Effect of neuromuscular electrical stimulation on muscle function in chronic low back pain patients: systematic review

Efeito da estimulação elétrica neuromuscular na função muscular em pacientes com dor lombar crônica: revisão sistemática

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ABSTRACT

BACKGROUND AND OBJECTIVES: Neuromuscular electrical stimulation (NMES) is one of the resources that can be used in the treatment of patients with chronic low back pain. It is possible that issues related to the stimulation parameters may affect the results obtained with the use of these currents. Therefore, the aim of this review was to investigate the effects of NMES on aspects of lumbopelvic muscle function in individuals with chronic low back pain.
CONTENTS: The study is a systematic review that used 10 databases for the search through a comprehensive combination of descriptors that met the research question. The selection criteria based on the PICOT strategy were population - individuals with chronic low back pain (specific and/or non-specific); intervention - NMES; outcomes - paravertebral and/or abdominal muscle changes (muscle power and endurance). The articles were selected by two independent reviewers, who developed the tools for data extraction. Four articles were included in this review. In three of them, there was a significant increase in muscle strength and endurance, as well as muscle cross-sectional area in the group that received NMES compared to the control group.
CONCLUSION: NMES showed positive effects in optimizing aspects of muscle function in individuals with chronic low back pain. However, the methods employed are very heterogeneous, which made it impossible to perform a quantitative analysis.

Keywords: Electric stimulation therapy, Low back pain, Skeletal muscle.

RESUMO

JUSTIFICATIVA E OBJETIVOS: A estimulação elétrica neuromuscular (EENM) é um dos recursos que podem ser utilizados no tratamento de pacientes com dor lombar crônica. É possível que questões relacionadas aos parâmetros de estimulação possam afetar os resultados obtidos com o uso dessas correntes. Portanto, o objetivo deste estudo foi investigar os efeitos da EENM em aspectos da função muscular da região lombopélvica em indivíduos com dor lombar crônica.
CONTEÚDO: Trata-se de uma revisão sistemática que utilizou 10 bases de dados para a busca por meio da combinação abrangente de descritores que atendessem a pergunta da investigação. Os critérios de seleção com base na estratégia PICOT foram: população - indivíduos com dor lombar crônica (específica e/ou não específica); intervenção - EENM; desfechos – alterações musculares de paravertebrais e/ou abdominais (potência e resistência muscular). A seleção dos artigos foi feita por dois revisores independentes que elaboraram as ferramentas para extração dos dados. Ao todo, quatro artigos foram incluídos nesta revisão. Em três deles, houve aumento significativo de força e resistência muscular, assim como da área de secção transversa muscular no grupo que recebeu EENM, em relação ao controle.
CONCLUSÃO: A EENM apresentou efeitos positivos na otimização dos aspectos da função muscular em indivíduos com dor lombar crônica. Porém, os métodos empregados são muito heterogêneos, o que impossibilitou a realização da análise quantitativa.

Descritores: Dor lombar, Musculoesquelético, Terapia por estimulação elétrica.

INTRODUCTION

Chronic low back pain (CLBP) is characterized by functional loss, pain or discomfort located in the area below the last rib and above the iliac crest in the lumbosacral region lasting for three months or longer[1,2]. In the urban area of São Paulo, a prevalence of individuals with low back pain (LBP) of 48.1%[3] was observed and the prevalence of chronic pain in Brazil was indicated at 45.59%, ranging from 23.02 to 76.17%[4]. CLBP is considered one of the greatest causes of limitations and absence from work activities, making it not only a disease of great clinical relevance, but also economic[5]. Since it is a multifactorial condition, more than 85% of cases have no specific cause[1,6]. Its treatment is often multidisciplinary, involving a combination of therapies such as pharmacotherapy and physical therapy, as well as physical

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exercises to increase power and endurance of the trunk muscles, aerobic and aquatic exercises to increase mobility and control movements, among others[7,8].

Currently, there is evidence of the occurrence of fat infiltration and uni or bilateral atrophy of the multifidus in individuals with CLBP, the mechanism that would lead to this may be related to a scenario of arthrogenic muscle inhibition and its occurrence seems to be proportional to the duration of symptoms, but difficult to reverse[9]. A decrease in the activation of the multifidus and transversus abdominis has also been observed in CLBP, a disorder that determines loss of lumbar spine support, increased stress and load on joints and ligaments located in the lumbar region[10].

