ORIGINAL ARTICLE

Nr 2019;9 (3):446-456

Neuromuscular electrical stimulation associated with core stability exercises in nonspecific postural low back pain: a randomized clinical trial

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DOI:
10.32098/mltj.03.2019.20

LEVEL OF EVIDENCE: 1B

SUMMARY

Background. Low back pain is one of the most frequent causes of disability. Therapeutics programs have been used to promote muscle strengthening and lumbar stability.
Methods. Randomized clinical trial with 30 female participants with chronic low back pain, divided into CORE Group (CG), NMES Group (NG), and CORE + NMES group (CNG). At the end of the intervention and six months later, the following were evaluated: pain level, functional status and disability, hamstring flexibility and evaluation of core stabilizing muscles. All groups received three weekly interventions for four weeks.
Results. Pain level was significantly reduced in all study groups ($p<0.05$). The CNG Group significantly reduced pain at the end of the intervention compared to the NG Group ($p<0.05$). The Oswestry Disability Index decreased in all intervention groups; however, the CNG Group more significantly reduced the score compared to the other groups ($p<0.05$). Lumbopelvic stability tests showed that the CNG Group had a significantly higher stability than the CG Group and NG Group ($p<0.05$).
Conclusion. Compared to the single use of CORE exercises or passive NMES, the association between NMES and CORE exercises resulted in greater analgesia, improved function, and greater lumbopelvic stability in patients with nonspecific low back pain.

KEY WORDS
Low back pain; problems and exercises; electrical stimulation therapy.

BACKGROUND

Lumbar pain, also called low back pain (LBP), is the most common musculoskeletal disorder affecting the adult population.1 It has been recognized as one of the most debilitating conditions worldwide.1 It can also lead to high economic costs to society due to productivity losses caused by early retirement or low-quality work (1)

Chronic low back pain has a high prevalence (reaching 84%), being characterized as lasting longer than 12 weeks.2 Despite its high prevalence, there are no specific causes for almost 85% of the cases, being denominated in these cases as nonspecific low back pain (2). In approximately half of them, pain is self-limited (1).

Regarding the therapeutic approach to LBP, exercises have evolved over time, with specific emphasis on maintaining spine stability (3). CORE muscle exercises improve lumbopelvic stability and can be included as part of prevention and clinical rehabilitation for patients with low back pain (1). CORE is a concept that describes the central part of the body, especially the thoracolumbar spine, pelvis, and hips (4). It is composed of a group of muscles formed anteriorly and laterally by the abdominal muscles, posteriorly by the paraspinal and gluteal muscles, having the diaphragm at the top and the pelvic floor and hip musculature at the bottom (5). The CORE strengthening program consists of lumbopelvic stability exercises that control tension in the lumbar-pelvic-hip complex to strengthen muscles, increase endurance, and improve posture (3). This exercise program has several advantages such as being easy to perform, with low direct costs and low risk of injury (3).

Another form of treatment used in musculoskeletal disorders in general is Neuromuscular Electrical Stimulation (NMES) (6). This technique involves the application of preprogrammed stimuli (pulse trains) in the superficial skeletal muscles by means of surface electrodes placed on the muscle belly with the ultimate goal of inducing visible tetanic contractions (7). Among the types of NMES, the Russian current is widely used in rehabilitation to aid in strength recovery, muscle re-education, hypotrophy prevention, and reduction of functional limitation (6). When associated with kinesiotherapy this treatment stimulates motor nerves by depolarizing the membranes, inducing maximal and synchronized voluntary muscle contraction and thus resulting in muscle strengthening (8)

The present study compared the effectiveness of the association between NMES and CORE exercises in patients with chronic nonspecific low back pain.

MATERIALS AND METHODS

Study Design

Randomized clinical trial (Registry: RBR-7ZT98F) with a sample of 30 female participants with chronic nonspecific postural low back pain, referred by the orthopedist in charge of physical therapy at the Clinical School of the University. The study was conducted at the Clinical School of Physiotherapy of the Lutheran University of Brazil, Torres/RS Campus, from October 2015 to October 2018. The study was approved by the Ethics and Research Committee of the Lutheran University of Brazil under number 1.244.273. The study meets the ethical standards of the journal.[9]

Sampling and Randomization

Thirty-two women were initially selected and included in the study. Of these, two were excluded due to three alternating absences in the interventions. Therefore, 30 participants concluded the study.

The 30 participants of the study were randomly allocated by an independent researcher by means of sealed envelopes containing the group name CORE (CG) (n=10), NMES (NG) (n=10), or CORE + NMES (CNG) (**Figure 1**).

