respiratory physiotherapy. 28 days FES[¤]	↑ Improved functionality, muscle strength, early orthostatism and less time in the ICU[¢].
Cebeci et al. (2022)	80 29 women 51 men	Sepsis/Septic shock	Control: Kinesiotherapy. Intervention: Physiotherapy + EENM§. 28 days FES[¤]	↑ muscle mass.
Mahran et al. (2023)	118 22 women 96 men	TBI[+], Septic and hypovolemic shock.	Control: Physiotherapy + EENM[§] placedo: Kinesiotherapy and respiratory physiotherapy Simulated EENM[§]: electrodes disconnected. Intervention: EENM[§]. 7 days AUSSIE	Reduction in IMV [µ] time and ICU stay[¢].
Nakamura et al. (2019)	37 12 women 25 men	Sepsis, heart failure, stroke, cardiopulmonary arrest, respiratory arrest, post-surgery and trauma.	Control: Kinesiotherapy. Intervention: EENM§. 10 days FES[¤]	Improved functionality and maintained muscle volume.
Silva et al. (2019)	60 8 women 52 men	Traffic accident; Fall, FAB[×] and Elective surgery.	Control: Kinesiotherapy. Intervention: EENM[§]. 14 days FES[¤]	↑ muscle mass.
Othman et al., 2024	120 59 women 61 men	Cardiovascular, Respiratory, Renal, Gastrointestinal and Trauma events.	Control: Kinesiotherapy and respiratory physiotherapy. Intervention: ROM [Ÿ] = Kinesiotherapy EENM[§] = EENM[§] ROM [Ÿ] + EENM[§] = Kinesiotherapy + EENM[§]. 7 days FES[¤]	Preservation of muscle strength, reduction of time in IMV[µ] and ICU stay[¢].

[+]TBI - Traumatic Brain Injury, [++]PO - Postoperative, [¶]EM - Early Mobilization, [§]EENM - Neuromuscular Electrical Stimulation, [¤]FES - Functional Electrical Stimulation, [µ]VMI- Invasive Mechanical Ventilation, [¢]ICU - Intensive Care Unit, [×]FAB - Blank Weapon Injury, [Ÿ] ROM - Range of Motion.

The review included five studies that used NMES associated with Functional Electrical Stimulation (FES) and one study that used Aussie current, as detailed in Table 2. FES is an electrical stimulation technique designed to recruit muscle fibers in conditions where voluntary control of movement is compromised. This current is particularly effective in improving motor function and muscle rehabilitation, as it simulates the natural nerve impulses responsible for initiating movements. On the other hand, the Aussie current is a type of low-frequency alternating current, commonly used to promote analgesia and facilitate muscle recovery. It is characterized by its modulation in low and high frequencies, providing a deeper effect on muscle and nerve tissues, with less discomfort for the patient.

Table 2- Description of Neuromuscular Electrical Stimulation parameters

AUTHOR/ YEAR	CURRENT TYPE/ FREQUENCY/ WAVE WIDTH	PULSE WIDTH	RISE/ DECAY	INTENSITY	MUSCLES	PROTOCOL DURATION
Campos et al. (2022)	FES[¤] 80 Hz[#] 400 µS[‡]	5 seconds	1 seconds X	Visible muscle contraction	Quadriceps femoris and tibialis anterior bilaterally	D[£]: 28 days F||: 1 session/day T[¥]: 60 minutes each session
Cebeci et al. (2022)	FES[¤] 45 Hz[#] 400 µS[‡]	12 seconds	0,8 seconds 0,8 seconds	Visible muscle contraction	Biceps brachii and rectus femoris bilaterally	D[£]: 28 days F||: 1 session/day T[¥]: 55 minutes each session
Mahran et al. (2023)	Aussie 30 Hz[#] X	1 seconds	1 seconds 1 seconds	Visible muscle contraction	Diaphragm and bilateral rectus abdominis	D[£]: 7 days F||: 1 session/day T[¥]: 40 minutes each session
Nakamura et al. (2019)	FES[¤] 20 Hz[#] 250 µS[‡]	5 seconds	X X	Visible muscle contraction	Muscles of the pelvic girdle, above the knees and ankles	D[£]: 10 days F||: 1 session/day T[¥]: 20 minutes each session
Silva et al. (2019)	FES[¤] 100 Hz[#] 400 µS[‡]	5 seconds	X X	Visible muscle contraction	Quadriceps femoris, hamstrings and tibialis anterior bilateral	D[£]: 14 days F[||]: 1 session/day T[¥]: 25 minutes each session
Othman et al. (2024)	FES[¤] 50 Hz[#] 400 µS[‡]	X	5 seconds 10 seconds	Visible muscle contraction	Rectus femoris, vastus lateralis and medial bilateral	D[£]: 7 days F[||]: 1 session/day T[¥]: 60 minutes each session

[¤]FES – Functional Electrical Stimulation, [#]Hz – Hertz, [‡]µS – Microsecond, [£]D – Duration, [||]F – Frequency, [¥]T – Time.

