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ORIGINAL RESEARCH

Assessment of neuromuscular electrical stimulation in critically ill patients: physical therapists' knowledge and barriers to its use

Avaliação do uso da estimulação elétrica neuromuscular em pacientes críticos: conhecimento dos fisioterapeutas e barreiras à implementação

Evaluación del uso de la electroestimulación neuromuscular en pacientes críticos: conocimiento de los fisioterapeutas y barreras para su implementación

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ABSTRACT | Transcutaneous neuromuscular electrical stimulation (NMES) is considered an important tool to prevent muscle mass and strength loss in patients admitted to intensive care units (ICU). This study aimed to evaluate physical therapists' profile and knowledge of NMES and identify the main barriers to its use in ICUs. This observational cross-sectional study was conducted via a structured questionnaire created by the authors. It consisted of 12 objective questions to analyze physical therapists' knowledge of NMES use in critically ill patients. Physical therapists were invited to participate in this study during an international symposium on NMES. In total, 56 physical therapists, with a mean age of 33.5±7.2 years and working an average of 9.7±7 years after graduation, completed the survey. Overall, 34 respondents worked in ICUs, of which only four (12%) reported regular NMES use in their ICUs. We found a low average of correct answers to our questionnaire (25%; 3/12). The main barriers reported to using NMES in ICUs were lack of knowledge (28; 50%) and equipment (24; 43%). The number of correct answers expert and non-expert physical therapists was not statistically significant (p=0.68). Thus, we observed participants' poor knowledge of NMES use in critically ill patients. Respondents showed that NMES has been underused in their ICUs. Lack of knowledge and equipment seems to be the main barriers for the use of NMES in ICUs.

Keywords | Electric Stimulation; Muscle Weakness; Polyneuropathies; Intensive Care Unit.

RESUMO | A estimulação elétrica neuromuscular transcutânea (EENM) é considerada uma importante ferramenta para prevenir a perda de força e massa muscular em pacientes internados em unidades de terapia intensiva (UTIs). Este estudo teve como objetivo avaliar o perfil e conhecimento dos fisioterapeutas sobre a EENM e identificar as principais barreiras para sua utilização na UTI. Foi realizado um estudo observacional transversal, por meio de um questionário estruturado elaborado pelos autores. O questionário foi composto por 12 questões objetivas que visavam analisar o nível de conhecimento dos fisioterapeutas sobre o uso da EENM em pacientes críticos. Os fisioterapeutas foram convidados a participar do estudo durante um simpósio internacional sobre EENM. Cinquenta e

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Corresponding address: Paulo Eugênio Silva – SMHS – Área Especial, Q. 101 – Brasília (DF), Brazil – ZIP Code: 70330-150 – E-mail: pauloeugenio.bsb@gmail.com – Financing source: nothing to declare – Conflict of interests: Paulo Eugênio Silva and Henrique Resende Martins have patents in neuromuscular electrical stimulation as inventors. They also have equity in Visuri SA and serves as scientific advisors. The remaining authors have no relevant conflicts to disclose – Presentation: Dec 29th, 2021 – Accepted for publication: Jun 22nd, 2022 – Approved by the Research Ethics Committee: Protocol No. 1,107,517.

seis fisioterapeutas completaram a pesquisa, a média de idade foi de 33,5±7,2 anos e o tempo médio de graduação de 9,7±7 anos. Trinta e quatro entrevistados trabalhavam na UTI, e destes apenas 4 (12%) relataram que a EENM era realizada rotineiramente em suas UTIs. Observou-se baixo nível de conhecimento sobre o uso da EENM em pacientes críticos no questionário, com média de 25% de acertos (3/12). Ao comparar os fisioterapeutas especialistas e não especialistas, o número de acertos não foi estatisticamente significativo (p=0,68). As principais barreiras relatadas para a utilização da técnica foram a falta de conhecimento 28 (50%) e a falta de equipamentos 24 (43%). Os entrevistados demonstraram que a EENM tem sido subutilizada em suas UTIs.
Descritores | Estimulação Elétrica; Fraqueza Muscular; Polineuropatias; Unidade de Terapia Intensiva.

