Comparison Between Transcutaneous Electrical Nerve Stimulation and Stabilization Exercises in Fatigue and Transversus Abdominis Activation in Patients With Lumbar Disk Herniation: A Randomized Study

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Abstract

Objective: The purpose of this study was to compare transcutaneous electrical nerve stimulation (TENS) and stabilization exercises in an attempt to prevent fatigue and improve muscle activation in patients with lumbar disk herniation associated with low back pain.
Methods: This study involved 29 patients (age range 25-58 years) randomized into 2 groups: the segmental stabilization group (n = 15), who received stabilization exercises on the transversus abdominis (TrA) and lumbar multifidus muscles; and the TENS group (n = 14), who received electrotherapy. Groups underwent 16 sessions, for 60 minutes, twice per week, and they were evaluated before and after intervention. Pain was measured using a visual analog scale, functional disability using the Oswestry Disability Index, muscle activation and fatigue with electromyography, and patients' ability to contract the TrA with a pressure biofeedback unit. Analyses within and between groups were performed.
Results: The stabilization group improved lumbar multifidus fatigue (median frequency [MF] initial [P = .002], MF final [P < .001], MF slope [P = .001], and resistance time [P < .001]), ability to contract the TrA (P < .001), pain (P < .001), and functional disability (P < .001). TENS only was effective for pain (P = .012).
Conclusion: Although it relieved pain, TENS was not effective as a single treatment to prevent fatigue, increase TrA contraction, and reduce functional disability in herniated disk patients. Stabilization exercises alone improved all measured outcomes. (J Manipulative Physiol Ther 2018;41:323-331)
Key Indexing Terms: *Muscle Fatigue; Abdominal Muscles; Transcutaneous Electrical Nerve Stimulation; Intervertebral Disk Displacement*

Introduction

Disk herniation can be defined as displacement of disk material beyond the margins of the intervertebral disk space.[1] It is considered the most frequent cause of lumbosacral radiculopathy.[2] Lumbar disk herniation (LDH) affects about 39% of chronic low back pain (cLBP) patients.[3] Lumbar stabilization treatment has recently been shown to be effective in treating cLBP.[4-6] This method focuses on retraining the deep muscles of the trunk and abdomen, lumbar multifidus (LM), and transversus abdominis (TrA), responsible for the stability and control of the spinal segment.[4,7] Studies show that these muscles are preferentially affected in cLBP, in the form of atrophy or decrease in activation speed.[8,9] Surface electromyography (sEMG) has been used to study fatigued LM muscles during sustained activities of the spine in

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participants with LDH, because they present less resistance in muscles to perform isometric contractions.[10,11]

Studies about the activity of the deep trunk muscles, particularly the TrA, have used needle electromyography (EMG).[12,13] This kind of analysis is invasive, painful, and carries risk of infection. Therefore, an alternative was developed to analyze the TrA muscle through a pressure biofeedback unit (PBU).[14] Some studies report that patients with cLBP have difficulty depressing the abdominal wall, which is associated with a weakening TrA muscle.[14,15]

In recent clinical trials on patients with lumbar disk degeneration, a reduction in pain intensity and improvement in functional disability was observed after 10 sessions of transcutaneous electrical nerve stimulation (TENS) alone in 1 trial and a combination of TENS with interferential current in another.[16,17] However, the benefit of TENS in reducing muscular fatigue is conflicting in literature, because there is evidence that this type of therapy stimulates a change in the biochemical and physiological muscular conditions, which leads to muscle relaxation.[18] No study was found to determine conclusively the effect TENS has on muscles with cumulative fatigue LDH patients.

The aim of the present study was to compare TENS and stabilization exercises for preventing fatigue and improving muscle activation capacity in patients with LDH associated with cLBP. It was hypothesized that due to its electrical and chemical effects on tissue, TENS may assist the healing process by returning damaged muscle tissues to a normal state, which would result in pain reduction and, consequently, prevention of muscle fatigue and improvement in other outcomes. It was further hypothesized that these beneficial effects may also be demonstrated in patients that underwent stabilization exercises.

Methods

Trial Design

The study was a randomized, controlled, assessment-blind study comparing 2 parallel groups. This study was approved by the Ethics Committee of the University Hospital (Protocol 1014-10) and the School of Medicine (Protocol 081-10), University of São Paulo, Brazil. All participants gave their informed consent before participation, and the trial was prospectively registered through Clinical Trial Registry (ID: NCT01640431).