Eligibility Criteria

The study included young adult women, aged between 18 and 35 years, presenting chronic nonspecific low back pain,

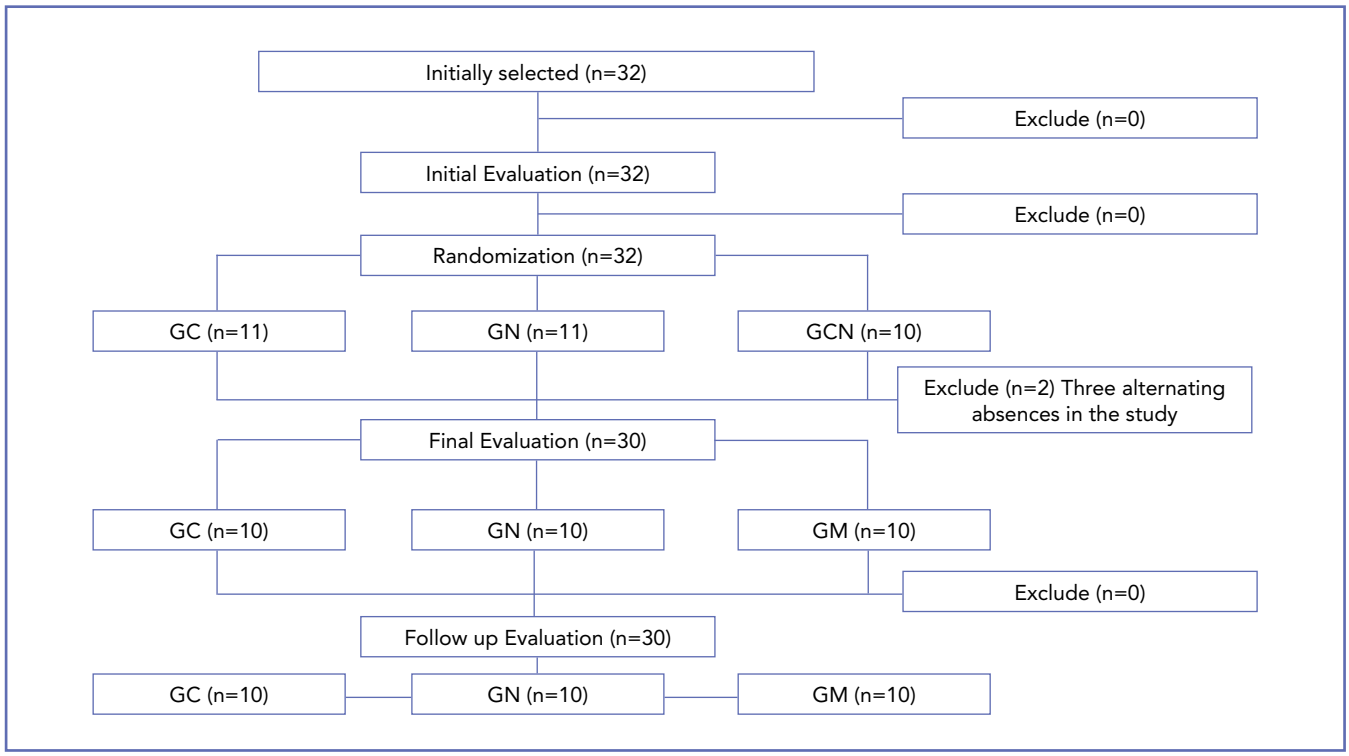

Figure I. Study flowchart

who did not practice regular physical activity, and with pain scores greater than four in the VAS.
The following subjects were excluded: young women with diabetes, with systemic arterial hypertension, with labyrinthitis, with cardiovascular disease, presenting acute inflammatory conditions of the lumbar spine, fracture or previous spinal surgery, neurological disorders, systemic pathology, cancer-carrying subjects, pregnant subjects, subjects with loss of skin integrity at the site of application of the Russian current, who underwent a rehabilitation program in the last three months, who presented hypersensitivity to the electrical stimulus, and who had two consecutive or three alternating absences during treatment.

Evaluation Protocol

The evaluation protocol was performed prior to randomization, at the end of the intervention protocol and six months after the intervention. Evaluations were performed by a previously trained examiner who did not know the group to which the participant belonged. The evaluator had extensive experience with the evaluation tools used. Initially, participants of both groups were evaluated for their anthropometric aspects. They were weighed wearing light clothing, without footwear, using a previously calibrated digital scale (Mallory®). Three measurements were performed, and their median was recorded. Subsequently, height was measured using a Megaforth® self-locking 8-meter measuring tape. Three measures were taken, and their median was recorded. Finally, the Body Mass Index (BMI) of all study subjects was calculated.
Pain level was measured using the visual analogue scale (VAS). Moreover, the Wells' bench was used to perform the hamstring flexibility test, where the subject seated with her feet resting on the device, and with her legs extended. She was then instructed to perform trunk and hip flexion with her hands overlapped and supported on the tape measure installed in the upper part of the Wells' bench. The maximum range of hip and trunk flexion was measured.
Data regarding functional status and disability were collected through the disability indexes Oswestry Disability Index (ODI) and Roland Morris Disability Questionnaire (RMDQ).
For the evaluation of core stabilizing muscles, the following tests were used: static trunk endurance, Sorenson Endurance, Side Bridge, and Prone Instability.