RESUMEN | La electroestimulación neuromuscular transcutánea (TENS) es una herramienta importante para prevenir la pérdida de fuerza y masa muscular en pacientes ingresados en unidades de cuidados intensivos (UCI). Este estudio tuvo como objetivo evaluar el perfil y el conocimiento de los fisioterapeutas sobre la TENS, así como identificar las principales barreras para su uso en la UCI. Se llevó a cabo un estudio observacional transversal mediante un cuestionario estructurado desarrollado por los autores. El cuestionario constaba de 12 preguntas objetivas cuyo objetivo era analizar el nivel de conocimiento de los fisioterapeutas sobre el uso de la TENS en pacientes críticos. Se invitó a los fisioterapeutas a participar en el estudio durante un simposio internacional sobre TENS. Cincuenta y seis fisioterapeutas completaron la encuesta, la edad media fue de 33,5±7,2 años, y el tiempo medio desde la graduación fue de 9,7±7 años. Treinta y cuatro encuestados trabajaban en la UCI, y de estos solo 4 (12%) informaron que la TENS se realizaba de forma rutinaria en las UCI donde trabajaban. Los resultados del cuestionario mostraron un bajo nivel de conocimiento sobre el uso de la TENS en pacientes críticos, con un promedio de 25% de respuestas correctas (3/12). En la comparación entre los fisioterapeutas especialistas y los no especialistas, el número de respuestas correctas no fue estadísticamente significativo (p=0,68). Las principales barreras reportadas para el uso de esta técnica fueron la falta de conocimiento 28 (50%) y la falta de equipamiento 24 (43%). Los encuestados demostraron que esta técnica es infrautilizada en las UCI.
Palabras clave | Estimulación Eléctrica; Debilidad Muscular; Polineuropatias; Unidade de Cuidados Intensivos.

INTRODUCTION

The development of therapeutic techniques and management in intensive care units (ICU) has increased survival rates for critically ill patients. However, this higher survival rate has also raised the incidence of neuromuscular electrophysiological disorders. These disorders are common in patients who develop ICU-acquired weakness (ICUAW)[1,2].

Studies have shown that early rehabilitation is the best non-pharmacological treatment to prevent and treat ICUAW[3-5]. Moreover, research has shown that early rehabilitation is safe and effective, considering some cardiovascular and laboratorial markers[6,7]. Among the various tools used in early rehabilitation, transcutaneous neuromuscular electrical stimulation (NMES) has gained great visibility. NMES contracts muscle fibers without patient cooperation, increasing strength and maintaining muscle mass[8-10]. NMES is an effective method to increase muscle protein synthesis and to reduce catabolic gene expression[11]. Therefore, studies have considered NMES as one of the most important tools for the early rehabilitation of critically ill patients[12,13].

Regardless of the scientific evidence supporting NMES, its use in Brazilian ICUs seems to be incipient. National research has no studies on NMES administration and the potential barriers to its use in Brazilian ICUs. For total safety and better efficacy, physical therapists need to master biophysical and electrotherapeutic concepts and the main indications and contraindications of NMES for critically ill patients[1,14]. Therefore, this study aimed to evaluate physical therapists' profile and knowledge of the routine and use of NMES and identify the main barriers to it in ICUs.

We hypothesized that NMES is still underused in ICUs. This could mainly relate to the lack of professional knowledge about NMES prescription and implementation.

METHODOLOGY

Study design

This observational cross-sectional study was conducted via a structured questionnaire. It was created by a group of experts on the use of NMES in ICUs (Supplementary Material)

based on current scientific literature. All participants were informed of the completion of the study and signed an informed consent form — according to Resolution 196/96, recommended by the National Research Ethics Commission to ensure volunteers' anonymity, data confidentiality, and withdrawal rights at any time. A convenience sample was used. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for writing observational studies[15] was followed.

Setting

The questionnaire was applied during the "International Symposium Update on Neuromuscular Electrical Stimulation: from ICU to Sport," held on November 22, 2016. This event was made possible with the support of the Federal District Research Foundation (FAP-DF) to fulfill the goals established in the project financing, i.e., training Brazil Unified Health System (SUS) professionals. Printed questionnaires were applied after the opening ceremony and before the beginning of lectures. Volunteers were encouraged to answer the questions based on their previous knowledge and without any consultation of bibliographic sources. After 60 minutes, the questionnaires were collected before the symposium lectures began.