Participants

Assessments were performed by a researcher who was not involved in the recruitment of the participants, using balanced randomization (1:1) with Microsoft Excel for Windows 10 edition (Windows, Redmond, Washington). Participants were allocated in 1 of the 2 groups secretly by a random number sequence, using sealed, opaque envelopes, containing a letter stating to which group the patient belonged. The sample was selected from a list of patients of the Department of Orthopedics of University Hospital at University of São Paulo. Patients with LDH associated with low back pain and diagnosed by magnetic resonance imaging or computed tomography were included. Participants diagnosed only radiologically or with myelography were not eligible to participate in the study because these techniques do not directly visualize disk herniation.[1] We included patients with disk herniation associated with cLBP (pain for more than 3 months) and disk protrusion or herniation diagnosed by magnetic resonance imaging or computed tomography. The exclusion criteria included previous lumbar surgery; carcinoma; rheumatologic diseases; patients involved in sports or load training for the spine over the 3 months prior to beginning treatment; or other causes of back pain, spinal stenosis, or lumbar spondylolisthesis. In addition, to avoid bias and interference in the present results, patients who received prior treatment (ie, manual therapy, traction, therapeutic exercise, biofeedback, cognitive behavioral therapy, etc) were excluded from the study.

Twenty-nine participants were randomized into 1 of 2 groups: the segmental stabilization (SS) group performed exercises for TrA and LM muscles (n = 15), and the TENS group received electrotherapy (n = 14).

Interventions

Interventions were conducted over 8 weeks, twice per week, with each session lasting 60 minutes. The sessions were supervised by the investigator, and the participants were instructed to report any adverse event, whether or not it was related to exercises or electrotherapy. Participants were instructed not to participate in any other physical training program during the study. In the SS group, exercises focused on the TrA and LM muscles. Transcutaneous electrical nerve stimulation current was used in the TENS group for 60 minutes, with a frequency of 20 Hz[17] (Fig 1).

Outcomes Measurements

Participants were assessed for fatigue of LM, TrA activation capacity, severity of pain, and functional disability at baseline and at the end of treatment by an investigator (physical therapist) blinded to the randomization.

LM Muscular Fatigue. Electromyography of the LM was conducted using equipment (EMG System of Brazil, São José dos Campos, Brazil), which consists of an 8-channel analogic-digital converter with 16-bit resolution and an input ranging from -12 to +12 volts. Each channel is coupled to 2 active bipolar circular electrodes (Medi-Trace Ag/AgCl) with a 10-mm diameter. They were placed in pairs, separated by 2 cm. The reference electrode was positioned on the spinous process of C7, according to the recommendations of Surface EMG for Non-Invasive Assessment of Muscles.[19]

Stabilization Exercises of the transversus abdominis and multifidus lumbar[7]

- Four-point kneeling exercises for the TrA
- Dorsal decubitus with flexed knees exercises for the TrA
- Ventral decubitus exercises for the LM
- Co-contraction of the TrA and LM in the upright position

Three series of 15 repetitions of each exercise were performed

TENS application [17]

- Frequency of 20 Hz and pulse width of 100 μs, continuous mode and two channels
- Electrodes: lumbar paraspinal points bilaterally
- Four adhesive 5 x 5 cm electrodes on the lines of the T12 and S1 vertebrae
- Intensity slowly increased to tolerable painful limit

Fig 1. *Treatment protocol in the stabilization and TENS groups.* LM, *lumbar multifidus;* TENS, *transcutaneous electrical nerve stimulation;* TrA, *transversus abdominis.*

A computer was connected to the sEMG equipment (high-impedance preamplifying system) with a 20-fold gain for the median frequency (Hz). The fast Fourier transform was used, and the signs adjusted for 2000 samples per second. The sEMG data were analyzed using a prespecified routine described in MATLAB (MATLAB R2008a, MathWorks, Inc., Natick, Massachusetts), and the following variables were compared: median frequency (MF) during the first 5 seconds (MF initial), MF during the final 5 seconds (MF final), change in MF (MF initial – MF final), and MF slope displaced in a linear regression over time adjusted for the MF initial (MF slope / MF initial × 100).[4,20] Adjustment used the Fourier transformation with the Hann window for periods of 1 second to displace frequencies. Using this procedure, the slope of the line was calculated; sEMG of the LM was measured bilaterally. Electrodes were placed at the level of L2-L3, lateralized by 3 cm, and aligned with the caudal portion of the posterosuperior iliac spine, per Surface EMG for Non-Invasive Assessment of Muscles recommendations.[19] Before positioning the electrodes, trichotomy and 70% alcohol antisepsis were applied.

