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Summary

Introduction. Although transcutaneous electrical nerve stimulation and diadynamic currents are widely used in the treatment of painful conditions, their effectiveness in acute low back pain is still controversial. The aim of this study was to evaluate the therapeutic effects of transcutaneous electrical nerve stimulation and diadynamic current therapy in patients with acute low back pain. The study was designed as a single-blind randomized controlled trial.

Material and Methods. A total of 60 patients with acute low back pain, recruited from physical therapy referrals, were included in the study. Thirty consecutive patients randomized to receive transcutaneous electrical nerve stimulation were in the experimental group, and 30 patients treated with diadynamic current were included in the control group. The primary outcome variable, measured at days 1 and 10, was lumbar paraspinal muscle tone evaluated by palpation of the affected paraspinal muscles, and hip range of motion during the straight leg raise test in the supine position. All the parameters in each group showed significant improvements after 10 days of physical therapy (p < 0.01). Statistical analysis showed that there were significant differences between the groups in pain relief and sensitivity of paraspinal muscles after the treatment, mostly due to the experimental group (p < 0.01). Conclusion. In conclusion, transcutaneous electrical nerve stimulation and diadynamic current therapy can be used in rehabilitation of patients with acute low back pain, but transcutaneous electrical nerve stimulation seems to have better pain modulation effect than diadynamic current therapy.

Key words: Transcutaneous Electric Nerve Stimulation; Electric Stimulation Therapy; Low Back Pain; Acute Pain; Pain Management; Pain Measurement; Treatment Outcome; Rehabilitation

Sažetak

Uvod. Iako se transkutana električna stimulacija nerva i dijadinamička struja široko koriste u lečenju bolnih stanja, njihova efikasnost u akutnom lumbalnom sindromu je i dalje kontroverzna. Cilj ove studije bio je da se proceni terapeutski efekat transkutane električne stimulacije nerva i terapija dijadinamičkim strujama kod pacijenata sa akutnim lumbalnim sindromom. Ispitivanje je dizajnirano kao jednostruko slepa randomizovana kontrolisana studija. Materijal i metode. U istraživanju je bilo uključeno ukupno 60 pacijenata sa akutnim lumbalnim sindromom regrutovanim po preporukama za fizioterapiju. Trideset pacijenata kojima je je sekvencijalno dodeljeno da primaju transkutanu električnu stimulaciju predstavljalo je eksperimentalnu grupu, a 30 pacijenata koji su lečeni dijadinamičkom strujom uključeni su u kontrolnu grupu. Prima marna promenljiva ishoda izmerena tokom prvog i desetog dana bila je intenzitet bola, izmeren pomoću vizuelne analogne skale. Sekundarne mere ishoda bile su fleksibilnost lumbosakralne kičme (mereno Sobem testom), tonus lumbalnih paraspinalnih mišića procenjen palpacijom zahvaćenih paraspinalnih mišića i opseg pokreta kuka pomoću dizanja ekstendirane noge u ležećem položaju. Rezultati. Svi parametri u svakoj grupi pokazali su značajna poboljšanja nakon 10 dana fizikalne terapije (p < 0.01). Statističke analize su pokazale da postoje značajne razlike među grupama u ublažavanju bolova i osjetljivosti paraspinalnih mišića. Zaključak. Transkutana električna stimulacija nerva i dijadinamička struja mogu se koristiti u programu rehabilitacije pacijenata sa akutnim lumbalnim bolom, mada se čini da transkutana električna stimulacija ima bolji efekat modulacije bola od dijadinamičke struje.
Introduction

Low back pain (LBP) is among the most common and costly socioeconomic and health problems with a prevalence of 65 to 80% over one’s lifetime [1–3]. Improvements in pain and disability as well as return to work occur in the first month after an initial episode, but LBP is a recurrent problem and 50% of the active workforce experience back pain every year [4]. In most cases, a precise pathoanatomic cause cannot be found [5]. Recent studies suggest that social and psychological factors contribute to the development of acute LBP and its progression to chronic LBP [3]. The most frequently reported factors are smoking, obesity, stress, anxiety, depression, and hard work [6].

The number of studies investigating the effects of treatments in patients with LBP has increased in the past decade. Electrotherapy has a role in conservative management of acute LBP, but its effects are conflicting. This is the consequence of the predominance of low-powered and low-quality trials, the heterogeneity of disorder subtypes and varied clinical parameters [2, 7, 8].