Participants

All healthcare providers who were enrolled in the symposium were assessed for eligibility. Physical therapy graduates from all genders were included. All participants who failed to fill the whole questionnaire were excluded. Moreover, event speakers and professionals who applied and developed the questionnaire were excluded from our survey.

Variables

The primary outcome was physical therapists' expertise on basic NMES prescription and implementation principles for critically ill patients. Sample characterization was included as a secondary outcome.

Measurements

The questionnaire consisted of 23 objective questions: 11 to characterize the sample and 12 about NMES (Supplementary Material). Questions about NMES aimed to analyze physical therapists' expertise on basic NMES prescription and implementation principles for critically ill patients. Didactically, these 12 questions were divided into three domains of knowledge: "Biophysical Concepts," "NMES implementation techniques and physiological responses," and "NMES risks and implementation for critically ill patients." Questions 1, 2, and 4 covered biophysics concepts; 3, 5, 6, 10, and 12 focused on NMES implementation techniques and physiological responses; and 7, 8, 9, and 11 addressed NMES risks and implementation for critically ill patients.

Study size

This study was conducted with a convenience sample.

Statistical analysis

A descriptive analysis of participants' professional profile and rate of correct answers to the questionnaire were shown as means, standard deviations, and percentages. Experts and non-expert healthcare providers' knowledge was compared by the chi-square test (χ^2). Statistically significant values were considered if $p<0.05$. The Statistical Package for Social Sciences (SPSS) version 20.0 was used for data tabulation and analysis (SPSS Inc. Chicago, USA).

RESULTS

In total, 103 subscribers attended the symposium, of which 72 completed the questionnaire. After applying our inclusion and exclusion criteria, our final sample included 56 respondents (Figure 1 details these figures).

Most analyzed physical therapists were women (43; 77%). Participants averaged 33.5±7.2 years of age, having graduated 9.7±7 years before our survey. Tables 1 and 2 show studied participants' professional profile and degree of familiarity with NMES and the main barriers to implementing this therapy in their ICUs.

Participants' overall performance on the 12 questions covering NMES prescription and implementation showed their poor knowledge of the technique (average: 26%±16 accurate). By analyzing performance per question, we found that the highest percentage of correct answers (82%) involved Question 4, and the lowest (4%), Questions 7 and 12 (Figure 2). Figure 3 shows the number of correct answers per respondent.

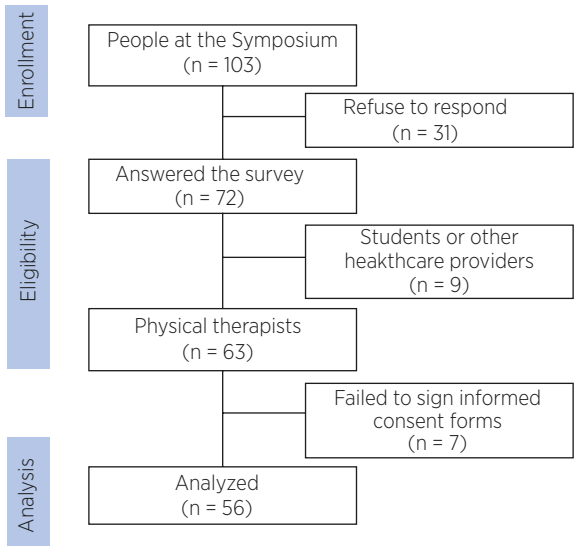

Figure 1. Flow chart

Table 1. Characterization and professional profile

Professional profile	
Sample size	56
Women, n (%)	43 (77%)
Age, years	33.5±7.2
Time after graduation, years	9.7±7
Are you specialized in respiratory physical therapy or certified by COFFITO for ICU care? Yes, n (%)	11 (20%)
Do you have a lato sensu (specialization) degree in respiratory physical therapy or ICU care? Yes, n (%)	22 (39%)
Do you have a stricto sensu (Master's or PhD) degree?	
Master Science Degree, n (%)	5 (9%)
PhD, n (%)	2 (4%)
Sector:	
Public, n (%)	35 (62%)
Private, n (%)	16 (29%)
Both n (%)	5 (9%)
Do you work at an ICU? Yes, n (%)	37 (66%)

Data are shown as means and standard deviations. COFFITO: Federal Council of Physical Therapy and Occupational Therapy; ICU: intensive care unit.