Fatigue Test. Lumbar multifidus fatigue was measured using EMG and the Sørensen test of efforts. This test was primarily developed to study mechanical variables of muscles, such as duration of isometric resistance. Both the EMG tool and the Sørensen test are reliable and useful in rehabilitation programs.[4,20-22] Individuals were placed in ventral decubitus, with legs fixed by belts placed around the hip, knee, and ankle, thereby minimizing activation of the hip extensors.[20,21] The test requested participants to extend their trunks by isometric contraction at an angle of 25° for 4 minutes or until exhaustion.[20,21] Exhaustion was defined as a decrease of 5° to 10° on the pre-established angle or dropping efforts altogether.[21,22] A universal goniometer was placed on the hip joint to monitor the amplitude of extension of the lumbar spine and to ensure that the individuals were holding the position through isometric contraction. The goniometer was placed with its fixed arm adjusted toward the lateral femoral condyle, and the mobile arm aligned to the medial axillary line, with axis on the anterosuperior iliac spine.[23] The universal goniometer is a reliable tool often used in rehabilitation.[24]

TrA Activation Capacity. Transversus abdominis activation capacity was assessed using a PBU (Chattanooga Group, Chattanooga, Australia), a reliable tool for analysis of this muscle contraction.[15] The PBU consists of a combined gauge/inflation bulb connected to a pressure cell. It is a simple device that registers changing pressure in an air-filled cell allowing body movement, especially spinal movement, to be detected during exercise. The gauge contains 16.7 × 24 cm of inelastic material. The pressure unit measures 0 to 200 mmHg, with a precision of 2 mmHg. Changes in body position modify air pressure, registered by a sphygmomanometer. The device was placed on the TrA (above the anterior superior iliac spine) while the participant was in ventral decubitus on a rigid surface. The depression of the abdominal muscles over the spinal cord typically decreases pressure by 4 to 10 mmHg in participants without cLBP. Before patients contracted the muscle, the device was inflated to a pressure of 70 mmHg. Then patients were instructed to draw the lower stomach gently off the pressure sensor without moving the back or the hip and to sustain it for 10 seconds, measured by a stop watch.

Pain. Pain was assessed using a visual analog scale. The visual analog scale consists of a 10-cm line, with the left extreme indicating "no pain" and the right extreme indicating "unbearable pain." Participants were asked to use the scale to indicate their current level of pain, with higher values suggesting more intense pain. This instrument showed good reproducibility in the assessment of pain.[10]

Functional Disability. Functional disability was estimated according to the Oswestry Disability Index, a functional scale that assesses the impact of cLBP on daily activities. This instrument was validated for the Portuguese language, with excellent psychometric properties and high reliability for the Brazilian population.[25] The score is calculated by adding the values assigned to each of the 10 individual questions to categorize an individual's disability as mild or no disability (0%-20%), moderate disability (21%-40%), severe disability (41%-60%), incapacity (61%-80%), and restriction to bed (81%-100%).

