Influence of pain prognosis and electrical stimulation modality on the amplitude of current elicited at sensory threshold in chronic lumbar pain sufferers

Influência do prognóstico para dor e da modalidade de estimulação elétrica na amplitude de corrente elicitada no limiar sensorial em lombálgicos crônicos

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ABSTRACT

BACKGROUND AND OBJECTIVES: Sensory function may be altered in chronic low back pain (CLBP), which may alter the perception of therapeutic currents. The aim of this study was to verify whether the risk of poor prognosis for CLBP pain influences the amplitude elicited at the sensory threshold (ST) in different modalities of neuromuscular electrical stimulation (NMES).

METHODS: This is a quasi-experimental counterbalanced study with 40 subjects divided into four groups (n=10 each), according to the risk of poor prognosis for pain: no risk (control group - CG), low (LrG), medium (MrG), and high (HrG) risks. Four modalities of NMES were tested: two medium frequency currents (Aussie current [AC] and Russian current [RC]) and two low frequency currents (commonly known as functional electrical stimulation [FES]), with two phase durations of 200 μs (FES_200) and 500 μs (FES_500), in the region of the lumbar multifidus muscles. All subjects were exposed to all current modalities with interval periods, and when the ST was reached, the amplitude of the current measured in mA was recorded.

RESULTS: The currents that elicited the highest and lowest amplitude in the ST were FES_200 and AC, respectively. As for the risk of poor prognosis, the highest amplitudes were for the HrG and the lowest for the LrG.

CONCLUSION: The amplitude of the current elicited in the ST tended to be higher among those with a higher risk of poor prognosis for pain and, among the currents, those of medium frequency elicited lower amplitudes.

Keywords: Electrical stimulation therapy, Low back pain, Psychosocial impact.

RESUMO

JUSTIFICATIVA E OBJETIVOS: A função sensorial é potencialmente alterada na presença de dor lombar crônica (DLC), o que pode alterar a percepção de passagem de correntes terapêuticas. O objetivo deste estudo foi verificar se o risco de mau prognóstico para DLC influencia a amplitude elicitada no limiar sensorial (LS) em diferentes modalidades de estimulação elétrica neuromuscular (EENM).

MÉTODOS: Trata-se de um estudo quase-experimental contrabalanceado composto por 40 voluntários alocados em quatro grupos (n=10 cada), de acordo com o risco de mau prognóstico para dor: sem risco (grupo controle – GC), baixo risco (GBR), médio risco (GMR) e alto risco (GAR). Foram testadas quatro modalidades de EENM: duas correntes de média frequência (corrente Aussie [CA] e corrente Russa [CR]) e duas correntes de baixa frequência (comumente denominada estimulação elétrica funcional [FES]), com duas durações de fases 200 μs (FES_200) e 500 μs (FES_500) na região dos músculos multífidos lombares. Todos os voluntários foram submetidos a todas as modalidades de corrente, com períodos de intervalos, e ao ser atingido o LS, foi realizado o registro da amplitude da corrente medida em mA.

RESULTADOS: As correntes que elicitaram a maior e a menor amplitude no LS foram, respectivamente, FES_200 e CA. Quanto ao risco de mau prognóstico, as maiores amplitudes foram do GAR e as menores do GBR.

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HIGHLIGHTS
- Psychosocial factors seem to influence the sensory threshold in chronic low back pain
- High risk of poor prognosis for pain elicits a higher amplitude in the sensory threshold
- The aussie current generates lower amplitude at the sensory threshold compared to other currents

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CONCLUSÃO: A amplitude da corrente elicitada no LS tendeu a ser mais alta entre aqueles com maior risco de mau prognóstico para dor e, dentre as correntes, aquelas de média frequência elicitaram amplitudes mais baixas.
Descritores: Dor lombar, Impacto psicossocial, Terapia por estimulação elétrica.