Intervention Protocol

The study participants were submitted to three weekly sessions for four weeks, totaling 12 intervention sessions. The intervention protocol was applied by three researchers previously trained and experienced with both the exercise protocol and the parameters and applicability of NMES. The same examiner followed the participant throughout the training program. The CORE program was based on core stability exercises using static postures. In each of the four weeks, CG participants performed four exercises per session, and in each exercise the posture was maintained for 10 seconds. Ten repetitions were performed with 20-second intervals between each series and one-minute intervals between each exercise. As the participants progressed throughout the program, the degree of difficulty of the exercises increased (**Table I**).
CNG participants performed the same exercise protocol of the CG group, but associated with a NMES program addressing gluteus maximus, gluteus medius, rectus abdominis, and bilateral transverse abdominis. A precalibrated 10-channel mid-frequency current generator (Neurodyn, Ibramed®) was used. The carrier frequency was 2500 Hz, turned on for 10 seconds and off for 20 seconds, with one second ramp-up and down intervals. Before the application, the skin was cleaned with 70% alcohol at the electrode site. Negative electrodes were positioned on the motor points, and positive electrodes proximal or distal to the muscle belly. The stimulus frequency started at 5 Hz for five minutes as a form of warming up. After that, we used a stimulus frequency of 35 Hz for 10 minutes and, finally, a frequency of 80 Hz for another 10 minutes. The stimulus intensity was the maximum needed to produce a strong, visible muscular contraction without causing discomfort to the patient. Electrostimulation was synchronized to CORE exercises, that is, static maintenance posture was performed during the stimulus time, and the participant rested during the off-time.
Finally, NG participants received only passive NMES, that is, without voluntary muscle action, with the same parameters used in the CNG.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 17.0 was used for data analysis. Initially, a descriptive analysis of the study variables was performed using absolute number, frequency, mean and standard deviation. Afterwards, data distribution normality was analyzed using the Shapiro-Wilk test. Finally, parametric data were statistically analyzed by paired Student's t-test for intragroup comparisons and by unpaired Student's t-test for intergroup comparisons, at both pre-intervention and post-intervention. For nonparametric variables, we used the Wilcoxon tests within each group and the Mann-Whitney tests for intergroup comparisons. The significance level established for the statistical test was $p<0.05$.

Table I. Intervention Protocol with CORE stability exercises

WEEK	EXERCISE	REPETITIONS / TIME
1	Prone bridge	10 x 10 sec
	Supine bridge	10 x 10 sec
	Side bridge	5 x 10 sec for each side
	Bird Dog with lower limb elevation	5 x 10 sec for each side
2	Prone bridge with elevation of one of the lower limbs	5 x 10 sec for each side
	Supine bridge with elevation of one of the lower limbs	5 x 10 sec for each side
	Side bridge with elevation of one of the lower limbs	5 x 10 sec for each side
	Bird Dog with alternating upper and lower limb elevation	5 x 10 sec for each side
3	Prone bridge with alternating elevation of one of the upper limbs and one of the lower limbs	5 x 10 sec for each side
	Supine bridge with upper limb and contralateral lower limb elevation	5 x 10 sec for each side
	Side bridge with upper and lower limb elevation	5 x 10 sec for each side
	Bird Dog with upper and lower limb elevation on the same side	5 x 10 sec for each side
4	Prone bridge with upper limbs supported on an unstable surface (Swiss ball)	10 x 10 sec
	Supine bridge on Swiss ball	10 x 10 sec
	Side bridge on Swiss ball	5 x 10 sec for each side
	Bird Dog with alternating upper and lower limb elevation on an unstable surface (two equilibrium discs)	5 x 10 sec for each side

Sec: seconds.

Sample Size and Calculation

The primary endpoint of the study was the pain variable. Therefore, based on the study by Tsauo et al. (2009) (10), we estimated the mean and standard deviation of the initial pain of the study participants (11.8 ± 3.6) and the mean and standard deviation of the final pain of the subjects (5.6 ± 3.2) after treatment in the Training group. An initial pain score of 10.5 ± 3.2 and final pain score of 9.2 ± 3.3 for the Control group Using a study power of 80%, a significance level of 95%, and a sample size ratio of 1: 1: 1 (CORE + NMES group: CORE group: NMES group), we reached the estimated number of 10 subjects for each intervention group. Considering losses and refusals to be around 30%, we reached the final number of 10 participants for each study group, totaling 39 participants.

RESULTS

The study participants were assigned to CORE (CG), CORE + NMES (CNG), and NMES (NG) groups, each group comprising 10 participants. The groups were homogeneous regarding the variables age, skin color, occupation, time of pain, and anthropometric aspects (**TableII**).

All groups significantly reduced pain after the intervention protocol and at follow-up compared to the initial evaluation. CG presented a pain level of 6.4 ± 0.84 points in the initial evaluation. After the intervention, the pain reduced to 2.10 ± 2.28 ($p<0.05$). However, in the follow-up evaluation, the pain level increased to 4.2 ± 2.15 points ($p<0.05$). CNG, in turn, presented an initial pain level of 6.6 ± 1.07 points, reducing to 0.4 ± 0.96 at post-intervention ($p<0.05$), and with 2.6 ± 2.31 points at follow-up ($p<0.05$). Finally, NG presented an initial pain level of 6.8 ± 0.42 points, reducing to 2.9 ± 1.28 after the intervention, and with 4.2 ± 1.47 points at follow-up ($p<0.05$). CNG demonstrated a significantly lower pain level than NG after the intervention ($p<0.05$) (**Figure 2**).