Stimulating electrotherapy, like diadynamic current (DDC) and transcutaneous electrical nerve stimulation (TENS) are effective in the treatment of LBP by inhibiting pain-related potentials on the spinal and supraspinal level, known as “gate control” [9, 10, 32]. Analgesic effects of TENS can be observed in the whole segmental region, both ipsilateral and contralateral [11].

The mechanism of action of TENS is still poorly understood [10]. However, the clinical benefits of TENS remain controversial and there is lack of consensus regarding its efficacy [12, 13]. Some studies [14, 15] suggest a lack of evidence to support its use in the treatment of LBP, while others found evidence of benefit [13, 16, 17].

It is important to say that TENS has been used in a large number of patients for many indications over many years and it has been found to be remarkably safe and free from significant side-effects, when compared with other methods of analgesia [10].

There are a small number of studies on effects of TENS and DDC therapy on acute LBP. The DDC is one of the most common electrotherapy treatments which use low currents with analgesic and spasmolytic effect. The DDC’s are mixed currents, which use effects of the concurrent application of galvanic and farad, or other impulse-like currents. This results in combined effects of both types of currents, especially induction of hyperemia and analgesia [18].

There are a limited number of studies investigating DDC effectiveness in the therapy of acute LBP and most of them are not in English language. The main objective of the study was to examine whether TENS is an effective treatment for acute LBP compared with the application of DDC.

Material and Methods

A prospective, single blind randomized controlled study included consecutive patients referred to a Physiotherapy Center with a diagnosis of nonspecific acute LBP. Inclusion criteria were patients aged 16 to 70 years, with a diagnosis of acute LBP lasting a maximum of 3 weeks. Exclusion criteria were patients with pacemakers, damaged or broken skin, malignancy, spinal infections, pregnancy, traumatic fractures, seriously impaired vision, and patients with contraindications to either treatment. The subjects with suspected above-mentioned exclusion factors underwent the following diagnostic methods: x-ray, magnetic resonance imaging, electromyography, and in case of need, laboratory tests were performed. In that way, serious pathology as a cause of acute lumbar pain was excluded.

Patients were randomly allocated to use either TENS or DDC. In the TENS group (30 patients) the stimulation was continuously applied for 15 minutes once a day at high frequency (150 Hz). Four graphic electrodes (4 cm x 4 cm) from a dual channel TENS unit were placed with aqueous gel. The electrodes were applied on the lumbosacral region, directly over the site of pain or adjusted to the painful area at a distance of 5 – 20 cm apart.

In the DDC group (30 patients) the stimulation was also given once a day, short period and long period modalities during 10 days. The electrodes were placed on the pain area in the paraspinal and lumbar region. Each application lasted for 6 minutes.

The assessment of treatment efficacy was done after each therapy on days 1, 5 and 10 during the treatment. The following parameters were evaluated by the physician: pain intensity, mobility of lumbosacral spine, paravertebral tonus, and hip range of motion. The pain intensity level was recorded over 10 days using the 100 mm non-interval visual analogue scale (VAS). Lumbosacral flexibility was measured by Schober method. Paravertebral muscle tonus was evaluated by the physician, with palpation of affected paraspinal muscles using 5-point numerical rating scale graded from 1 to 5 as follows: 1. Hypotonia, 2. Eutonia, 3. Spasm, 4. Strong spasm, and 5. Extremely strong spasm. The hip range of motion was measured by straight leg raise test (SLRT) [2].

The data were evaluated using the Statistical package for the social sciences, version 17.0 for Windows. For the purpose of statistical analysis, measures of descriptive statistics - frequency, mean, and measures of variability were used. Parametric (t-test) and nonparametric (Mann Whitney test, chi-square test) tests were used to compare the distribution between the two groups. To compare three or more groups of respondents the analysis of variance and Kruskal-Wallis tests were used. Correlation of continuous variables was examined by Pearson correlation coefficient.
Ethical approval was given by the Ethics Committee of the School of Medicine, University of Belgrade, and informed consent to participate in the study was obtained from all the patients.

Results

Sixty patients were recruited and randomized into the study; 30 into the TENS group and 30 into the DDC group. All patients completed the trial.