INTRODUCTION

Chronic low back pain (CLBP) is a prevalent syndrome that has physical and social consequences[1]. CLBP has a multifactorial etiology and, in addition to physical factors, biopsychosocial factors also contribute to the clinical scenario and negatively affect the prognosis[2,3]. In proportion to the level of contribution of biopsychosocial factors, which is reflected in the manifestation of the clinical scenario, those with CLBP can be subgrouped in terms of the risk of developing a poor prognosis, these subgroups being: low, medium or high risk of poor prognosis for pain[4,5].
In association, CLBP also impairs local muscle control, compromising the function of the stabilizing muscles and causing damage to the mobility, strength and protection of the spinal joints. The lumbar multifidus muscles are the main stabilizers of the lumbar-pelvic region[6] and, in those with CLBP, their voluntary activation can be impaired and become inefficient for the stabilization function[7]. It is believed that the mechanism that leads to the deficit in motor control and loss of stabilization quality is similar to that described to explain arthrogenic muscle inhibition of the quadriceps[8,9]. In addition, people with CLBP show signs of fatty infiltration and atrophy in the lumbar multifidus[10,11], which also compromises the muscle's ability to generate tension. For these reasons, interventions capable of optimizing aspects of muscle function are essential for restoring stabilizing capacity, such as electrotherapy.
Electrotherapeutic modalities, which consist of the application of transdermal electric currents[12], are frequently used by physiotherapists for their beneficial therapeutic effects aimed at aspects of muscle function and because they are well accepted by patients[13-15]. The sequence of activation of nerve fibers by neuromuscular electrical stimulation (NMES) ranges from the recruitment of the Aβ fibers responsible for the sensation of paresthesia that marks the sensory threshold, to the C fibers responsible for conducting nociceptive information and, depending on the amplitude of the NMES current, may produce muscle contraction if the motor threshold is exceeded[16].
Among the different modalities of NMES aimed at strengthening muscles, medium-frequency currents stand out, such as Aussie (AC) and Russian (RC) currents, as well as low-frequency currents, such as functional electrical stimulation (FES). These currents are known to promote the recruitment of motor units, inducing gains in muscle strength and reducing pain[17-19], as well as curbing the mechanism of arthrogenic muscle inhibition[9].
NMES is a biomechanical approximation of real biological electrical impulses and is used to maintain, restore or improve neuromuscular function[20,21]. Although NMES is not among the therapies proposed in treatment guidelines for CLBP, it has been shown to be useful for interrupting muscle reflex inhibition and, consequently, optimizing joint stabilization, strength, tone and muscle trophism[22-24].
Therefore, the therapeutic potential of NMES in CLBP cannot yet be disregarded, including the analgesic effect of excitomotor currents, as highlighted by some studies[15,17,24-26], although dosimetry is still a challenge to be overcome. In addition, it is suggested that medium-frequency currents, compared to low-frequency currents, are capable of minimizing the discomfort produced by the passage of the current[14], as well as increasing multifidus activity and reducing pain intensity in patients with CLBP[26].
It is known that the primary motor cortex, and consequently motor acts, are influenced by inputs from the sensory cortex[27]. However, considering that the chronic pain experience takes place through cognitive, emotional and autonomic processing[28,29] and that, consequently, the contribution of psychosocial aspects can affect the quality of pain without there being a clear association between the characterization of the painful event from a biomedical perspective[30,31], it is necessary to identify whether the perception of current is different between the different risk strata of poor prognosis in CLBP. People who suffer from chronic pain may have an amplification of the pain signaling network located in the central nervous system, known as central sensitization, which produces a painful condition even without a clear nociceptive origin, and also hypersensitivity to pain as a form of protection to avoid new possible damaging stimuli[32].
In addition, in cases of chronic spinal pain, the role of central alterations, such as abnormal changes in brain structures and hyperexcitability of the central nervous system, in maintaining pain is increasingly recognized[33]. Considering that nociception, related to the perception of noxious stimuli, and pain, which involves affective and motivational aspects, are distinct concepts[34], it is possible that in the case of CLBP, nociception is also altered. For this reason, it is believed that those with a high risk of poor prognosis for pain are more sensitive to the passage of current and, consequently, will have a lower current amplitude at the sensory threshold.
The present study's objective was to see whether the risk of poor prognosis for pain in CLBP influences the amplitude of the current elicited at the sensory threshold (ST) in different NMES modalities. The hypothesis of the study is that the amplitude of the current at the SL, regardless of the NMES modality, decreases inversely to the risk of poor prognosis for pain and that medium-frequency currents elicit the lowest amplitudes.