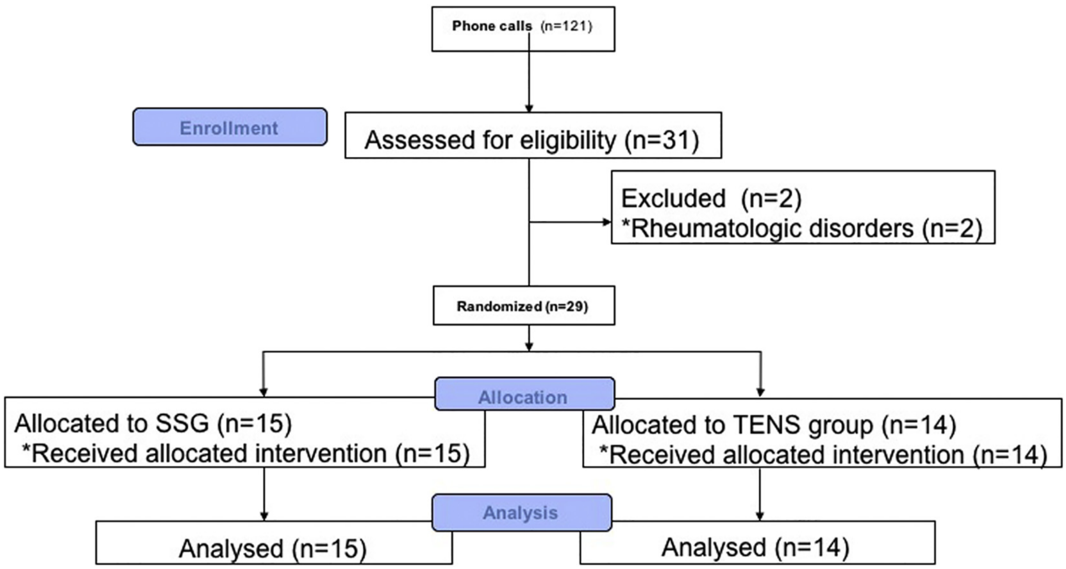

Fig 2. *Illustration of study flow.* SSG, *segmental stabilization group;* TENS, *transcutaneous electrical nerve stimulation.*

Sample Size Calculation

The sample size was calculated using 80% statistical power and 95% confidence interval and by considering the baseline standard deviation of variables measured in both groups. A required sample size of 15 individuals per group was calculated.

Statistical Analysis

All statistical tests were applied using SigmaStat 3.5 software (Systat Software GmbH, Erkrath, Germany). Data were tested for normality using the Shapiro-Wilk test and were presented as mean and standard deviation. We compared intragroup data between the 2 moments (before and after the intervention), using *t* test for normally distributed variables and Mann-Whitney test for the not normally distributed one. One-way analysis of variance was used for intergroup comparisons to determine the effect of the type of intervention as a categorical variable (factor 1: TENS vs factor 2: SS) on the Δ (difference before and after treatment) of outcomes values.

Results

Figure 2 illustrates the study flow.

Sample Characterization

Table 1 shows the demographic data and demonstrates no significant differences in age, weight, height, and body mass index.

Clinical characteristics and baseline of the study population are presented in Table 2. No significant differences were seen in the clinical variables (pain, MF

Table 1. *Demographic Data of the Study Population*

Features	SS Group (n = 15) Mean (SD)/n (%)	TENS Group (n = 14) Mean (SD)/n (%)	*P* Value [a]
Age, y	40.9 (5.57)	43.3 (5.98)	.269
Weight, kg	71.7 (8.65)	72.9 (9.73)	.729
Height, cm	1.63 (0.08)	1.65 (0.06)	.562
BMI, kg/m^2	26.8 (2.98)	26.6 (2.61)	.857
Sex			
Male	8 (53.3%)	7 (50%)	-
Female	7 (46.6%)	7 (50%)	
Marital Status			
Single	5 (33.3%)	4 (28.5%)	-
Married	8 (53.3%)	7 (50%)	-
Divorced	2 (13.3%)	3 (21.5%)	-
Years of Study			
0 to 8	2 (13.3%)	3 (21.5%)	-
9 to 12	8 (53.3%)	9 (64.2%)	-
>12	5 (33.3%)	2 (14.2%)	-
Smoker, Yes	5 (33.3%)	3 (21.5%)	-

BMI, body mass index; *SD*, standard deviation; *SS*, segmental stabilization; *TENS*, transcutaneous electrical nerve stimulation.
[a] *P* value for *t* test.

Table 2. *Clinical Characteristics and Baseline Values of the Study Population*

Features	SS Group (n = 15) Mean (SD)/n (%)	TENS Group (n = 14) Mean (SD)/n (%)	*P* Value [a]
Pain (% of total)			
12 to 24 mo	5 (33.3%)	5 (35.7%)	-
>24 mo	10 (66.6%)	9 (64.2%)	-
Fatigue			
MF initial, Hz	163.3 (12.1)	148.8 (10.4)	.005 [a]
MF final, Hz	153.5 (13.1)	145.1 (10.7)	.065
MF slope angle	-0.0247 (-0.032/-0.012)	-0.029 (-0.033/-0.017)	.616
Contraction of TrA PBU (4 to -10 mmHg) [b]	-1.13 (0.51)	-1.50 (0.65)	.103
Pain: VAS (0-10 cm) [b]	6.0 (1.84)	5.13 (1.30)	.152
Functional Disability-Oswestry (0-45) [b]	14.8 (2.42)	16 (3.57)	.269

MF, median frequency; *PBU*, pressure biofeedback unit; *SD*, standard deviation; *SS*, segmental stabilization; *TENS*, transcutaneous electrical nerve stimulation; *TrA*, transversus abdominis; *VAS*, visual analog scale.
[a] *P* value for *t* test.
[b] Normal range.