Only CG and CNG showed a significant increase in flexibility after the intervention ($p<0.05$). Notwithstanding, regarding the follow-up assessment, only CG maintained the level of flexibility achieved in the final evaluation. In the initial evaluation, CG showed a flexibility of 25.9 ± 5.74 cm, increasing to 31.3 ± 6.41 cm in the final evaluation ($p<0.05$), and with 29.0 ± 5.22 cm at follow-up. CNG, in turn, showed 26.5 ± 9.28 cm in the initial evaluation, increasing to 32.8 ± 6.35 cm in the final evaluation ($p<0.05$), but decreasing to 30.3 ± 6.97 cm in the follow-up assessment (**Figure 3**).

The Oswestry Disability Index decreased significantly in CNG compared to CG and NG after the intervention ($p<0.05$). However, all groups improved their scores at the

Table II. Characterization of the study sample (n=30)

	Intervention Group (mean ± SD)			
Variable	CG (n=10)	CNG (n=10)	NG (n=10)	p-value
Age, years (n ± sd)#	26.40 ± 3.41	25.50 ± 5.28	27.10 ± 4.95	0.74
Skin color, n (%)&				1.00
White	10 (100)	10 (100)	10 (100)	
Black	0 (0.0)	0 (0.0)	0 (0.0)	
Time of pain, years (n ± sd) #	3.70 ± 2.32	5.60 ± 2.72	3.60 ± 2.67	0.17
Occupation, (n ± sd) &				0.19
Administrative Assistant	0 (0.0)	0 (0.0)	2 (20.0)	
Administrative Secretary	3 (30.0)	0 (0.0)		
Householder	0 (0.0)	2 (20.0)	1 (10.0)	
Student	2 (20.0)	2 (20.0)	3 (30.0)	
Sales clerk	0 (0.0)	1 (10.0)	0 (0)	
Other	5 (50.0)	5 (50.0)	6 (40.0)	
Weight, kg (n ± sd)#	61.00 ± 11.61	69.40 ± 15.99	71.70 ± 16.33	0.25
Stature, cm (n ± sd)#	164.00 ± 8.00	163.80 ± 4.98	160.30 ± 6.96	0.40
BMI, kg/cm^2 (n ± sd)#	22.56 ± 3.35	25.79 ± 5.50	27.74 ± 5.36	0.07

One-way ANOVA. & Chi-square.

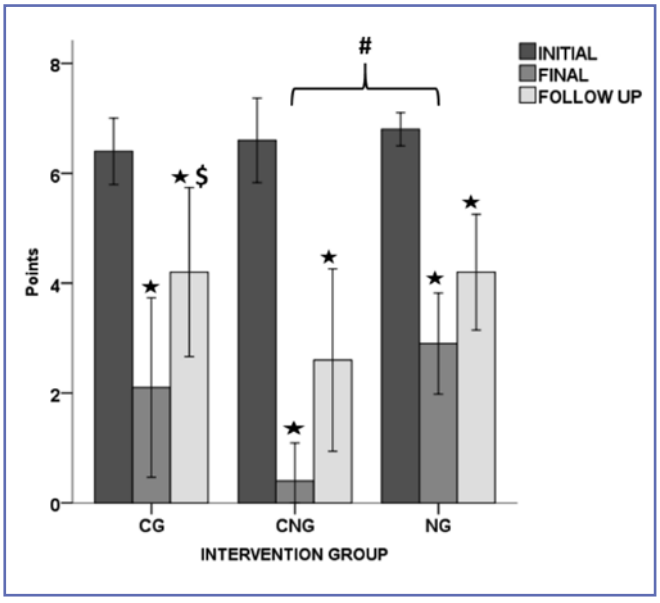

Figure 2. Analysis of lumbar pain assessed by VAS
* p<0.05 compared to the initial assessment of the same group. ANOVA for repeated measures.
$ p<0.05 compared to the final assessment of the same group. ANOVA for repeated measures.
# p<0.05 compared between the same evaluation group. One-way ANOVA.

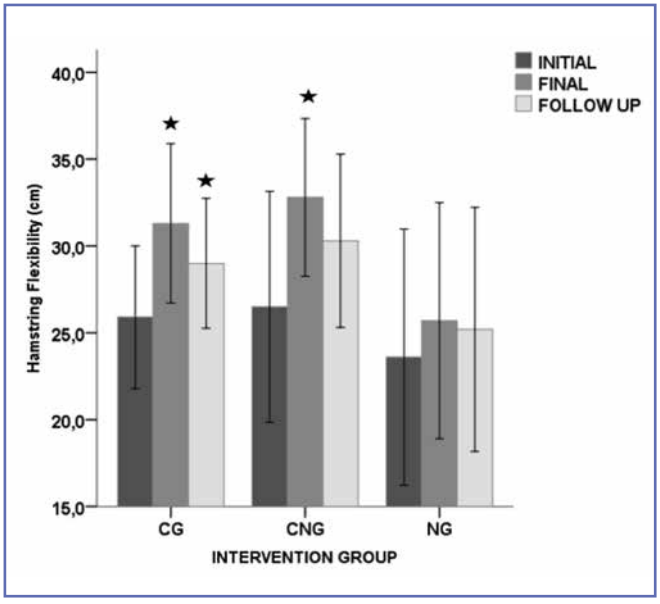

Figure 3. Analysis of hamstring flexibility assessed through the Wells' Bench.
* p<0.05 compared to the initial assessment of the same group. ANOVA for repeated measures.