Systematic reviews suggest that interventions that promote co-contraction of the transverse abdominis and multifidus muscles are effective in both improving function and relieving symptoms related to CLBP, which may be a local mechanical phenomenon or through central analgesia pathways[11,12]. Studies support the use of endurance training and muscle stabilization for reducing the pain levels of these patients[7,13].

One form of muscle training that promotes strength increase is neuromuscular electrical stimulation (NMES), which consists of an external application of an electrical current that excites the nerve and causes involuntary muscle contraction[2]. NMES is often used in cases of osteomuscular system injuries or post-surgery, and it can also be an important tool in the treatment of patients with CLBP. However, because the current can be uncomfortable, it is often adjusted according to the patient's tolerance, which does not necessarily reflect the intensity required to produce contraction and, consequently, muscle gains[14].

In traditional exercise training, the external load (defined as the overload imposed by the ratio between the intensity and volume of the stimulus) is a determining parameter for the generation of muscle adaptation[15]. Taking into account the functional and histomorphological characteristics of lumbopelvic stabilizer muscles related to strength endurance, the dosimetric parameters should respect the principle of training specificity in order to induce muscle benefits. Despite not presenting an advantage in strength gain when compared to voluntary exercise[16], NMES is useful in early rehabilitation phases or in individuals with severe motor disabilities[17,18]. Thus, it is important to analyze in the literature the effects of NMES use in patients with CLBP and its standardization in order to ensure its effects on muscle strength. Therefore, the present study's objective was to investigate the NMES parameters in the optimization of muscle function aspects of the lumbopelvic region in patients with CLBP.

CONTENTS

A systematic review based on the PRISMA statute, which used the following databases: Pubmed, CINAHL, Cochrane, Embase, Scopus, Web of Science, Livivo, LILACS, PsycINFO, and Google Scholar. The electronic search occurred between June and July 2021 and made use of the following descriptors: "Chronic low back pain", "Neuromuscular electrical stimulation", "Core stabilization" and "Muscle strength" plus the Boolean operators ("AND" and "OR"); the same terms were also used in Portuguese and Spanish. The terms were searched in the titles and abstracts of the articles. Studies published in English, Portuguese, and Spanish were considered without restriction as to year of publication.

In order to formulate the selection criteria, the PICO strategy was used. Therefore, to be included in this review, the studies should have: used as samples individuals with CLBP (for at least 3 months, regardless of being specific or not) of any age or gender; used NMES as intervention; evaluated muscle outcomes of paravertebral and/or abdominal function, both power and endurance; and presented comparison with some kind of control group (no therapy or placebo) or alternative therapy. The following were excluded: studies that evaluated acute LBP, experimental studies, cross-sectional studies, studies without a control group, observational studies, book chapters, randomized clinical trial records, and studies that did not evaluate muscle outcomes or that provided incomplete data.

A reference management software (EndNote Web®, Thomson Reuters), which allowed the initial exclusion of duplicate references, was used for the selection of studies and collection of results. Next, they were imported into Rayyan QCRI® (Qatar Computing Research Institute), which was used to double-check references and perform the study analysis process. Two independent reviewers performed an exploratory reading of all titles and abstracts to see if they met the research criteria. In the next step, the selected articles were read in full and ranked again. Divergences between reviewers were resolved by a third reviewer.

Finally, the included studies had the information extracted in tables prepared by the researchers themselves in order to sort and summarize the information. The data collected were: country; characteristics and sample quantitative; interventions; comparative group(s); variables related to strength (endurance or power); dosimetry relative to the current; number of sessions, sets, and contractions; analyzed muscle outcomes; and results.

In order to calculate the external load through the NMES, the load control calculations used in weight training were adapted. For this, the terminology already proposed was used[15,19], in which the load volume (LV) is the product of the intensity multiplied by the number of repetitions (the NMES intensity here would replace the endurance mass); the total of repetitions (TR) is the product of the number of sets multiplied by the number of repetitions (repetitions = number of contractions); and the stimulation intensity (SI) would be calculated by the result of the load volume divided by the number of repetitions. The stimulation density (SD) was obtained by the result of the volume divided by the stimulation duration.

LV = intensity * number of repetitions

TR = number of sets * number of repetitions

SI = LV / number of repetitions

DE = LV / stimulation duration

The ROB2® instrument was used to analyze the risk of bias, in which five dimensions were analyzed (randomization process, deviations from planned interventions, missing outcome data, outcome measures, and selection of reported outcomes), and the scoring in the system is generated as: low risk, some concerns, and high risk, thus automatically presented for the dimensions and as an overall result.