The mean age of participants was 42 ± 11.5 years. In the TENS group, 53.3% of patients were males and 46.7% were females, while in the DDC group, 46.7% were males and 53.3% were females. In the TENS group, 18 (60%) patients had one or more earlier episodes of LBP and in the DDC group, 19 (63%) patients had earlier LBP episodes. Analysis of all demographic data demonstrated no significant difference between groups (Table 1).

Pain intensity

The outcome measures between baseline and day 10 are summarized in Table 2. Compared with baseline values, the TENS group showed a significant (p < 0.01) decline (ranging from 44.00 ± 24.47 to 3.43 ± 4.57) in back pain severity (VAS score after ther-

Table 1. Basic characteristics of the participants

| Treatment   | Age/Starost | Average pain intensity (VAS 0 - 100) | Lumbosacral mobility, Schober | Tonus of paravertebral muscles (TPEN, steperen) |
|-------------|-------------|-------------------------------------|---------------------------------|-----------------------------------------------|
| TENS group  | N = 30 (16 male and 14 female) | 58.80 ± 24.55 | 18.13 ± 17.80 | 3.57 ± 0.68 | 61.3 ± 19.2 |
| DDS group   | N = 30 (14 male and 16 female) | 58.86 ± 23.96 | 18.20 ± 16.64 | 3.67 ± 0.66 | 60.5 ± 18.8 |

\[X \pm SD\]

Legend: X = mean value; SD = standard deviation; VAS = visual analogue scale; TENS = transcutaneous electrical nerve stimulation; DDS = diadynamic current; SLRT = straight leg raise test; TPEN = Test podizanja ekstendirane noge

Table 2. Change in outcome measures (mean ± standard deviation) prior to therapy (prior), immediately after first therapy (post 1) and at 10 days follow up (post 10)

| Outcome measures | TENS/TENS (n = 30) Mean ± SD | DDC/DDC (n = 30) Mean ± SD |
|------------------|-------------------------------|-----------------------------|
| Pain intensity (VAS) | 58.80 ± 24.55 | 58.86 ± 23.96 |
| Post 1/Posle 1 | 44.00 ± 24.47 | 51.66 ± 21.81 |
| Post 5/Posle 5 | 18.17 ± 14.11 | 34.30 ± 16.73 |
| Post 10/Posle 10 | 3.43 ± 4.57 | 9.97 ± 6.78 |
| Lumbosacral mobility (cm) | 18.13 ± 17.80 | 18.20 ± 16.64 |
| Post 5/Posle 5 | 18.83 ± 13.47 | 18.76 ± 12.50 |
| Post 10/Posle 10 | 20.13 ± 10.90 | 20.00 ± 9.46 |
| Paravertebral tonus | 3.57 ± 0.68 | 3.67 ± 0.66 |
| Post 10/Posle 10 | 2.43 ± 0.50 | 2.70 ± 0.47 |
| SLRT (degrees) | 61.3 ± 19.2 | 60.5 ± 18.8 |

Legend: SD = standard deviation; VAS = visual analogue scale; TENS = transcutaneous electrical nerve stimulation; DDS = diadynamic current; SLRT = straight leg raise test; TPEN = Test podizanja ekstendirane noge

a Statistically significant difference from DDC/Statistički značajna razlika u odnosu na DDS;
b Statistically significant difference from Prior/Statistički značajna razlika u odnosu na pre; c Statistically significant difference from Post 1/Statistički značajna razlika u odnosu na posle 1
apy). Also, the DDC group showed a significant (p < 0.01) decline in back pain intensity (from 51.66 ± 21.81 to 9.97 ± 6.78). In the TENS group, pain scores were significantly (p < 0.01) lower than in the DDC group after 10 days of therapy.

Lumbosacral flexibility

Compared with the baseline values, the TENS group showed a significant (p < 0.01) increase in the trunk range of motion after 5 and 10 days of therapy. The range of flexion increased at all follow-ups from 18.13 ± 17.80 cm to 20.13 ± 10.90 cm (Table 2). The DDC group also showed a significant (p < 0.01) increase in the trunk motion at all follow-ups which extended from 18.20 ± 16.6 cm to 20.00 ± 9.46 cm. There were no significant differences between the TENS and DDC groups (p > 0.5) in the trunk range of motion after 5 and 10 days of therapy.