Table 3. *MF Initial, MF Final, MF Slope, Resistance Time, Contraction of TrA, Pain, and Functional Disability in Those Receiving SS at the Pretreatment and Posttreatment Assessments*

	SS Group (n = 15)		
	Pretreatment Mean (SD/Median)	Posttreatment Mean (SD/Median)	*P* Value [a]
Fatigue			
MF initial, Hz	163.3 (155.8/165.1)	171.2 (166.9/175.5)	.002
MF final, Hz	153.5 (148.5/155.5)	167.5 (162.8/169.2)	<.001
MF slope angle	-0.030 (-0.033/-0.023)	-0.026 (-0.036/-0.017)	.001
Resistance time, s	172.5 (120/240)	240 (240/240)	.001
Contraction of TrA PBU (4 to -10 mmHg) [b]	-1.13 (0.51)	-3.73 (0.86)	<.001
Pain: VAS (0-10) [b]	5.13 (1.30)	1.40 (1.18)	<.001
Functional Disability (0-45) [b]	14.8 (2.42)	5.8 (2.47)	<.001

MF, median frequency; *PBU*, pressure biofeedback unit; *SD*, standard deviation; *SS*, segmental stabilization; *TrA*, transversus abdominis; *VAS*, visual analog scale.
[a] Statistically significant difference comparing pretreatment and posttreatment.
[b] Normal range.

final, MF slope, functional disability, and ability to activate TrA), except for MF initial.

Pre-Post Treatment Results

The data of the group SS are shown in Table 3. The MF initial ($P = .002$) and MF final ($P < .001$) show significant improvement in LM fatigue, pain, functional disability, and posttreatment ability to contract the TrA ($P < .001$).

Table 4 shows the results of group TENS. Pain ($P = .012$) was the only outcome that showed significant improvement from treatment.

Intergroup Comparisons

Figure 3 compares the results between groups. We can observe that group SS shows better results in all outcomes than group TENS.

Table 4. *MF Initial, MF Final, MF Slope, Resistance Time, Contraction of TrA, Pain, and Functional Disability in Those Receiving TENS at the Pretreatment and Posttreatment Assessments*

	TENS Group (n = 14)		
	Pretreatment Mean (SD)/Median	Posttreatment Mean (SD)/Median	*P* value [a]
Fatigue			
MF Initial	148.8 (12.1)	156.5 (13.3)	.121
MF Final	145.1 (10.7)	150.7 (12,06)	.115
MF Slope	-0.024 (-0.032/0.012)	-0.027 (-0.042/-0.023)	.613
Resistance time, s	240 (240/150)	240 (240/240)	.314
Contraction of TrA PBU (4 to -10 mmHg) [b]	-1.50 (0.65)	-1.71 (0.84)	.460
Pain: VAS (0-10) [b]	6.0 (5.0/7.0)	3.50 (3.0/5.0)	.012
Functional Disability (0-45) [b]	16.0 (3.57)	14.6 (5.55)	.449

MF, median frequency; *PBU*, pressure biofeedback unit; *SD*, standard deviation; *TENS*, transcutaneous electrical nerve stimulation; *TrA*, transversus abdominis; *VAS*, visual analog scale.
[a] Statistically significant difference comparing pretreatment and posttreatment.
[b] Normal range.