Table 2. Experience and main barriers to the use of neuromuscular electrical stimulation in ICUs

Experience with NMES#	
Have you performed an electrodiagnosis stimulus test in critically ill patients? Yes, n (%)	1 (3%)
Have you performed NMES in critically ill patients? Yes, n (%)	10 (27%)
Is NMES routinely performed in your ICU? Yes, n (%)	4 (11%)
What are the main barriers to the implementation of NMES in your ICU?	
1. Lack of knowledge about this therapy, n (%)	28 (50%)
2. Lack of equipment, n (%)	24 (43%)
3. Time for completing the treatment, n (%)	20 (36%)
4. Lack of supplies (e.g., electrodes, gel, etc.), n (%)	16 (29%)
5. Patients' clinical condition, n (%)	5 (9%)
6. Other	4 (7%)

NMES: neuromuscular electrical stimulation; ICU: intensive care unit; #Calculated based on the 37 respondents who work in ICUs.

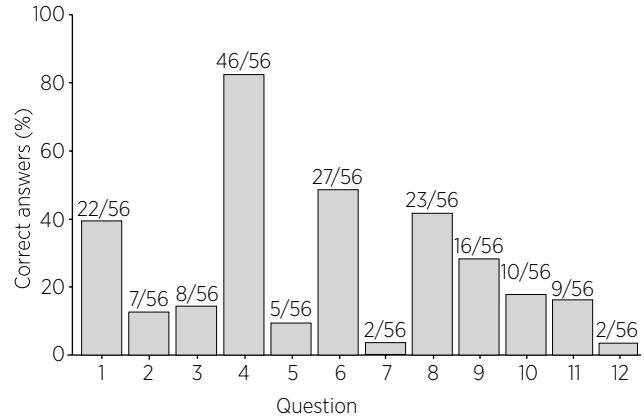

Figure 2. Percentage of correct answers per questions from all participants

This figure shows the overall percentage of correct answers per question. Most of the 56 respondents correctly answered Question 4 (82%), covering basic biophysical and electrotherapeutic concepts. We found the worst scores for the seventh and twelfth questions. Only about 4% of respondents correctly answered these two questions. Question 7 assessed knowledge about NMES indications and contraindications for critically ill patients (other than their physiological responses to it). Question 12 assessed knowledge about NMES prescription (dose-response).

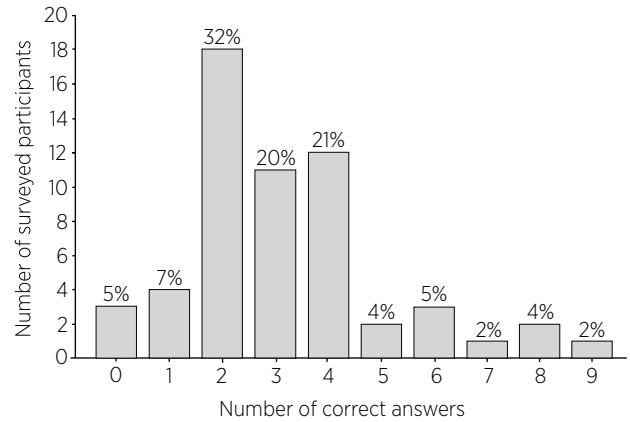

Figure 3. The number of respondents with correct answers per question

This histogram shows the number of correct answers per respondent. Only one participant (2% of the sample) achieved a score greater than 70% (>8 correct answers).