Concerning the methodological quality of the studies in this review, the research identified that all six articles evaluated were classified as being of high methodological quality according to the Jadad Scale. Table 3 describes this analysis.

Table 3 - Presentation of methodological quality with the Jadad Scale

AUTHORY/YEAR	1A- RAMDOMIZED	1B-ADEQUATE	1C- INADEQUATE	2A- SOUBLE-BLIND	2B-APPROPRIATE	2C- INCORRECT	3-ALL PATIENTS	TOTAL SCORE
Campos et al. (2022)	1	1	0	0	0	0	1	3/5
Cebeci et al. (2022)	1	1	0	0	0	0	1	3/5
Mahran et al. (2023)	1	1	0	1	1	0	1	5/5
Nakamura et al. (2019)	1	1	0	0	0	0	1	3/5
Silva et al. (2019)	1	1	0	1	1	0	1	5/5
Othman et al. (2024)	1	1	0	1	1	0	1	5/5

DISCUSSION

This integrative review aimed to report the effects of NMES use on the respiratory and motor function of individuals under invasive ventilatory support admitted to the ICU. The main findings are that the use of NMES promoted a significant increase in muscle strength, reduced time on IMV, reduced hospital stay, and functional improvement observed by the Functional Status Score in the ICU (FSS-ICU) and Barthel scales in the volunteers in the experimental groups. All the studies included were of high methodological quality.

Concerning gaining muscle strength through NMES, five authors successfully used the FES current[,21,23,24,25]. When analyzing the protocol parameters, five studies showed a variation in current frequency and four researchers programmed a wavelength of 400 μS[7,21,24,25]. We observed that, despite this difference in parameters, in all the studies there was an increase in muscle strength[,21,23,24,25]. Another similarity between the studies was the location where the NMES was applied; of the five studies, four focused on the quadriceps femoris muscles[21,23,24,25]. The literature shows the importance of strengthening these muscles since atrophy occurs early and this involvement can prolong hospitalization time[32,33].

This review identified the use of FES and Aussie current[9,25]. When analyzing the effect of the currents, although the authors used different muscles, both studies showed a significant reduction in mechanical ventilation time[9.25]. The study that used the Aussie current applied NMES with the same objective as FES, but also aimed to provide less discomfort during electrostimulation, without reaching the pain threshold[9,34]. Regardless of the type of electrical current employed in the intervention, critically ill patients demonstrate consistent and significant clinical benefits.

Considering the outcome related to the length of hospital stay, this review identified that of the three studies that investigated this outcome, two used FES and only one used the Aussie current[9,21,25]. When we compared the studies that used the FES current with the Aussie current, there was no difference, as all the studies showed that the individuals had shorter hospital stays[9,21,25]. When analyzed, we found that regardless of the current, the duration of the protocol, the clinical condition, and the muscles stimulated, the individuals showed positive results.

Regarding the functionality improvement of critically ill patients with the use of NMES as an intervention, two studies were identified[21,23]. Both studies used the FES current in various clinical conditions[21,23]. In one study, kinesiotherapy and respiratory physiotherapy were also used[21]. To assess the functionality of these individuals, the authors described two scales. In one study they used the Functional Status Score of the ICU (FSS-ICU) scale [23]. The other study used the Barthel index scale [21.26]. The difference between the scales is that the FSS-ICU is used for critically ill individuals to assess mobility and basic activities in the ICU, while the Barthel index is applied in various clinical conditions to assess activities of daily living more broadly. We found that although different functional assessment scales were used, both studies achieved the same outcome. From the description of the protocol, we identified that NMES, either alone or in combination, results in improved functionality in subjects with different clinical situations.