METHODS

This study was classified as a quasi-experimental counterbalanced study. All the volunteers signed the Free and Informed Consent Term (FICT) in two copies, one held by the volunteer and the other by the researcher. This study was approved by the institutional ethics research committee involving human beings (protocol no. 5151050).
The sample consisted of volunteers of both sexes, aged between 18 and 59, with and without CLBP, recruited non-probabilistically and consecutively. The volunteers were divided into groups, with one group consisting of volunteers with no musculoskeletal

disorders in any body segment in the last 12 months (control group - CG), and three other groups with LBP volunteers stratified according to the risk of poor prognosis for pain, classified by the STarT Back Screening Tool (SBST)[4,5] questionnaire as low risk (LrG), medium risk (MrG) and high risk (HrG). SBST is an assessment tool capable, in itself, of predicting short and medium term disability in the Brazilian population with CLBP[35] and is listed among the most commonly used tools for assessing nonspastic pain[36].

All the volunteers were exposed to four types of NMES, two medium-frequency currents (Aussie current [AC], with a phase duration of 500 μs, and Russian current [RC], with a phase duration of 200 μs), and two low-frequency currents (the type commonly referred to as functional electrical stimulation [FES]), with two phase durations, 200 μs (FES_200) and 500 μs (FES_500).

Data from a previous study[7], from which the effect size was calculated, was used as the basis for the sample calculation. The GPower 3.1 software was used to determine the sample size, with the following input data: effect size of 0.70; alpha of 0.05; power of 0.95; four groups; four as the number of measurements. The sample calculation returned a minimum of 40 volunteers in total, 10 in each group.

For inclusion in the CG, volunteers had to report hypokinetic physical behavior because they did not reach the minimum level of weekly physical activity recommended by the physical activity guidelines, which is 150 min per week[37], and deny episodes of low back pain in the last year. The following criteria were adopted for inclusion in the CLBP groups: a) physically hypokinetic volunteers reporting persistent and/or recurrent low back pain for more than three months; b) low back pain with physical characteristics compatible with mechanical etiology, in the categories of non-specific low back pain or low back pain potentially associated with radiculopathy or spinal stenosis, according to the evaluation and treatment guidelines proposed by the American College of Physicians and the American Pain Society[38].

The non-inclusion and exclusion criteria were: a) a history of back surgery; b) pregnancy; c) a history of acute or chronic pain reported in any body segment other than the lumbar spine; d) pain amplitude at the time of the test and/or at rest measured by the Visual Analog Scale (VAS) greater than six, preventing the research protocol from aggravating the pain.

Methodological procedures

Initially, an interview was carried out to record the volunteers' physical, functional and sociodemographic history, as well as their anthropometric measurements. The following measurements to characterize the sample were recorded: age (years), body mass (kg), height (m), level of physical activity, length of lower limbs (m), gender and body mass index (BMI). The screening assessment for CLBP followed a script prepared with systematized questions.

The SBST was administered to all volunteers with CLBP. This instrument consists of a set of nine questions, with the first four addressing issues related to referred pain, dysfunctions and comorbidities, while the last five address psychosocial aspects[5]. Initially, each volunteer answered the nine questions, the first eight of which offered the choice of "agree" (scoring one point) or "disagree" (scoring zero points). In the ninth question, there were five answer options: "not at all," "a little," "moderate" (scoring zero points), "a lot," "extremely" (worth one point).

If the total score obtained was in the range of zero to three, the participant was categorized as having a low risk of developing a poor prognosis related to pain. For final scores above three, the score was recalculated, but now using only the sum of the answers to questions five to nine, which relate to psychosocial aspects. In this case, participants with recalculated scores up to three were stratified as having a moderate risk of developing a poor prognosis for pain, while those with scores above three were stratified as having a high risk of developing a poor prognosis.

The Neurodyn Multicurrent electrostimulator (Ibramed®, Amparo/SP, Brazil) was used to apply the different NMES modalities. The lumbar region was aseptically cleaned so that the electrodes could be placed bilaterally in the region of the multifidus muscles, two cephalic electrodes at the level of the second lumbar vertebra and two caudal electrodes at the level of the first sacral vertebra. The electrodes were flexible, made of rubber/silicone, with water-soluble gel between the electrode and the skin[7], measuring 3 x 5 cm so that they could be adjusted appropriately in the area corresponding to the muscle being studied, while still ensuring dimensions close to those already tested in terms of their influence on comfort and current density[39].