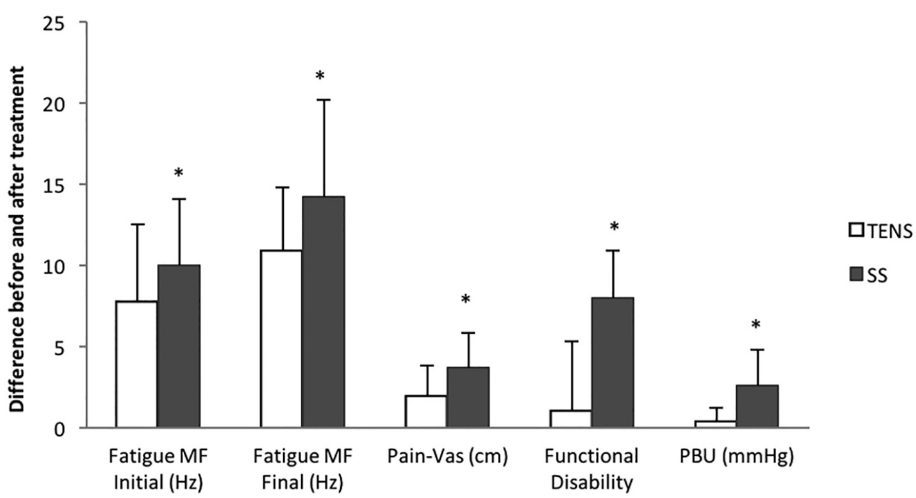

Fig 3. *Comparison of Δ (difference of outcomes values before and after treatment) between groups. One-way analysis of variance.* MF, *median frequency;* PBU, *pressure biofeedback unit;* Vas, *visual analog scale.*
* *P* < .001.

Discussion

This study compared 2 types of intervention (SS and TENS) in relieving pain symptoms, functional disability, LM fatigue, and activation of the TrA muscle in individuals with LDH. Although both interventions were effective in relieving pain, only the SS was effective to reduce LM fatigue, improve TrA activation, and minimize functional disability.

LM Fatigue

Only the SS group showed better results in their initial and final measurement of LM muscle fatigue and in the MF slope. These EMG parameters in association with physiological features through time are often observed when a muscle is under fatigue.[26] Some studies have shown that patients with cLBP are more easily fatigued in their back muscles than people without back pain, and there is an association between muscle fatigue and endurance with activity limitations in patients with LDH.[27,28] However, the way in which TENS may prevent fatigue in these muscles (if it really does) is not solved in the literature. The result of this study disentangles the conflicting literature by rejecting our initial hypothesis and demonstrating no effectiveness of TENS in fatigue prevention. Transcutaneous electrical nerve stimulation is classified into low-frequency and high-frequency types, according to the stimulation parameters. In the present study, low-frequency TENS was used because it has analgesic effect, which is maintained after the stimulation is stopped. Several studies have shown that this type of TENS is effective at reducing pain and improving physical function in cLBP patients, but none of them assessed muscle fatigue directly by using EMG, as presented here.[15,16,29,30]

In line with our findings, a recent study investigated the effect of low-frequency electrical stimulation on fatigue recovery of the erector spinae with cumulative fatigue and concluded that TENS was not effective for muscle fatigue recovery.[31]

Activation of TrA Muscle

In this study, only the stabilization group, which performed specific TrA contracting exercises, showed depression of PBU close to the ideal values of -1.13 mmHg to -3.73 mmHg after treatment. The TENS group, in contrast, began the study with an average of -1.5 mmHg and finished with -1.71 mmHg. Similar results can be observed in others studies.[32,33] According to Richardson et al,[8] an ideal PBU response in participants without cLBP is a decrease in pressure between -4 and -10 mmHg and ≥-5.82 mmHg.

A previous study evaluated the capacity for TrA depression by PBU in 3 different groups: those with no history of cLBP, those having cLBP, and those who had no current pain but did in the past. They observed that individuals with no history of back pain had a greater ability to depress the abdominal wall compared with individuals who had experienced pain but were now asymptomatic. The results of this study suggest that the resolution of pain is not enough to restore full motor control of the TrA.[34]

A recent study performed in patients with nonspecific cLBP compared the effectiveness of stabilization exercises and stretching. Both groups showed a reduction in pain symptoms, with greater gains in the group that performed specific exercises for motor control of the TrA and LM. This was accompanied by improvement in the ability to activate the TrA.[4]

In our study, even with the reduction of pain in the TENS group, the members of that group could not properly depress the abdominal wall with the correct activation of the TrA, which, according to a previous study, is also considered insufficient contraction of this muscle.[21] This might be explained by reflex inhibition, which occurs when sensory stimulation decreases the correct activation of a muscle. This afferent stimulation is caused by injury in a joint where the muscle is located.[35] Our results agree with this explanation, as the SS group, which performed specific exercises for the TrA, showed better results in the ability to develop the TrA muscle.[8]

The TENS group, on the other hand, began the study with an average of -1.5 mmHg and finished with -1.71 mmHg. The initial and final values are both in the range of insufficient TrA contraction capacity. There are few studies regarding TENS therapy and analyzing the activation capacity of the TrA.