In addition to the theoretical considerations, this study has important practical implications for the field of rehabilitation and intensive care. The results indicate that the application of NMES can be an effective strategy both in preventing musculoskeletal and circulatory complications and in supporting respiratory function in critically ill patients, especially those in the ICU. NMES has shown benefits in strengthening respiratory muscles and reducing mechanical ventilation time, which is crucial for lung recovery. Based on these findings, it is suggested that NMES be systematically incorporated into treatment protocols, aiming not only at functional recovery during hospitalization but also in the transition to post-discharge, optimizing long-term rehabilitation. Clinical practice can benefit from implementing this technique as a complement to traditional physiotherapy, providing a more complete and personalized approach for critically ill patients.

The limitation of this integrative review is the small number of published clinical trials on the use of NMES in critically ill individuals that report a positive effect on respiratory and motor function.

CONCLUSION

The use of NMES in critically ill individuals resulted in gains in muscle strength, shorter hospital stays, and shorter duration of IMV. In addition, we identified that NMES, both alone and combined with conventional physiotherapy, brings significant benefits to subjects in the ICU in IMV. However, more studies on the use of NMES in individuals undergoing IMV are needed to better understand the potential of NMES in the management of critically ill subjects.

REFERENCES

1. Gomes VCL, Gomes VS, Oliveira NA. Intensive care medicine –ICU: Experiences, procedures and Technologies. Brazilian Journal of Health Review. 2023;6(2):7969-7981. https://doi.org/10.34119/bjhrv6n2-281
2. Brill NG, Rangel RF, Zamberlan C, Ilha S. Humanization of care in an intensive care unit: potentialities, challenges and strategies. Disciplinarum Scientia. 2020;21(2):113-125. https://doi.org/10.37777/dscs.v21n2-010
3. Aguiar LMM, Martins GS, Valduga R, Gerez AP, Carmo EC, Cunha KC, et al., Profile of adult intensive care units in Brazil: systematic review of observational studies. Rev. Bras Ter Intensiva. 2021;33(4):624-634. https://criticalcarescience.org/article/profile-of-adult-intensive-care-units-in-brazil-systematic-review-of-observational-studies/
4. Castro MLM, Almeida FAC, Amorim EH, Carvalho AILC, Costa CCC, Cruz RAO. Perfil de pacientes de uma unidade de terapia intensiva de adultos de um município paraibano. Revista Enfermeria Actual. 40:1-13. http://dx.doi.org/10.15517/revenf.v0i40.42910
5. Santos FV, Cipriano G, Vieira L, Chiappa AMG, Cipriano GBF, Vieira P, et al., Neuromuscular electrical stimulation combined with exercise decreases duration of mechanical ventilation in ICU patients: A randomized controlled trial. Physiotherapy Theory and Practice, 2020;36(5):1-9. https://www.tandfonline.com/doi/full/10.1080/09593985.2018.1490363
6. Miranda FEMH, Dias BCA, Macedo LB, Dias CMC. Eletroestimulação em doentes críticos: uma revisão sistemática. Revista Pesquisa em Fisioterapia. 2013;3(1):79-91. https://doi.org/10.17267/2238-2704rpf.v3i1.111
7. Cebeci GC, Cebeci H, Kucuk MP, Kucuk AO, Bayrak IK, Ulger F. Neuromuscular electrical stimulator as a Protective Treatment against Intensive Care Unit Muscle Wasting in Sepsis/Septic Shock Patients. J Coll Physicians Surg Pak. 2022;32(10):1300-1307. https://jcpsp.pk/article-detail/pneuromuscular-electrical-stimulator-as-a-protective-treatment-against-intensive-care-unit-muscle-wasting-in-sepsisorseptic-shock-patientsorp
8. Silva ACA, Aguiar FP, Sousa LAS, Silva MPSF, Moschella NL, Gardenghi G. Effects and application modes of neuromuscular electrical stimulation in critical ill patients. ASSOBRAFIR Ciência. 2016;7(1):59-68. https://assobrafirciencia.org/journal/assobrafir/article/5dd542840e88259051c8fca6
9. Mahran GSK, Mehany MM, Abbas MS, Shehata AER, Abdelhafeez AS, Obiedallah AA, et al., Short-Term Outcomes of Neuromuscular Electrical Stimulation in Critically Ill Patients. Crit Care Nurs Q. 2023;46(2):126-135. https://journals.lww.com/ccnq/abstract/2023/04000/short_term_outcomes_of_neuromuscular_electrical.3.aspx
10. Ayala LAS, Yamauchi LY. Efeitos da eletroestimulação neuromuscular nos desfechos clínicos e funcionais de pacientes internados em unidade de terapia intensiva: uma revisão integrativa. Instituto de Saúde e Sociedade. 2022; 1-27. https://hdl.handle.net/11600/62822
11. Castro IC, Matos RJC, Torres DC, Coelho CSC. Muscle weakness in intensive care unit patients with progressing Sepsis: an integrative review. Brazilian Journal of Development. 2023;9(6):19470-19479. https://doi.org/10.34117/bjdv9n6-051
12. Lins A, Souza DP, Baia BER, Pereira JCD, Leal NNM, Mangueira TAS. Effects of motor physiotherapy in adult patient with muscle weakness acquired in the Intensive Care Unit: systematic review. Brazilian Journal of Development. 2023;9(8):25207-25215. https://doi.org/10.34117/bjdv9n8-132
13. Maramattom BV, Wijdicks EFM. Acute neuromuscular weakness in the intensive care unit. Crit Care Med. 2006;34(11):2835-2841. https://journals.lww.com/ccmjournal/abstract/2006/11000/acute_neuromuscular_weakness_in_the_intensive_care.19.aspx