RESULTS

After performing the definitive search strategies in all databases, 375 records were found and 255 remained after removal of duplicates. Next, 245 studies were removed after reading the titles and abstracts, 10 articles were analyzed in full, and four were included in the present review. The entire process of search and selection of studies was presented in a flowchart (Figure 1).

Of the included studies, one specifically used Aussie current, one used Russian current, and two did not specify the current. Three studies were conducted in Brazil and one in the United States, and the year of publication ranged from 2011 to 2020. All were written in English. Regarding sample size, the number of participants ranged per group from 13 to 30, aged between 18 and 60 years. Data extracted from the included articles were described in detail in table 1.

Muscle strength

When checking the data concerning muscle strength, one study did not find significant differences when intra- or intergroup comparisons were made after 12 NMES sessions for the paravertebral muscles[20]. Another study showed an increase in trunk endurance after 12 Russian current sessions applied to the paravertebrae[2]. In a third study, there was a significant difference in muscle endurance for the electrostimulation group compared to the initial evaluation, but a group that associated NMES with core exercises showed superior results[21]. Finally, another study found greater trunk strength in the group treated with Aussie current applied to the paravertebrae immediately after treatment and after one month of follow-up[22].

Muscle thickness

In a study that applied Russian current in 12 sessions, there was no significant difference in the cross-sectional area of the multifidus through ultrasound images[2]. On the other hand, using the Aussie current, an increase in the cross-sectional area was observed after 12 sessions and one month of follow-up[22]. Similarly, there was an increase in the cross-sectional area of the transverse abdominis and internal oblique during anterior straight leg raising and in the cross-sectional area of the relaxed multifidus after 70 sessions of NMES in abdomen and paravertebrae[23].

Dosimetry

The parameters of ramp time and total stimulation time varied widely in the studies. As for the On/Off time, the dose varied from 14 s/50 s[20], 12 s/12 s[2], 5 s/3 s[23], 12 s/20 s[21] and 10 s/10 s[22]. The total session time was 15 minutes[23], 20 minutes[2,20,22] and 25 minutes[21] over 12 treatment sessions. More details are presented in table 2.

External load calculations

Of the four analyzed studies, none presented sufficient data for calculating the load volume, since this would require intensity