Two NMES rounds were performed, with a 10-minute interval between these two rounds, so that the four current configurations could be given to all the volunteers: AC, RC, FES_200 and FES_500. During the interval between rounds, the volunteer remained in the assessment position, lying prone. In the first round, two configurations of currents were evaluated, one in each channel and with a washout interval of 2 min between the delivery of the currents. In the second round, the other two remaining configurations were evaluated using the same protocol as the first. In each round, the channels were activated individually and sequentially, but both the order and the current modality were determined randomly by lottery to minimize bias.

Before receiving the NMES, all the volunteers were familiarized with the currents and instructed to verbally express the first sensation perceived by their stimulation, and this response was considered the ST level. The order of delivery of the currents was randomized for channels 1 to 4. The first current selected for the participant was the same one used for pre-test familiarization and ST-familiarization definition. The experimental protocol and the position of the electrodes can be seen in figure 1, and the configurations of the current modalities in table 1.

The protocol was identical for all current settings. At each increase in amplitude, the researcher asked the volunteer about their perception of the current and, when informed of the ST, the amplitude in milliamps (mA) was recorded.

Statistical analysis

SPSS 20 software was used for statistical analysis. The significance level adopted was 5% (α=0.05). For the comparisons,

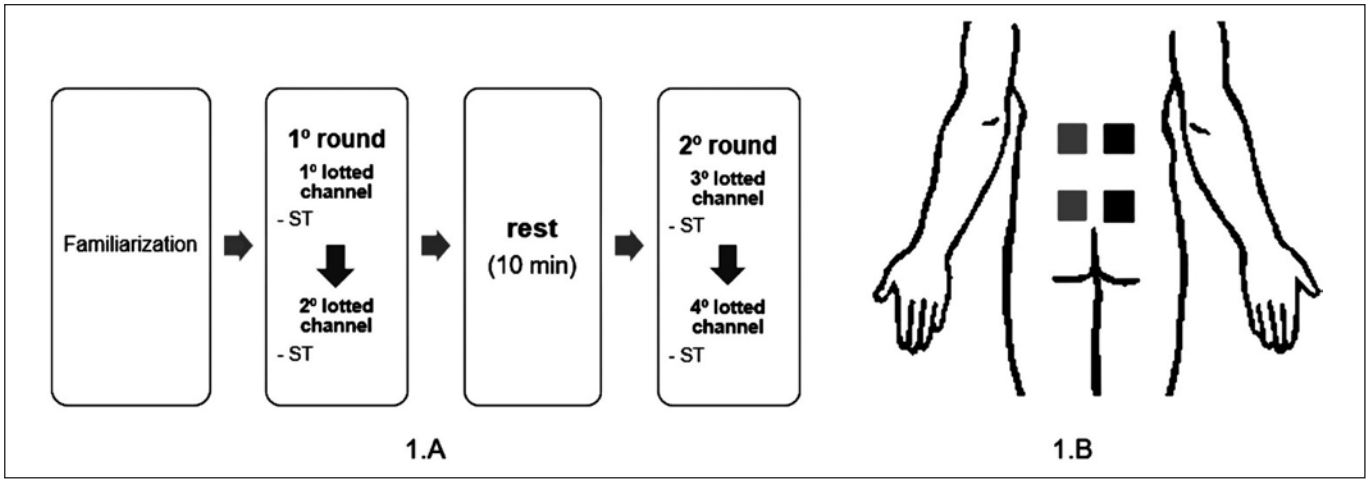


Figure 1. Schematic representation of the channel activation sequence (1.A) and the arrangement of electrode pairs (1.B) for identifying the sensory threshold

Table 1. Configuration parameters for the different current modes

Currents	Configuration
AC	Operating mode: synchronous Base frequency: 1000 Hz Burst duration: 4 ms Burst frequency (modulation): 50 Hz On time: - climb time: 1 s; - hold time: 60 s; - descent time: 1 s; Off time: 1 s
RC	Operating mode: synchronous Base frequency: 2500 Hz Duty cycle: 20% Burst frequency (modulation): 50 Hz On time: - climb time: 1 s; - hold time: 60 s; - descent time: 1 s; Off time: 1 s
FES_200	Operating mode: synchronous Frequency: 50 Hz Pulse phase duration: 200 µs On time: - rise time: 1 s; - sustain time: 60 s; - descent time: 1 s; Off time: 1 s
FES_500	Operating mode: synchronous Frequency: 50 Hz Pulse phase duration: 500 µs On time: - climb time: 1 s; - hold time: 60 s; - descent time: 1 s; Off time: 1 s

AC = Aussie current; RC = Russian current; FES = functional electrical stimulation, with phase durations of 200 µs (FES_200) and 500 µs (FES_500).