14. Gerovasili V, Stefanidis K, Vitzilaios K, Karatzanos E, Politis P, Koroneos A, et al. Electrical muscle stimulation preserves the muscle mass of critically ill patients: a randomized study. Crit Care. 2009;13(5):1-14. https://ccforum.biomedcentral.com/articles/10.1186/cc8123
15. Zanotti E, Felicetti G, Maini M, Fracchia C. Peripheral muscle strength training in bed-bound patients with COPD receiving mechanical ventilation: effect of electrical stimulation. Clinical Investigation in critical care. 2003;124(1):292-296. https://journal.chestnet.org/article/S0012-3692(15)36023-2/abstract
16. Silva MHA, Soares VP, Sales M, Eutasquio MC, Dias MMMG, Souza DCB, et al. Aplicabilidade da estimulação elétrica funcional nas diferentes disfunções motoras de origem neurológica: uma revisão narrativa. Cadernos de Pós-Graduação em Distúrbios do Desenvolvimento. 2023;23(2):32-52. http://dx.doi.org/10.5935/cadernosdisturbios.v23n2p32-52
17. Zayed Y, Kheiri MRCP, Barmarawi M, Chintalapati S, Bachuwa GMHSA, Al-Sanouri I, et al. Effects of neuromuscular electrical stimulation in critically ill patients: A systematic review and meta-analysis of randomised controlled trials. Aust Crit Care. 2020;33(2):203-210. https://www.australiancriticalcare.com/article/S1036-7314(19)30001-3/abstract
18. Xu C, Yang F, Wang Q, Gao W. Effect of neuromuscular electrical stimulation in critically ill adults with mechanical ventilation: a systematic review and network meta-analysis. BMC Pulm Med. 2024;24(1):24-56. https://bmcpulmmed.biomedcentral.com/articles/10.1186/s12890-024-02854-9Sevilla
19. GGP, Pinto BSP. Effectiveness of physical exercise and neuromuscular electrical stimulation interventions for preventing and treating intensive care unit-acquired weakness: A systematic review of randomized controlled trials. Intensive Crit Care Nurs. 2023;74:1-12. https://www.sciencedirect.com/science/article/abs/pii/S0964339722001367?via%3Dihub
20. Balke M, Teschler M, Schafer H, Papel P, Mooren FC, Schmitz B. Therapeutic Potential of Electromyostimulation (EMS) in Critically Ill Patients-A Systematic Review. Frontiers in Physiology. 2022;13:1-21. https://doi.org/10.3389/fphys.2022.865437
21. Campos DR, Bueno TBC, Anjos JSGG, Zoppi D, Dantas BG, Gosselink R, et al. Early Neuromuscular Electrical Stimulation in Addition to Early Mobilization Improves Functional Status and Decreases Hospitalization Days of Critically Ill Patients. Crit Care Med. 2022;50(7):1116-1126. https://journals.lww.com/ccmjournal/abstract/2022/07000/early_neuromuscular_electrical_stimulation_in.9.aspx
22. Jadad AR, Moore RAndrew, Carroll D, Jenkinson C, Reynolds DJohnM, Gavaghan DJ, et al. Assessing the quality of reports of randomized clinical trials: is blinding necessary? Control. Clin. Trials. 1996;17(1):1-12. https://www.sciencedirect.com/science/article/abs/pii/0197245695001344?via%3Dihub
23. Nakamura K, Kihata A, Naraba H, Kanda N, Takahashi Y, Sonoo T, et al. Efficacy of belt electrode skeletal muscle electrical stimulation on reducing the rate of muscle volume loss in critically ill patients: A randomized controlled trial. J Rehabil Med. 2019;51(9):705-711. https://medicaljournalssweden.se/jrm/article/view/9565
24. Silva PE, de Cássia Marqueti R, Livino-de-Carvalho K, de Araujo AET, Castro J, da Silva VM, et al. Neuromuscular electrical stimulation in critically ill traumatic brain injury patients attenuates muscle atrophy, neurophysiological disorders, and weakness: a randomized controlled trial. J Intensive Care. 2019;7:1-13. https://jintensivecare.biomedcentral.com/articles/10.1186/s40560-019-0417-x
25. Othman SY, Elbiaa MA, Mansour ER, El-Menshawy AM, Elsayed SM. Effect of neuromuscular electrical stimulation and early physical activity on ICU-acquired weakness in mechanically ventilated patients: A randomized controlled trial. Nurs Crit Care. 2024;29(3):584-596. https://onlinelibrary.wiley.com/doi/10.1111/nicc.13010