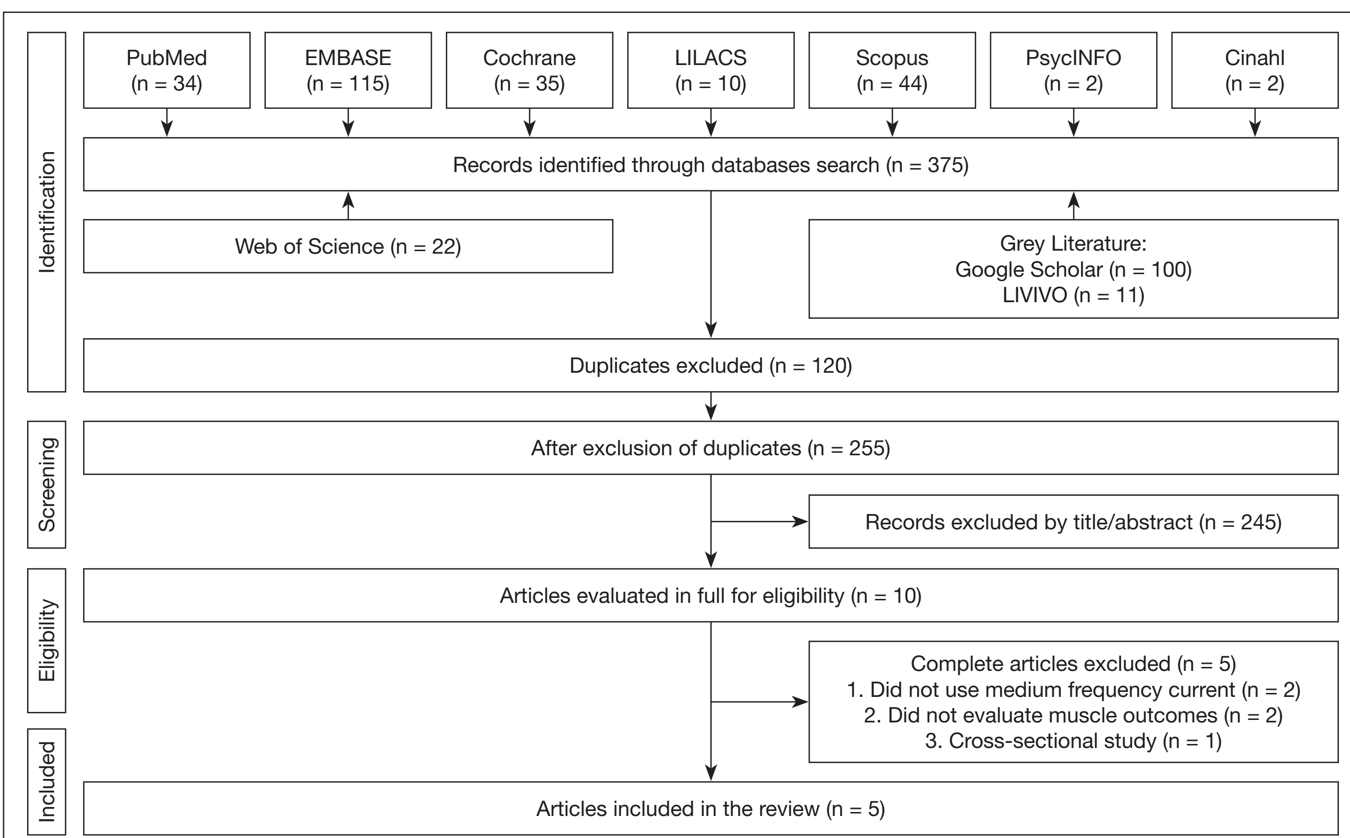

Figure 1. Flowchart of the literature search and selection criteria.

Table 1. Synthesis of included studies

Authors	Country	Sample	Interventions	Comparisons	Strength manifestations	Muscle outcomes	Evaluations	Results
Alrwaily et al.[20]	USA	30 individuals of both genders; Age between 18 and 60 years; CLBP ≥ 3 months; BMI ≤ 34; Pain intensity ≥ 3; Modified Oswestry Disability Questionnaire ≥ 20.	Nonspecific NMES: - Applied to lumbar paravertebral muscles bilaterally via 2 self-adhesive electrodes; Stabilization exercise protocol: - Performed under the supervision of a physical therapist; - Consisting of 13 abdominal strengthening exercises subdivided into: 5 strengthening exercises without weight bearing, 5 exercises with weight bearing and 3 exercises in the 4 supports position; - 20 to 30 repetitions of each exercise were performed, with the times of bearing varying from 4 to 10 sec; - Total protocol duration: 20 min; - Frequency: 2 times a week, for 6 weeks, totaling 12 sessions.	- Exercise Group (EXG): performed a stabilization exercise protocol, n=156. - Exercise + Electrostimulation Group (EXNMESG): underwent exercise protocol and NMES, n=15.	Not reported.	Lumbar paravertebral muscle strength (dynamometer).	- Pre-treatment (EV 1). - After 12 sessions (EV 2).	No significant difference between groups and evaluations.
Batistella et al.[2]	Brazil	24 sedentary women; Age between 18 and 30 years; Nonspecific CLBP; with symptoms for at least 12 weeks.	Russian Current: - Applied to the lumbar paravertebral muscles bilaterally via 2 channels containing 4 electrodes (using water-soluble gel as the coupling medium).	- Control Group (CG): no intervention, n=12. - Russian Current Group (RCG): underwent Russian current treatment, n=12.	Not reported.	Trunk endurance test.	- Pre-treatment (EV 1). - After 12 sessions (EV 2). - One month after end of treatment (EV 3).	Increase in muscle endurance between EV 1 and EV 2 in RCG; increase between RCG versus CG in EV 3. No significant difference between groups and between evaluations (at all time points).
Dimer da Luz et al.[21]	Brazil	30 sedentary women; Age between 18 and 35 years; Nonspecific CLBP ≥ 4 on VAS.	Nonspecific NMES of 2500 Hz: - NMES was applied synchronously with the CORE exercises (exercise isometrics were performed when current was On, and rest when the current was Off); - The electrodes were positioned in the region covering gluteus maximus and medius, rectus abdominis, and transversus abdominis bilaterally. Exercise protocol for CORE strengthening : - Performed under the supervision of the researchers; - Composed of static postures sustained in isometrics; - In each session the participants performed 4 sets (postures) of 10 repetitions sustained for 10 seconds each, with an interval of 20 seconds between repetitions and 60 seconds between sets; - Total protocol duration: 25 min; - Frequency: 3x/week for 4 weeks, totaling 12 sessions.	- CORE Group (CG): underwent CORE strengthening protocol, n=10. - Electrostimulation group (EG): underwent treatment with N, n=10. - Electrostimulation + CORE Group (ECG): underwent treatment with NMES synchronized with voluntary contraction during CORE strengthening exercises, n=10.	Not reported.	CORE muscles stabilization strength (average in sec): trunk static endurance test, Sorenson's test, side bridge test and prone instability test.	- Pre-treatment (EV 1). - After 12 sessions (EV 2). - Six months after end of treatment (EV 3).	Significant increase between EV 2 and EV 3 versus EV 1 in ECG in all tests; significant increase between EV 2 versus EV 1 in EG in Sorenson's test; and significant difference between ECG versus CG and EG in all tests.
Pelegrini et al.[22]	Brazil	24 sedentary women; Age between 18 and 30 years; Nonspecific CLBP; with symptoms for at least 12 weeks.	Aussie Current: - Applied on the lumbar paravertebral muscles bilaterally by means of 2 channels containing 4 electrodes (using water-soluble gel as a coupling medium).	- Control Group (CG): no intervention, n=12 - Aussie Current Group (ACG): submitted to treatment with Aussie current, n=12.	Not reported.	Trunk endurance test. Cross-sectional area of the Multifidus muscles (ultrasound).	- Pre-treatment (EV 1) . - After 12 sessions (EV 2). - One month after end of treatment (EV 3).	Increase in muscle endurance between ACG versus CG in EV 2 and EV 3. Increase in cross-section between ACG versus CG at EV 2 and EV 3.