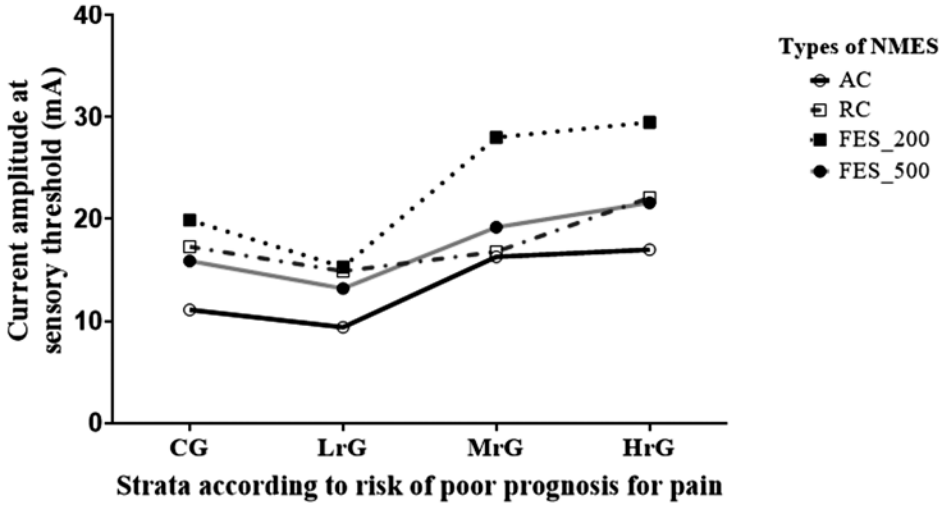
the statistical test used was the generalized estimating equations (GEE) model, which is based on maximum likelihood and uses the Wald chi-square test (Wald X^2) to identify the variable's effect over the generalized linear model. The outcome variable was the amplitude of the current in the unit of mA at which ST was reported. The factors for analysis were risk stratum (CG, LrG, MrG, HrG) and currents (AC, RC, FES_200, FES_500). Interactions between the factors (stratum*current) were also considered for the analysis. The Bonferroni test was used post-hoc. The effect size (ES) was added to the inferential analysis. The ES chosen was Hedge's g, as it is the most suitable for small samples[40]. ES was interpreted using the following criteria[40,41]: null (<0.10); very small (0.10 to 0.19); moderate (0.20 to 0.79); large (0.80 to 1.19); very large (1.20 to 1.99); immense (>2.0).

RESULTS

The sample was made up of 40 volunteers with an average age of 38.8±13.4 years, BMI of 77.1±19.9 kg and height of 1.67±0.12m. All the participants reported that they did not systematically carry out any physical activity.

The effects of risk stratum (X^2 [3] = 22.33 and p<0.001), current (X^2 [3] = 57.59 and p<0.001) and stratum*current interaction (X2 [9] = 43.37 and p<0.001) were observed. According to the parameters estimated by the model, available in the supplementary material, with regard to the stratum effect, there was a significant difference between the means only between CG and HrG, and in HrG the current amplitude in ST was 5.90 mA higher than in CG. As for the currents effects, there was a significant difference between the mean amplitudes in ST for RC, FES_200 and FES_500 compared to AC, with the amplitudes of RC, FES_200 and FES_500 being higher, 6.20 mA, 8.80 mA and 4.80 mA respectively.