26. Sponton J, Minosso M, Amendola F, Regina M, Alvarenga M, Amélia M, et al. Validation of the Barthel Index in elderly patients attended in outpatient clinics, in Brazil. Acta Paul Enferm. 2010;23(2):218-223. https://doi.org/10.1590/S0103-21002010000200011
27. Santana LGL, Rebequi R de S, Romero JR, Filoni E, Lazzareschi L, Santos EL dos, et al. Evaluation of Medium Frequency Neuromuscular Electric Stimulation (Aussie Current) in the Brachial Triceps Muscle Strength in a Non-Physically Active Woman. Revista Cientifica UMC. 2019;4(2):1-11. https://seer.umc.br/index.php/revistaumc/article/view/367
28. Reis FA dos, Palma C, Barbosa PIM, Reis FA dos, Pereira DM. Effectiveness of Aussie Current in the Improvement of Quadriceps Strength in bed restricted Individuals. Ensaios Cienc. 2018;2(22):112-118. https://doi.org/10.17921/1415-6938.2018v22n2p112-118
29. Silva VZM da, Araújo Neto JA de, Cipriano Júnior G, Pinedo M, Needham DM, Zanni JM, et al. Brazilian version of the Functional Status Score for the ICU: translation and cross-cultural adaptation. Rev Bras Ter Intensiva. 2017;29(1):34-38. https://criticalcarescience.org/article/brazilian-version-of-the-functional-status-score-for-the-icu-translation-and-cross-cultural-adaptation/
30. Souza GCR de, Cazotto GA, Simões GMS, Peyneau LG. Analysis of the functionality of patients in the ICUof a philanthropic hospital in Vitória-ES. Brazilian Journal of Development. 2022;8(4):32065-32073. https://doi.org/10.34117/bjdv8n4-610
31. Turton P, Hay R, Taylor J, McPhee J, Welters I. Human limb skeletal muscle wasting and architectural remodeling during five to ten days intubation and ventilation in critical care – an observational study using ultrasound. BMC Anesthesiology. 2016;119:1-8. https://bmcanesthesiol.biomedcentral.com/articles/10.1186/s12871-016-0269-z
32. Lima RVSA de, Fernandes JS, Sousa ASL de, Lima DT de, Rodrigues AF, Pedrosa R, et al. Análise ultrassonográfica do quadríceps femoral de pacientes críticos sob ventilação mecânica. Conscientiae Saúde. 2020;19(1):1-14. https://doi.org/10.5585/conssaude.v19n1.17090
33. Ward AR, Toumbourou SL, McCarthy B. A comparison of the analgesic efficacy of medium-frequency alternating current and TENS. Physiotherapy. 2009;95(4):280-288. https://www.physiotherapyjournal.com/article/S0031-9406(09)00083-2/abstract
34. Paula ABD, Carvalho OC, Spiguel LC, Cardoso RS, Arêas PT, Santana SAA. Impactos da eletroestimulação neuromuscular em pacientes internados em uti. Brazilian Journal of Implantology and Health Sciences. 2023;5(5):748-759. https://doi.org/10.36557/2674-8169.2023v5n5p748-759