Tonus of the paravertebral muscles

The TENS and DDC groups showed a significant (p < 0.01) decrease in paravertebral muscle tonus after 10 days of therapy. Compared with the baseline values, the tenderness of paravertebral muscles in the TENS group decreased from 3.57 ± 0.68 to 2.43 ± 0.50. In the DDC group, the decline of paravertebral muscle tonus was from 3.76 ± 0.66 to 2.70 ± 0.47. The TENS group displayed significantly (p < 0.05) lower paravertebral muscle tonus compared with the DDC group after 10 days of therapy.

Straight leg raise test

Compared with the pretherapy values, patients in the TENS and DDC groups showed a significant (p < 0.01) improvement in the hamstring flexibility measured by SLRT after 10 days of therapy (Table 2). Between the TENS and DDC groups there were no significant differences in extremity range of motion (p > 0.05).

Discussion

This study evaluated the effectiveness of the TENS and DDC therapy in patients with acute LBP, without neurological deficiency. We observed that subjects demonstrated significant improvement in all outcome measures following both therapeutic interventions. The main limitation of this study is the small sample size, potentially affecting the obtained treatment effects. Another issue is that we have considered short-term effects (immediate post-treatment) associated with electrotherapy.

The mean age of participants included in present study was 42 years. The age and gender range of subjects recruited to the study appear to reflect the clinical population most often affected by LBP [19]. In the TENS group, 60% of patients had one or more earlier attacks of LBP, and in the DDC group 63% of patients had earlier LBP episodes. The present results are in agreement with previous findings indicating a high level of LBP recurrences [3].

In our study, the TENS and DDC groups showed a significant (p < 0.01) decline in back pain severity by VAS score after the therapy compared with baseline values. Also the TENS group pain scores were significantly (p < 0.01) lower than the DDC group scores after therapy (Table 2). This is comparable with the results of Can F. et al. [20] who compared the efficacy of TENS and DDC therapy in a group of patients with patellofemoral pain syndrome, showing that both therapies were effective in terms of pain management and activity level. But, they also demonstrated that there was no significant difference in analgesic effects between the two groups, which is in contrast with our results.

Reviewing the published literature on the treatment of painful conditions using electrotherapy, Rushton reported that TENS has proved to be remarkably safe and provides significant analgesia in about half of patients experiencing moderate predictable pain [10]. Also, Cheing et al. reported that TENS significantly reduced chronic pain [21]. A recent clinical trial compared the effectiveness of rhythmic stabilization exercises and TENS and their combination in treating women with chronic LBP. Their results suggested that combined treatment was superior to placebo [13].

The present results disagree with the recent findings of Keller et al. who reported small to moderate pooled effect size of TENS therapy for short-term pain relief in patients with chronic LBP [14]. A systematic review of acupuncture for LBP also found no difference in pain relief between TENS and acupuncture [12, 22]. Also, Chou et al. in a systemic review of the therapies for acute and chronic LBP reported that TENS has not been shown to be effective for chronic, subacute, or acute LBP and that the only therapy with good evidence of efficacy was superficial heat [12]. Analgesic effective of DDC are showed in the study of Linsinsi et al. who reported that DDC is very effective in managing pain in patients with knee osteoarthritis [23]. Beside the above mentioned results, the effectiveness of TENS and especially DDC therapy is difficult to assess because of limited quantity and quality of studies [2, 9, 20].

The differences between our results and other studies could be attributed to differences in physical as well as psychosocial factors between the patients with acute and chronic LBP [13, 24–26, 33]. Furthermore, differences among studies in the methodology and outcome measures used to test the effectiveness may also contribute to the above observation.

Compared with the baseline values, the TENS and DDC groups showed a significant (p < 0.01) increase in trunk range of flexion after 5 and 10 days of therapy. No significant differences were found between the TENS and DDC groups (p > 0.5) in the ability to flex the lumbar spine after 10 days of therapy. The range of flexion increased from 18 cm at baseline to 20 cm after therapy. From the clinical point of view, achievement of 20 cm in lumbosacral anteflexion after TENS and DDC therapy indicates that the goals of this particular therapy
have been met since lumbosacral anteflexion of 20 cm is considered as normal flexion measured by Schober (Table 2) [27, 30]. Such improvements indicate that subjects were able to perform daily activities comfortably and without pain.

Research on the effects of high-frequency TENS on trunk flexibility is scarce and no definite conclusions can be made regarding its effectiveness [9]. Kofotolis et al. showed that the rhythmic stabilization program resulted in significantly better improvement in functional disability and trunk flexion compared with TENS therapy in chronic LBP patients [13, 29].