When we compared professional experts in intensive care or respiratory physical therapy (with a *lato sensu* degree or certified by COFFITO) to other non-certified healthcare providers, we found no statistically significant difference between their success rates (p=0.68). When we compared providers working in ICUs with the others, we also observed no statistically significant difference (p=0.53). Our comparison between specialists certified and not certified by COFFITO also showed no significant difference (p=0.82). In this sample, COFFITO certification, graduate *lato sensu* degrees, and ICU work failed to improve questionnaire results.

DISCUSSION

Our study showed that this sample of professionals had insufficient knowledge about prescribing and implementing NMES for critically ill patients. We showed that lack of knowledge might be the main barrier to implement this therapy in ICUs. Moreover, specialist degrees (COFFITO certifications) and ICU or related specializations failed to translate into better performance on our questionnaire.

In this study, 28 (50%) professionals said that lack of knowledge on this topic was a barrier to routinely performing NMES in their units, confirming our hypothesis. The fact that only one (3%) professional had ever performed electrodiagnosis stimulus tests in ICU patients and only 10 (27%) had ever performed NMES in critically ill patients emphasizes our result. Moreover, only four (11%) respondents reported performing routine NMES in their intensive care units. This shows that, besides their lack of knowledge, these professionals' ICUs lack standard NMES operating protocols. This can reduce the prescription rate of this therapy and compromise the safety and efficacy of NMES protocols.

Healthcare providers' lack of knowledge and experience is also evident in the low rate of correct answers for questions on NMES applicability, its physiological effects, and its use in ICUs. This corroborates Maffiuletti's recommendation[16] of the need for improving knowledge of NMES use and patients' physiological responses to it. These authors also claimed that only thus would it be possible to effectively and routinely use NMES[16].

Question 4, which had the highest percentage of success, dealt with biophysical concepts. Books on electrotherapy and early manuscripts used at undergraduate courses[17,18] describe these concepts, which could have influenced participants' better success rates.

Question 5 correlated biophysical concepts with standard physiological responses of motor recruitment and muscle contraction obtained via NMES. Only five (9%) respondents correctly answered this question. The recruitment pattern of motor units in voluntary muscle contraction follows the principle of size, according to which fast motor units follow the recruitment of slow motor units[19]. However, NMES clutters and spatially fixates such patterns[19,20], implying that it repeatedly activates the same motor unit via a fixed electric current, consequently leading to the early onset of muscle fatigue[19,21]. NMES protocols must carefully monitor and consider this fatigue in critically ill patients[3,19].

Question 12 focused on the implementation of NMES techniques and patients' physiological responses to it. This question assessed knowledge on the dose-response (treatment intensity, volume, and frequency) which would suit strength and muscle mass gains, including the appropriate strategies to be adopted by physical therapists to achieve these goals. Only two (4%) respondents correctly answered this question, which shows participants' poor understanding of NMES concepts. They involve determining motor points, electrically evoked torque, and total charge. Total charge is the product of pulse duration and frequency. This parameter directly influences NMES efficiency[22]. The greater the total charge, the greater the evoked peak torque and thus, the greater the gained strength and muscle volume[19,22]. Motor points are small muscle regions in which motor plates are more crowded, usually at the muscle belly[23]. Stimulus electrodiagnosis tests can detect motor points[1,23]. Muscles are more sensitive to electrical stimulation at this point, thus requiring a lower pulse intensity to evoke torque. Therefore, this is the ideal point to measure neuromuscular excitability and apply NMES. Studies have found a correlation between pulse intensity and pain sensation in NMES use[24]. As the pain produced during NMES can significantly limit the evoked torque, motor points must be carefully located[14]. Thus, physical therapists must master these concepts to safely and effectively implement NMES.

Only two (4%) respondents correctly answered question 7. It assessed participants' knowledge of NMES eligibility criteria, including its contraindications in ICUs. The correct answers for this question deconstruct the idea that critically ill patients are ineligible for early rehabilitation. Also, it reinforces the idea that using NMES is a feasible and safe option in patients admitted to ICUs[14,25].

This study opens the doors for future research assessing the knowledge of physical therapists from other Brazilian regions and countries. Although ours is a regional survey, some participants had already undertaken the national exam for professional proficiency. Thus, our results may be partially extrapolated to other parts of Brazil. This study should draw the attention of scientific associations and institutions responsible for training professionals in Brazil and motivate them to ensure that this issue is better addressed in their programs.