end of the intervention (p<0.05). In the follow-up assessment, CG and CNG maintained significantly lower scores compared to the initial evaluation, while NG returned to the values obtained in the initial evaluation. CG showed 15.9 ± 5.06 points in the initial evaluation, decreasing to 5.7 ± 3.19 points in the final evaluation, and with 8.30 ± 5.57 points at follow-up (p<0.05). CNG reduced pain from 11.8 ± 1.93 points in the initial evaluation to 1.2 ± 0.91 points in the final evaluation, with 4.2 ± 4.05 points at follow-up (p<0.05). NG, in turn, reduced pain from 13.4 ± 4.00 in the initial evaluation to 6.1 ± 4.14 points in the final evaluation (p<0.05); at follow-up, the score increased to 8.3 ± 5.29 points (**Figure 4**).

All groups significantly reduced the Roland Morris Disability Questionnaire (RMDQ) score in both final and follow-up assessments (p<0.05). In the comparison between groups, CNG showed a significant reduction of the score in relation to NG in the final evaluation and follow-up (p<0.05). In the initial evaluation, CG presented a score of 11.5 ± 2.71 points, decreasing to 2.6 ± 3.06 points in the final evaluation (p<0.05). However, in the follow-up evaluation, the score increased to 4.5 ± 3.62 points (p<0.05). CNG reduced pain from 11.9 ± 2.33 points in the initial evaluation to 0.5 ± 0.85 points in the final evaluation, with 1.9 ± 2.37 points at follow-up (p<0.05). Finally, NG reduced pain from 10.0 ± 4.42 in the initial evaluation to 3.6 ± 3.02 points in the final evaluation, remaining with 5.9 ± 4.72 points at follow-up (**Figure 5**).

Regarding lumbopelvic stability tests, CG and CNG improved the posture maintenance time in all tests, in both final and follow-up assessments (p<0.05), except for the static trunk endurance test, in which CG did not improve results at follow-up. NG showed a significant increase in posture maintenance time only in the Sorenson test, in the final evaluation. In the comparison between groups, CNG showed significantly better results in all lumbopelvic stability tests compared to the other groups (p<0.05) (**Table III**).

DISCUSSION

Few studies in the current literature address lumbopelvic stability exercises associated with the use of NMES in core stability muscles. Six previous studies evaluated the effectiveness of NMES in the therapeutic approach of low back pain (11-17). As a conclusion of this study, the results showed significant effects for CNG compared to the

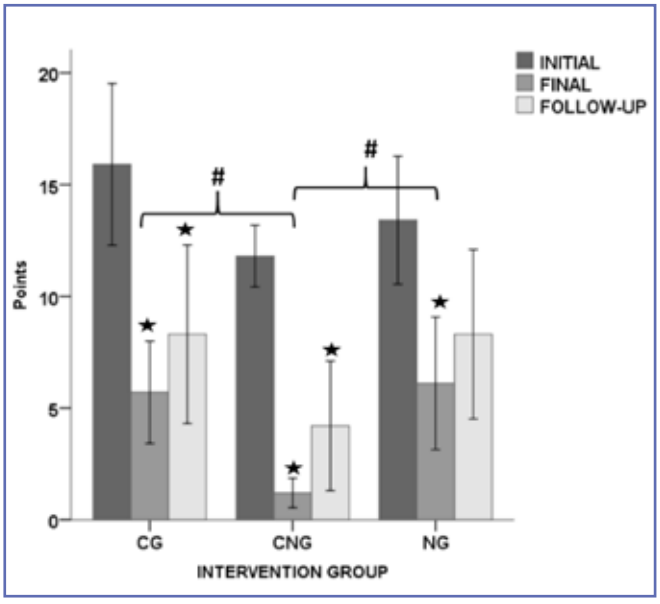

Figure 4. Oswestry Disability Index (ODI) score in study groups
* p<0.05 compared to the initial assessment of the same group. ANOVA for repeated measures.
# p<0.05 compared between the same evaluation group. One-way ANOVA.