EV = evaluation; CLBP = Chronic Low Back Pain; min = minutes; sec = seconds; BMI = body mass index; VAS = Visual Analog Scale; NMES = neuromuscular electrical stimulation.

Table 2. NMES dosimetry in the included studies

Authors	Current	Ramp time in seconds					Intensity	Total time	No. of sessions	No. of sets	No. of contractions (TR)
		On	A	Su	D	Off					
Alrwaily et al.[20]	Non-specific NMES	14	4	6	4	50	Highest levels tolerated by patients	20 min	2 x/week 6 weeks Total: 12	1	19
Batistella et al.[2]	Russian current	12	2	8	2	12	Highest levels tolerated by patients, increasing according to comfort	20 min	3 x /week 4 weeks Total: 12	1	60
Dimer da Luz et al.[21]	Non-specific NMES of 2500 Hz	12	1	10	1	20	Highest levels tolerated by patients without causing discomfort	25 min	3 x /week 4 weeks Total: 12	1	50
Pelegrini et al.[22]	Aussie current	10	1	8	1	10	Highest levels tolerated by patients, increasing according to comfort	20 min	3 x/week 4 weeks Total: 12	1	60

D = descent; NMES = neuromuscular electrical stimulation; Hz = Hertz; Min = minutes; No. = number; A = ascent; Su = sustaining; TR = total repetitions.

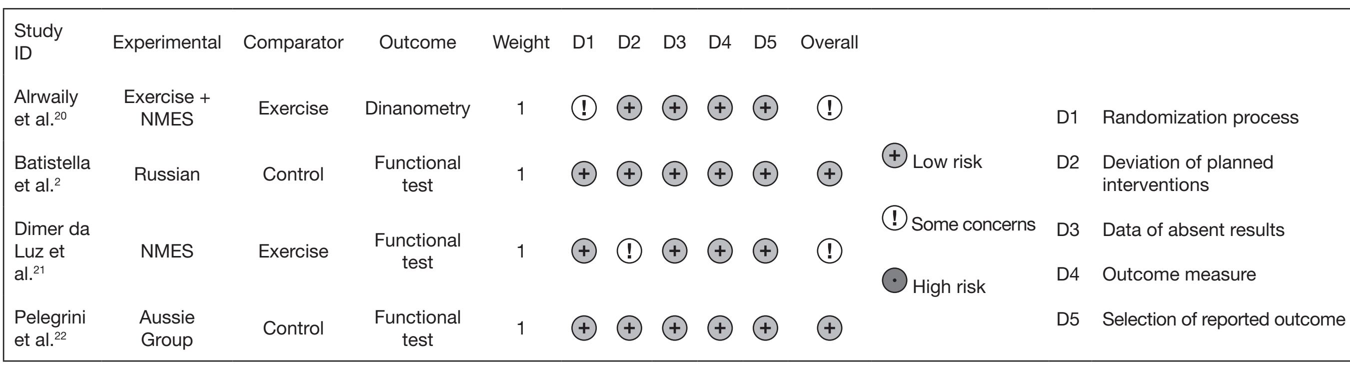

Figure 2. Representation of the risk of bias outcomes analyzed via ROB2 according to study and size.