The questionnaire used in this study may have some limitations since it lacks previous validation[26]. Thus, research must conduct further studies to evaluate the properties of the proposed questionnaire and, if possible,

improve its evaluation capacity. Future studies can analyze the difficulty of understanding the issues, the time necessary to answer the questions, and the appropriate number of questions. The studied sample size and region may limit the extrapolation of results to the entire nation.

CONCLUSION

We showed that the surveyed professionals had insufficient knowledge about prescribing and implementing NMES in critically ill patients. Moreover, our results support the conclusion that the lack of theoretical and practical knowledge on the use of NMES is the main barrier to implementing this therapy in ICUs. Lack of equipment and supplies can also be associated with the non-use of NMES in critically ill patients. Physical therapy specialist degrees in intensive care and related areas failed to improve success rates to questions regarding the basic physical and physiological principles of NMES.

REFERENCES

1. Silva PE, Maldaner V, Vieira L, Carvalho KL, Gomes H, Melo P, et al. Neuromuscular electrophysiological disorders and muscle atrophy in mechanically-ventilated traumatic brain injury patients: new insights from a prospective observational study. J Crit Care. 2018;44:87-94. doi: 10.1016/j.jcrc.2017.10.026.
2. Lacomis D. Electrophysiology of neuromuscular disorders in critical illness. Muscle Nerve. 2013;47(3):452-63. doi: 10.1002/mus.23615.
3. Rodriguez PO, Setten M, Maskin LP, Bonelli I, Vidomlansky SR, Attie S, et al. Muscle weakness in septic patients requiring mechanical ventilation: protective effect of transcutaneous neuromuscular electrical stimulation. J Crit Care. 2012;27(3):319.e1-8. doi: 10.1016/j.jcrc.2011.04.010.
4. Routsi C, Gerovasili V, Vasileiadis I, Karatzanos E, Pitsolis T, Tripodaki E, et al. Electrical muscle stimulation prevents critical illness polyneuromyopathy: a randomized parallel intervention trial. Crit Care. 2010;14(2):R74. doi: 10.1186/cc8987.
5. Schweickert WD, Pohlman MC, Pohlman AS, Nigos C, Pawlik AJ, Esbrook CL, et al. Early physical and occupational therapy in mechanically ventilated, critically ill patients: a randomised controlled trial. Lancet. 2009;373(9678):1874-82. doi: 10.1016/S0140-6736(09)60658-9.
6. Stiller K. Safety issues that should be considered when mobilizing critically ill patients. Crit Care Clin. 2007;23(1):35-53. doi: 10.1016/j.ccc.2006.11.005.
7. Schujmann DS, Annoni R. The role of physiotherapy on the care of patients with Covid-19 in intensive care units. Fisioter Pesqui. 2020;27(3):218-9. doi: 10.1590/1809-2950/00000027032020.
8. Maffiuletti NA, Roig M, Karatzanos E, Nanas S. Neuromuscular electrical stimulation for preventing skeletal-muscle weakness and wasting in critically ill patients: a systematic review. BMC Med. 2013;11:137. doi: 10.1186/1741-7015-11-137.
9. Hirose T, Shiozaki T, Shimizu K, Mouri T, Noguchi K, Ohnishi M, et al. The effect of electrical muscle stimulation on the prevention of disuse muscle atrophy in patients with consciousness disturbance in the intensive care unit. J Crit Care. 2013;28(4):536.e1-7. doi: 10.1016/j.jcrc.2013.02.010.
10. Fornusek C, Davis GM, Russold MF. Pilot study of the effect of low-cadence functional electrical stimulation cycling after spinal cord injury on thigh girth and strength. Arch Phys Med Rehabil. 2013;94(5):990-3. doi: 10.1016/j.apmr.2012.10.010.
11. Weber-Carstens S, Schneider J, Wollersheim T, Assmann A, Bierbrauer J, Marg A, et al. Critical illness myopathy and GLUT4: significance of insulin and muscle contraction. Am J Respir Crit Care Med. 2013;187(4):387-96. doi: 10.1164/rccm.201209-1649OC.
12. Dirks ML, Hansen D, Van Assche A, Dendale P, Van Loon LJC. Neuromuscular electrical stimulation prevents muscle wasting in critically ill comatose patients. Clin Sci (Lond). 2015;128(6):357-65. doi: 10.1042/CS20140447.
13. Burke D, Gorman E, Stokes D, Lennon O. An evaluation of neuromuscular electrical stimulation in critical care using the ICF framework: a systematic review and meta-analysis. Clin Respir J. 2016;10(4):407-20. doi: 10.1111/crj.12234.
14. Silva PE, Babault N, Mazullo JB, Oliveira TP, Lemos BL, Carvalho VO, et al. Safety and feasibility of a neuromuscular electrical stimulation chronaxie-based protocol in critical ill patients: a prospective observational study. J Crit Care. 2017;37:141-8. doi: 10.1016/j.jcrc.2016.09.012.
15. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453-7. doi: 10.1016/S0140-6736(07)61602-X.
16. Maffiuletti NA. Physiological and methodological considerations for the use of neuromuscular electrical stimulation. Eur J Appl Physiol. 2010;110(2):223-34. doi: 10.1007/s00421-010-1502-y.
17. Meireles ALF, Meireles LCF, Queiroz JCES, Tassitano RM, Soares FO, Oliveira AS. Effectiveness of electrical stimulation in expiratory muscle on cough of patients after stroke. Fisioter Pesqui. 2012;19(4):314-9. doi: 10.1590/s1809-29502012000400004.
18. Cancelliero KM, Ike D, Sampaio LMM, Santos VLA, Stirbulov R, Costa D. Transcutaneous electrical diaphragmatic stimulation (TEDS) for the respiratory muscle strengthening: randomized and controlled clinical study. Fisioter Pesqui. 2012;19(4):303-8. doi: 10.1590/s1809-29502012000400002.
19. Maffiuletti NA, Minetto MA, Farina D, Bottinelli R. Electrical stimulation for neuromuscular testing and training: state-of-the art and unresolved issues. Eur J Appl Physiol. 2011;111(10):2391-7. doi: 10.1007/s00421-011-2133-7.