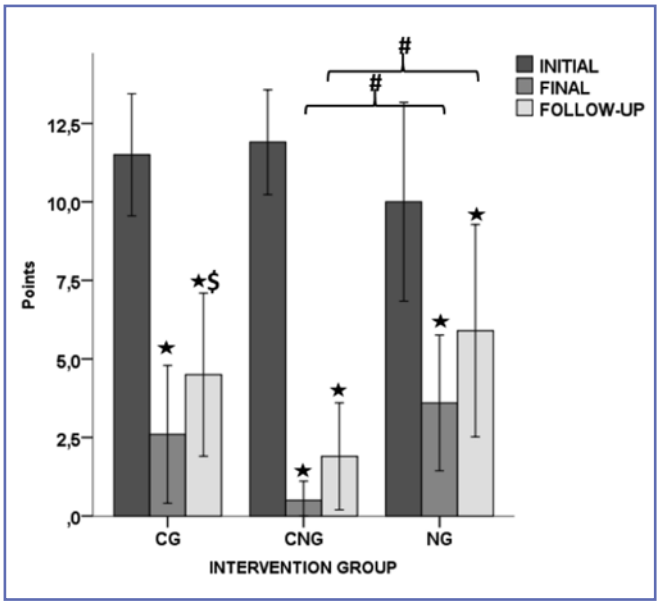

Figure 5. Roland Morris Disability Questionnaire (RMDQ) score in study groups
* p<0.05 compared to the initial assessment of the same group. ANOVA for repeated measures.
$ p< 0.05 compared to the final assessment of the same group. ANOVA for repeated measures.
# p<0.05 compared between the same evaluation group. One-way ANOVA.

Table III. Results of lumbopelvic stability tests (n=30)

	Intervention Group (mean ± SD)			
Variable	**CG (n=10)**	**CNG (n=10)**	**NG (n=10)**	**p-value**
Static Trunk Endurance Test, seconds				
Initial	30.40 ± 15.38	53.30 ± 21.91	29.90 ± 24.13	0.03[a,b]
Final	46.30 ± 19.67[#]	133.40 ± 53.02[#]	39.30 ± 25.29	0.00[a,b]
Follow-up	37.10 ± 13.70	83.60 ± 41.92[$]	40.10 ± 23.24	0.00[a,b]
Sorenson Test, seconds				
Initial	35.00 ± 16.99	46.60 ± 29.52	35.10 ± 23.90	0.48
Final	60.70 ± 15.74[#]	91.60 ± 23.77[#]	59.50 ± 28.30[#]	0.01[a,b]
Follow-up	58.10 ± 17.61[#]	67.90 ± 22.78[$]	52.10 ± 24.63	0.28
Right Side Bridge Test, seconds				
Initial	22.10 ± 10.48	23.80 ± 12.70	12.60 ± 10.92	0.06
Final	36.60 ± 11.11[#]	50.20 ± 7.61[#]	18.10 ± 9.99	0.00[a,b,c]
Follow-up	30.20 ± 11.63[$,&]	28.30 ± 10.35[$]	17.10 ± 10.82	0.03[a,c]
Left Side Bridge Test, seconds				
Initial	22.40 ± 10.36	24.40 ± 13.49	16.10 ± 8.74	0.23
Final	35.70 ± 2.72[#]	49.30 ± 2.47[#]	15.38 ± 7.78	0.00[a,b,c]
Follow-up	30.00 ± 10.22	29.20 ± 11.31[$]	18.90 ± 10.24	0.05[c]

a p<0.05 in the comparison between CNG and NG. One-way ANOVA.
b p<0.05 in the comparison between CNG and CG. One-way ANOVA.
c p<0.05 in the comparison between CG and NG. One-way ANOVA.
# p<0.05 compared to the initial evaluation. ANOVA for repeated measures.
$ p<0.05 compared to the final evaluation. ANOVA for repeated measures.
& p<0.05 compared to the final evaluation. ANOVA for repeated measures.

other intervention groups. The pain threshold decreased after intervention in all intervention groups, but with a significantly greater reduction in CNG compared to NG. Hamstring flexibility improved only in the CNG and CG groups. In the disability and functionality questionnaires, CNG was superior to the other groups, showing a possible enhancement of CORE exercises through NMES. In the lumbopelvic stability tests, GCN and CG obtained significantly better results than NG, showing that CORE exercises influenced the increase in static posture maintenance time.

According to Maffiuletti et al. (11), patients should be encouraged to use high-intensity NMES, with stimulation amplitudes set at the highest tolerable level. This is because the production of muscle strength increases linearly with the current intensity (11). Physiotherapists and patients should be aware that the current intensity needs to be increased periodically, according to tolerance, aiming to avoid accommodation (11). Risk factors such as adipose tissue or edema may result in increased impedance and the generation of a limited contractile force (11). Differences in age, sex, body composition, body impedance, and pain tolerance are factors that contribute to the need to sustain high NMES training intensities in the general population (11). It is important to note that high-intensity NMES used for muscle strengthening can be very uncomfortable for many patients (11).