A recent study of participants with nonspecific cLBP concluded that stretching resulted in a reduction of pain after 6 weeks of treatment. However, no improvement in the ability to contract the TrA was measured by PBU. As in the present study, there was no specific TrA training in the TENS group. It seems that the reduction in pain by itself has no effect on the improvement of motor control of the deep muscles of the lumbar spine. Moreover, this result was expected, due to nonspecific training.[4]

Pain

Pain decreased after treatment in both groups, with greater gains in the stabilization group. Several studies support the pain relief by using electrotherapy, especially.[16,17,29] Different theories have been proposed for the action mechanism of TENS. Among these, the most popular is the gate control theory, proposed by Melzack and Wall, as cited in Sluka and Walsh.[36] According to this theory, nociceptive information of small-diameter afferent fibers is annulled by the stimulation of large-diameter fibers to prevent painful stimulus from reaching the supraspinal structures. However, neuropharmacological studies indicate that spinal and supraspinal mechanisms are related to the in the neurotransmitters in the analgesia produced by TENS, which contains endogenous opioids.[36]

Concerning the treatment with stabilization exercises, O'Sullivan et al[37] observed a significant decrease in pain after specific training in motor control for the deep muscles of the trunk. Hides et al[7] also showed that specific exercises for the LM may increase the trunk's muscle mass in participants with cLBP, thereby reducing atrophy and painful episodes. In the present study, co-contraction of the TrA and LM muscles was stimulated. The most significant reduction in pain can be explained by the fact that these 2 muscles are primarily affected in the presence of cLBP. Selective atrophy of LM has been found after a first episode of cLBP.[8]

Functional Disability

The improvement of functional disability in this study was significant only in the SS group, which usually accompanies the muscular performance and relief of pain. Similar results were observed after treatment for the deep muscles of the abdomen and trunk in patients with cLBP.[7,37] In a recent study, participants with cLBP who underwent specific exercises for the TrA and LM reported improvement in functional disability with good clinical gait; however, the TENS group experienced no significant improvement.[4] However, in a study on the treatment of cLBP, patients who received TENS did report an improvement in disability, and 84% ceased analgesic or anti-inflammatory use after treatment.[17] In a randomized study, as well as in the present study, there was improvement in the functionality of individuals with cLBP associated with disk protrusion or extrusion who were treated with TENS for 4 weeks.[38]

Limitations

A more specific analysis of the LM and TrA muscles using ultrasound imaging was not performed, and a control group without treatment was not included in this study; thus, there may be bias in the results. In addition, to make the study robust and demonstrate lasting effects, a follow-up period should have been included between 3 and 12 months postintervention.

Practical Applications

- This study suggests that SS exercises performed in patients with LDH improve the ML fatigue and TrA activation capacity.
- The SS exercises are effective for improving pain and functional disability.
- The SS exercises proved to be superior to treatment carried out with the TENS.

Conclusion

After an 8-week protocol, stabilization exercises were effective to reduce fatigue of LM, improve ability to contract the TrA muscle, relieve pain, and minimize functional disability in participants with LDH associated cLBP. As a single treatment, however, TENS seemed to be effective only to reduce pain after the same period of intervention.

Funding Sources and Conflicts of Interest

This study received public financial support from the Coordination of Improvement of Higher Education Personnel and the State of São Paulo Research Foundation. No conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): L.A.V.R., F.J.R.F, A.P.M.
Design (planned the methods to generate the results): L.A.V.R., F.J.R.F, A.P.M.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): A.P.M.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): L.A.V.R., F.J.R.F.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): L.A.V.R., B.C., M.O.M., T.N.B., A.P.d.M.C.C.e.S., G.P.L.A., J.C.
Literature search (performed the literature search): L.A.V.R., B.C., M.O.M., T.N.B., A.P.d.M.C.C.e.S., G.P.L.A., J.C.
Writing (responsible for writing a substantive part of the manuscript): L.A.V.R., B.C., F.J.R.F., M.O.M., A.P.M.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): L.A.V.R., B.C., F.J.R.F., M.O.M., A.P.M.

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