20. Gregory CM, Bickel CS. Recruitment patterns in human skeletal muscle during electrical stimulation. Phys Ther. 2005;85(4):358-64.

21. Gondin J, Cozzone PJ, Bendahan D. Is high-frequency neuromuscular electrical stimulation a suitable tool for muscle performance improvement in both healthy humans and athletes? Eur J Appl Physiol. 2011;111(10):2473-87. doi: 10.1007/s00421-011-2101-2.

22. Gregory CM, Dixon W, Bickel CS. Impact of varying pulse frequency and duration on muscle torque production and fatigue. Muscle Nerve. 2007;35(4):504-9. doi: 10.1002/mus.20710.

23. Botter A, Oprandi G, Lanfranco F, Allasia S, Maffiuletti NA, Minetto MA. Atlas of the muscle motor points for the lower limb: implications for electrical stimulation procedures and electrode positioning. Eur J Appl Physiol. 2011;111(10):2461-71. doi: 10.1007/s00421-011-2093-y.

24. Medeiros FVA, Vieira A, Carregaro RL, Bottaro M, Maffiuletti NA, Durigan JLQ. Skinfold thickness affects the isometric knee extension torque evoked by Neuromuscular Electrical Stimulation. Braz J Phys Ther. 2015;19(6):466-72. doi: 10.1590/bjpt-rbf.2014.0114.

25. Kho ME, Truong AD, Zanni JM, Ciesla ND, Brower RG, Palmer JB, et al. Neuromuscular electrical stimulation in mechanically ventilated patients: a randomized, sham-controlled pilot trial with blinded outcome assessment. J Crit Care. 2015;30(1):32-9. doi: 10.1016/j.jcrc.2014.09.014.

26. Boynton PM, Greenhalgh T. Selecting, designing, and developing your questionnaire. BMJ. 2004;328(7451):1312-5. doi: 10.1136/bmj.328.7451.1312.