Initially, it is important to analyze the NMES protocols found in the literature addressing low back pain. In this study, the NMES protocol associated with stability exercises used an electrical stimulator with electrodes placed bilaterally on the gluteal (maximal and medial) muscle belly, rectum, and transversus abdominis. A stimulation frequency ranging from 5 Hz (heating) to 80 Hz (potentiation), with stimulation time of 10 seconds and rest time of 20 seconds, was used three times a week for four weeks. The protocol was associated with active exercises for core stabilizers. Baek et al. used NMES passively on the anterolateral abdominal wall and paraspinal muscles at a frequency of 50 Hz, considering eight seconds of contraction and 10 seconds of rest, for three sessions (12). Coghlan et al. used NMES alone with an electrostimulator with a frequency between 20-30 hz, considering four seconds of activation and three seconds of rest. Stimulation took place in the paraspinal muscles and anterolateral wall, for 15 to 30

minutes (13). Guo et al. associated stability exercises with NMES in lumbar paraspinal muscles, using a frequency of 50 Hz and considering 10 seconds of stimulation and 30 seconds of rest, for 30 minutes. Sessions were held once per week for four weeks (14) Pugliesi et al., in turn, supplemented stability exercises with NMES applied to paraspinal muscles, with 50 pulses per second, considering 10 seconds of contraction and 60 seconds of rest (15). The protocol was applied twice weekly for 12 weeks (15). Alrwaily et al. performed a stabilization exercise program supplemented with NMES in paraspinal muscles at a frequency of 75 pulses per second, considering 10 seconds of contraction and 50 seconds of rest. The protocol was applied twice weekly for six weeks (16). Finally, Hicks, Sions and Velasco applied NMES to paraspinal muscles in association with stabilization exercises. The authors used a frequency of 50 pulses per second, with contraction time of 10 seconds and rest time of 60 seconds, for 15 minutes. Sessions were held twice per week for 12 weeks (17). All protocols, including that of this study, used the maximum visible and comfortable contraction to the patient as stimulation intensity.

In this study, the sample consisted of 30 young female adults. The use of an exclusively female sample is justified by the higher prevalence of LBP in this population. Graup et al. (18) pointed out the female gender as one of the factors associated with nonspecific low back pain. Silva et al. (19) reported that the high prevalence of postural low back pain in females may be related to household tasks and lumbar spine overload.

Lumbar pain decreased significantly in all intervention groups. However, analgesia was significantly higher in CNG. Coghlan et al. observed an average reduction of 2.7 ± 1.6 for this variable after two weeks of stabilization exercises + NMES (13). Pugliesi reported an improvement from 5 to 8 points during day-to-day activities (15). These findings corroborate with our study, in which this variable decreased from 6.60 ± 1.75 to 2.60 ± 2.32 points six months after intervention. A randomized controlled trial conducted by Areeudomwong et al. (20) evaluated the effect of a 10-week CORE exercise program on pain, disability, and activation of trunk muscles in individuals with clinical instability of the lumbar spine. The results of this study indicated a reduction in pain and disability in both treatment groups (20). Nonetheless, the ratio activation of transversus abdominis and internal oblique relative to rectus abdominis was improved in subjects who were treated with CORE stability exercises (20). These exercises increase the activation capacity of segmental muscles and decrease pain in individuals with chronic nonspecific low back pain (20).

Low back pain is a common disorder in the general population. Lumbopelvic muscles are responsible for providing stability to the spine (12), and loss or incoordination in their action is directly implicated in the development of LBP (12). Individuals with chronic LBP may have multifidus muscle atrophy and asymmetry, which may negatively impact spinal stability and function (15). A possible mechanism to elucidate the greater analgesia in the association of stabilization exercises to NMES is given by the fact that when applied to abdominal (especially transverse and oblique) muscles, NMES generates a greater activation of these muscles during the distribution of spinal loads (12-15).

However, some studies have not yet shown evidence of the efficacy of NMES in LBP. Alrwaily et al. did not observe clinical efficacy of NMES associated with stabilization exercises in paraspinal muscles for patients with LBP (16) Li et al. (21) investigated the effect of NMES in Chinese patients with LBP. After four weeks of treatment, there were no significant improvements in any of the measured outcomes compared to the pretreatment period (21). The negative effect may be a result of the low NMES dose associated with only one intervention per week, in addition to the short treatment period (21). Notwithstanding, it is important to highlight the topographic muscular area of application of NMES electrodes, as well as their form of action: alone or in association with an active exercise. The exercise of deep lumbar stabilizing muscles is essential for the rehabilitation of low back pain, and it has been suggested that the application of NMES in the abdominal wall activates deep lumbar stabilizers (12). Coghlan et al. (13) reported that NMES applied to the abdominal wall and lumbar paravertebral area led to an increase in the thickness of deep lumbar stabilizing abdominal muscles in patients with low back pain. In addition, these patients had a significant improvement in self-reported pain levels (13). Motor nerve stimulation is believed to induce effective maximal voluntary muscle contraction, resulting in muscle strengthening (13). Transverse and oblique abdominal muscles provide a great capacity for spinal stabilization after NMES (13). This is due to the improvement in the tonic activation of these muscles, as well as their greater coactivation in recruitment patterns under spinal loads (13). Another important factor is that the use of NMES associated with active stabilization exercises is effective compared to passive treatment techniques, which may not induce clinically important improvements in these patients (15).

Kamel et al. (22) evaluated the effect of NMES on the recovery of abdominal muscle strength in postpartum women with diastasis of the rectus abdominis muscles. The benefits of the abdominal exercise program in the group that received NMES were the same as those achieved by the group that did not receive NMES (22). Notwithstanding, there was a more significant improvement in favor of group

A, which can be attributed mainly to the application of NMES, which activates large nerve fibers (type II) at relatively low levels of stimulation and influences the excitability of the motor cortex (22). Moreover, NMES can recruit deep muscle fibers at lower training intensities because the nerves stimulated by NMES are distributed throughout the muscle (22). In addition, NMES-induced muscle contractions activate a greater proportion of type II muscle fibers in relation to voluntary exercise at a comparable intensity, since type II fibers are typically activated during high-intensity voluntary contractions (22).