data from the NMES. As a consequence, it was not possible to arrive at a result regarding the intensity and density of stimulation. It was only possible to reach results regarding the total number of repetitions, which is calculated by the number of sets multiplied by the total number of contractions (Table 2). It was possible to analyze the risk of bias with the ROB2[*24] instrument on the included studies. Two studies[20,21] presented some points that should be analyzed with caution (due to some problems observed in the risk of bias) and two[2,22]generating social and economic repercussions, the most relevant symptoms being pain and functional disability. Conservative treatment is often based on stabilizing spinal muscles with exercises: the Russian current (RC with low risk of bias (Figure 2).

DISCUSSION

Among the included clinical trials, most obtained improvement in strength and increased cross-sectional area of the multifidus, transverse abdominis, and internal oblique muscles in patients with CLBP treated with NMES. Other articles that also made use of NMES applied on such muscles in sedentary individuals without diseases[25,26] corroborate the findings of improvement in the aspects of muscle function.

In this review, an attempt was made to relate the data obtained by calculating the external load with the strength manifestations. However, that was not possible to achieve due to divergences between the methods and measurement units of the clinical trial evaluations found. In addition, none of the articles brought data on the mean intensity obtained, which also contributed to the impossibility of calculations. If the load parameters are not specified in the studies, it is not possible to know whether or not the loads being delivered are adequate to promote adaptation in aspects of muscle function.

A study exploring the effects of NMES intensity on the multifidus muscles observed that, at 37mA intensity, there was an increase in the cross-sectional area of the muscle[27]. However, less than 50% of the participants self-selected this amplitude. Thus, guiding the intensity only at levels tolerated by patients may result in sub-therapeutic levels of NMES, since high intensities can increase the thickness of the multifidus beyond the effects caused by exercise alone. This might be the reason why a study did not find a significant difference when associating the use of the current with stabilization exercises[20].

One of the muscle groups that act on lumbopelvic stabilization is the multifidus, which works mainly in the lumbar spine[28]. In individuals with CLBP, their anatomy and function are often altered[29]. There are studies that address joint strengthening and stabilization with the use of NMES[23,30,31], but the literature is still poor regarding the use of NMES in lumbopelvic stabilization[22]. Considering that NMES generates muscle contraction for strength gain, using it according to strength training principles tends to generate better results.

Of the included studies, only two[2,22] specified which current was used – Russian and Aussie, respectively. Authors[32] conducted a study comparing the effects of the Russian current (medium frequency) with low frequency currents, and concluded that there was no significant difference regarding muscle torque, however, the discomfort with the Russian current was lower and the level of tolerated current amplitude increased. As for the Aussie current, which features a medium frequency base current but is modulated at low frequency, is considered the most comfortable and effective among the different forms of NMES. Nevertheless, even though this current is a good option for CLBP treatment, its use for this purpose is still scarce in the literature[33].

Based on this, it is a challenge to develop NMES protocols for patients with CLBP based on available literature, since there is no consistency in the parameters to be used. There is great divergence in the choice of physical parameters applied in the tests related to the choice of frequency, ramp time, current intensity and methodology of NMES use, directly influencing the results obtained.

The limited number of studies included in the present review and the heterogeneity of methods and parameters employed are pointed out as limitations of this study, besides a possible bias of the publication language, since only studies in Portuguese, English and Spanish were considered.

New randomized clinical trials conducted in a standardized manner must be encouraged, aiming to aid in the better understanding of the parameters and efficacy of NMES, since a conclusion as to the ideal parameters to achieve muscle benefits has not yet been reached. However, it should be emphasized that, due to the low risks of bias observed, it is possible to identify that methodologically the studies can be considered viable for clinicians to make use of this resource in individuals with CLBP.

CONCLUSION

Based on the analyzed studies, NMES has positive effects in optimizing aspects of muscle function in individuals with CLBP. However, new clinical trials are still needed in order to clarify the methods and parameters used, since important information is still scarce in the literature.

AUTHORS' CONTRIBUTIONS

Alessandra Linzmeyer
Data Collection, Conceptualization, Resource Management, Research, Methodology, Writing - Preparation of the original, Visualização

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Data Collection, Conceptualization, Research, Methodology, Writing - Preparation of the original, Visualizing

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Data Collection, Conceptualization, Project Management, Methodology, Writing - Review and Editing, Supervision

Alberito Rodrigo Carvalho
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