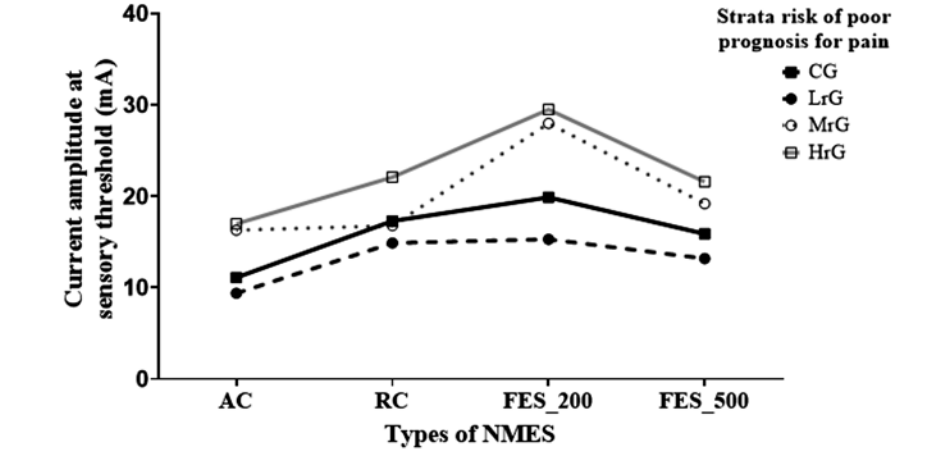
Pairwise comparisons were made looking at the effect of the stratum*current interaction. FES_200 was the current modality that induced the highest amplitudes in ST, and AC was the one that induced the lowest amplitudes. LrG had the lowest ST amplitude values in all currents, while HrG had the highest values. For most of the comparisons, ES ranged from large to immense. The inferential and descriptive statistics, as well as the ES values for the pairwise comparisons can be seen in figures 2 and 3.



Comparison pairs	CG			LrG			MrG			HrG		
	≠ mean	p-value	ES (strength)	≠ mean	p-value	ES (strength)	≠ mean	p-value	ES (strength)	≠ mean	p-value	ES (strength)
SAC – RC	-6.2	*	4.1 (huge)	-5.5	*	4.7 (huge)	-0.5	ns	0.1 (small)	-5.1	*	2.7 (huge)
AC – FES_200	-8.8	*	3.9 (huge)	-5.9	*	7.7 (huge)	-11.7	*	3.1 (huge)	-12.5	*	5.3 (huge)
AC – FES_500	-4.8	*	2.9 (huge)	-3.8	*	4.5 (huge)	-2.9	ns	0.8 (large)	-4.6	ns	2.1 (huge)
RC – FES_200	-2.6	ns	1.1 (large)	-0.4	ns	0.2 (moderate)	-11.2	*	3.2 (huge)	-7.4	*	3.0 (huge)
RC – FES_500	1.4	ns	0.8 (large)	1.7	ns	1.2 (very large)	-2.4	ns	0.7 (moderate)	0.5	ns	0.1 (small)
FES_200 – FES_500	4.0	*	1.6 (very large)	2.1	ns	1.9 (very large)	8.8	ns	3.4 (huge)	7.9	*	2.9 (huge)

Figure 2. Presentation of the mean values of current amplitude at the sensory threshold for each current modality in each stratum of risk of poor prognosis, as well as pairwise comparisons, their respective effect sizes and their strength.

CG = control group; LrG = low risk group; MrG = medium risk group; HrG = high risk group; AC = Aussie current; RC = Russian current; FES = functional electrical stimulation with two phase durations 200 μs (FES_200) and 500 μs (FES_500); ES = effect size; mean difference between means (≠ mean).
Asterisks indicate statistically significant differences (p<0.05).



Comparison pairs	AC			RC			FES_200			FES_500		
	≠ mean	p-value	ES (strength)	≠ mean	p-value	ES (strength)	≠ mean	p-value	ES (strength)	≠ mean	p-value	ES (strength)
CG – LrG	1.7	ns	0.5 (moderate)	2.4	ns	1.5 (very large)	4.6	ns	2.1 (huge)	2.7	ns	1.8 (very large)
CG – MrG	-5.2	ns	2.4 (huge)	0.5	ns	0.2 (moderate)	-8.1	ns	3.9 (huge)	-3.3	ns	1.1 (large)
CG – HrG	-5.9	*	3.6 (huge)	-4.8	ns	2.7 (huge)	-9.6	*	3.4 (huge)	-5.7	ns	2.6 (huge)
LrG – MrG	-6.9	*	1.8 (very large)	-1.9	ns	0.8 (large)	-12.7	*	3.1 (huge)	-6.0	ns	2.1 (huge)
LrG – HrG	-7.6	*	2.2 (huge)	-7.2	*	4.0 (huge)	-14.2	*	6.7 (huge)	-8.4	*	4.4 (huge)
MrG - HrG	-0.7	ns	0.3 (moderate)	-5.3	ns	2.2 (huge)	6.2	ns	6.7 (huge)	-2.4	ns	0.7 (moderate)

Figure 3. Presentation of the mean values of the current amplitude at the sensory threshold for each risk stratum of poor prognosis in the different current modalities, as well as pairwise comparisons, their respective effect sizes and their strength.