Durmus et al. (23) investigated the additional benefits of NMES associated with muscle training in 41 adult women with chronic low back pain. Greater reductions in pain and improvements in LBP-related disability were found among those who received exercises associated with NMES (23). Changes at the muscle level may help to explain improvements in LBP, physical function, and reduced LBP-related disability in these patients (15). These findings corroborate those found in the present study, where the association between CORE and NMES led to more expressive results on pain and disability.

All study groups significantly reduced the RMDQ score in this study. However, CNG was significantly better than NG. Our findings corroborate those found by Koumantakis et al. (25), who found an improvement of approximately 4.65 points in RMDQ in people with recurrent low back pain who performed stability exercises for 20 weeks. Shaughnessy and Caulfield (25) applied a 10-week CORE stability exercise program to 41 volunteers with LBP. In the intervention group, the RMDQ score decreased five points, which was significant (26). Furthermore, Bayraktar et al. (27) revealed that LBP patients who participated in land and water CORE stability exercises reported an improvement of 5 and 4.5 points in the RMDQ scores, respectively.

Regarding the functional level assessed through ODI, the present study demonstrated a significant reduction of scores in all intervention groups. CNG showed significantly lower rates of disability than CG and NG. Ahmed et al. (28) corroborate our findings. In their study, 30 subjects with LBP were randomized into two groups, where the intervention (experimental) group performed lumbar stabilization exercises using Swiss ball, and the control (conventional) group received orientation and postural care for six weeks (28). The following were analyzed at preintervention and during the second, fourth, and sixth weeks: abdominal muscle endurance (pressure biofeedback), pain intensity (VAS), and functionality (ODI) (28). Both groups had significant results for all variables analyzed (28). However, the group that performed core stability exercises obtained better results when compared to the control group, demonstrating that core stability exercises with Swiss ball are effective in the functionality of patients with chronic LBP (28). The possible explanations for these findings are the improvement of trunk muscle activity and an increase in the lumbar range of motion, which leads to decreased disability and functional recovery.

Regarding lumbopelvic stability tests, CNG and CG obtained significantly better results than NG. Sung (29) assessed back muscle endurance after performing CORE exercises and spine flexibility exercises in patients with chronic nonspecific LBP subjected to four weeks of intervention (29). Back muscle endurance was evaluated by the Sorensen test (29). The author concluded that muscle fatigue decreased significantly after CORE exercises and, consequently, muscle endurance increased (29). However, there was no significant difference between the groups (29). Subjects who performed CORE stability exercises demonstrated greater endurance after the intervention (29).

In the study by Paungmali et al. (30) lumbopelvic stability was analyzed through a pressure biofeedback device. Participants were 25 subjects with chronic nonspecific LBP, randomly assigned to three types of intervention, including lumbopelvic stability training, placebo treatment, and controlled intervention with 48-h interval sessions (30). The results demonstrated a significant increase in lumbopelvic stability after CORE exercise training compared to the placebo and control interventions (30). These findings corroborate those found in the present study, where the groups that used CORE exercises obtained better results.

Another important factor to be analyzed is a possible adverse effect to be observed in patients subjected to NMES. Corroborating with other studies (11-17), in the present study, NMES was well tolerated by participants. In addition, there were no adverse events associated with the use of NMES.

STUDY LIMITATIONS

This study has some limitations. Initially, despite satisfying the sample calculation, the sample size used is small, with a view to allow a greater capacity to extrapolate the results. Aiming at treatment standardization and unbiased results, only female participants were analyzed. Thus, further studies are needed to determine whether the same results can be obtained in males.

Second, the study included only a four-week treatment period, which is considered a short-term intervention to conclusively validate the present results. This study did not consist of a control group. Therefore, future studies should include a control group to better investigate this therapy for LBP. Moreover, ODI and RMDQ may not be the best instrument for quantifying disability in an active population experienc-

ing LBP. Three previously trained researchers conducted the exercise sessions. Although previously trained and conducting the entire intervention program in the same participant, this can lead to inconsistencies in the instructions, verbal suggestions, and a biased intervention. Another limiting factor of the study is the fact that the participants' intake of analgesic drugs was not evaluated or controlled, which may interfere with the results.

CONCLUSION

This study showed promising results regarding the effects of NMES associated with core stability exercises in patients with nonspecific LBP. In particular, exercise enhancement through NMES was shown to reduce pain and improve the function and stability of the lumbopelvic complex.

Conflict of interest

The authors declare no conflict of interest.

List of abbreviations

NMES: neuromuscular electric stimulation
CORE: core stability exercises
CG: *CORE* group
NG: *NMES* group
CNG: *CORE* + *NMES* group
VAS: visual analogue scale
ODI: Oswestry Disability Index
RMDQ: Roland-Morris Disability Questionnaire
LBP: low back pain
BMI: Body Mass Index

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