CG = control group; LrG = low risk group; MrG = medium risk group; HrG = high risk group; AC = Aussie current; RC = Russian current; FES = functional electrical stimulation with two phase durations 200 μs (FES_200) and 500 μs (FES_500); ES = effect size; mean difference between means (≠ mean).
Asterisks indicate statistically significant differences (p<0.05).

DISCUSSION

The hypotheses of this study were that: (1) the amplitude of the current in ST, regardless of NMES modality, would decrease inversely with the risk of poor prognosis for pain and that (2) medium-frequency currents would elicit the lowest amplitudes. The hypotheses of this study were partially met, as medium-frequency currents tended to elicit lower current amplitudes in ST; however, volunteers in medium and high risk groups presented higher amplitudes than those in the control and, especially, the low risk groups. The high effect sizes corroborate the clinical relevance of the findings.

When it comes to individuals with pain dysfunction, the reduction in the nociceptive threshold must be taken into account in both acute and chronic cases[42,43]. This can influence the perception of a current aimed at stimulating muscle contraction[44].

Although the greater the contribution of psychosocial factors, the greater the risk of poor prognosis for pain[4], not everyone who experiences chronic pain necessarily develops alterations in central pain processing, although the relationship between central sensitization and psychosocial aspects can be predicted by traits of anxiety and sensory hypersensitivity[32,45]. In this sense, one study observed that, in the presence of central sensitization, various dysfunctional beliefs were present[46].

These reflections may help to understand the response of the sample in this study to the perception of the current. Since the volunteers in low risk group suffered a lower impact from psychosocial factors compared to the medium and high risk groups, it is speculated that the pain phenotype in LrG preserved characteristics of nociceptive pain (pain resulting from the actual occurrence or threat of damage to non-neural tissue[32]), while in the MrG and HrG the characteristics of nociplastic pain (pain resulting from altered nociception)[32] prevailed.

The nociplastic pain phenotype is recent, and its concept was introduced in 2016. Therefore, even with the advances in research on the subject, the pathophysiology of this condition still has many gaps to be explored. There are three pathophysiological mechanisms of nonspastic pain currently proposed[36]: i) supraspinal mechanisms with the presence of hyperresponsiveness to painful stimuli, hyperactivity and connectivity between brain regions responsible for pain perception, reduced activity and connectivity of brain areas involved in pain inhibition, concentrations of substance P and glutamine in the cerebrospinal fluid with inhibition of GABA neurotransmitters; ii) spinal mechanisms encompassing the regionalization of clusters and convergence of signals from various areas of discomfort, reorganization of the spinal cord, amplification of spinal reflex transmission, reduction of spinal inhibition, temporal integration and accumulation, as well as activation of the immune system, including various glial cells; iii) peripheral mechanisms encompassing the proliferation of sodium channels and sympathetic-efferent coupling. The current lack of tools to quantify and qualify all the morphofunctional adaptations resulting from the painful experience suggests that the response to pain is something very unique, and this may have influenced the interpretation of the present study's findings. A previous study[47] observed that the amplitude of NMES is significantly dependent on the modulation performed by brain activity. It is therefore speculated that a higher risk of poor prognosis may induce changes in the circuitry of the central nervous system, such as central sensitization, which in turn affect the recruitment of sensory pathways elicited by NMES.

AC has been described as a comfortable current and capable of producing positive adaptations in the muscular function of patients with CLBP[25]. Therefore, the fact that AC was the current with the lowest current amplitude in ST seems to be in line with the literature.

A limitation of this study is the absence of more specific muscle function analyses, such as electroneuromyography, which could contribute to understanding muscle activation in the responses elicited by NMES. The main clinical message of this study is that the risk of poor prognosis for chronic low back pain may affect the way patients respond to NMES.

CONCLUSION

The amplitude of the current elicited in the ST seems to be higher among those with a higher risk of poor prognosis for chronic low back pain and, among the currents, those of medium frequency elicited lower amplitudes.

AUTHORS' CONTRIBUTIONS

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Data Collection, Research, Writing - Preparation of the Original
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Gladson Ricardo Flor Bertolini
Conceptualization, Methodology, Writing - Review and Editing, Supervision
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Statistical Analysis, Funding Acquisition, Conceptualization, Project Management, Methodology, Writing - Review and Editing, Supervision

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