Also, there is no evidence on DDC therapy effectiveness in the patients with acute LBP. Most studies of electrotherapy cover DDC therapy in a very superficial way, and a considerable proportion of the literature is not easily available in English. Because of that, the role of this therapy in functional disability of patients with acute LBP remains unclear.

Our study indicates that the pain relief following a 10-day therapy using TENS as well as DDC therapy program was sufficient to affect the trunk flexibility. More high-quality studies are needed to determine the role of DDC therapy in the management of functional disability in patients with acute LBP.

The TENS and DDC groups showed a significant (p < 0.01) decrease in paravertebral tonus after 10 days of therapy. A comparison between groups revealed that the TENS group displayed significantly (p < 0.05) lower paravertebral tonus compared with the DDC group. In our study, the mean paravertebral tonus dropped from baseline value of 3.57 to 2.43 during 10 days. The effectiveness of TENS on spasticity was studied by Hsueh et al. who reported on the effects of a single TENS treatment (60 Hz; 20 minutes) in 20 patients with chronic trigger points (trapezius muscle) [28, 31]. They found a significant decrease in trigger points tenderness and pain intensity in patients receiving TENS, compared with placebo treatment. In the Cochrane Review of Electrotherapy for Mechanical Neck Disorders, Kroeling et al. found limited evidence of benefit of the DDC therapy for the pain outcome and reduction of trigger point pain [9]. Besides that, we identified no results on DDC therapy effects on muscle spasticity in acute LBP.

Conclusion

Our findings showed that, in comparison with the pretreatment values, patients in the transcutaneous electrical nerve stimulation group and diadynamic current group showed a significant (p < 0.01) improvement in hamstring flexibility, as measured by straight leg raise test after 10 days of therapy. Between transcutaneous electrical nerve stimulation and diadynamic current groups there were no significant differences in extremity range of motion (p > 0.05). Since positive result has been defined as radiating pain observed at 30 to 70 degrees of hip flexion we can say that our patients achieved normal values in extremity range of motion.

In conclusion, the present results indicate that transcutaneous electrical nerve stimulation and diadynamic current therapy are effective in reducing back pain severity and paravertebral tonus as well as improving trunk and hamstring flexibility in patients with acute low back pain. Further studies examining these specific interventions are needed because the existing evidence is limited and conflicting.

References

1. Walker BF. The prevalence of low back pain: a systematic review of the literature from 1966 to 1998. J Spinal Disord. 2000;13(3):205-17.
2. Gregory DS, Seto CK, Wortley GC, Shugart CM. Acute lumbar disk pain: navigating evaluation and treatment choices. Am Fam Physician. 2008;78(7):835-42.
3. Gurcay E, Bal A, Eksisoglu E, Hasturk AE, Gurcay AG, Cakci A. Acute low back pain: clinical course and prognostic factors. Disabil Rehabil. 2009;31(10):840-5.
4. Patel AT, Ogle AA. Diagnosis and management of acute low back pain. Disabil Rehabil. 2000;22(6):348-51.
5. Atlas SJ, Deyo RA. Evaluating and managing acute low back pain in the primary care setting. J Gen Intern Med. 2001;16(2):120-31.
6. Nicholas MK, Linton SJ, Watson PJ, Main CJ. Early identification and management of psychological risk factors (“yellow flags”) in patients with low back pain: a reappraisal. Phys Ther. 2011;91(5):737-53.
7. Bloodworth DM, Nguyen BN, Garver W, Moss F, Pedrozzi C, Tran T, et al. Comparison of stochastic vs. conventional transcutaneous electrical stimulation for pain modulation in patients with electromyographically documented radiculopathy. Am J Phys Med Rehabil. 2004;83(8):584-91.
8. Nwuga VC. Ultrasound in treatment of back pain resulting from prolapsed intervertebral disc. Arch Phys Med Rehabil. 1983;64(2):88-9.
9. Kroeling P, Gross AR, Goldsmith CH; Cervical Overview Group. A Cochrane review of electrotherapy for mechanical neck disorders. Spine (Phila Pa 1976). 2005;30(21):641-8.
10. Rushton DN. Electrical stimulation in the treatment of pain. Disabil Rehabil. 2002;24(8):407-15.
11. Stucki G, Kroeling P. Physical therapy and rehabilitation in the management of rheumatic disorders. Baillieres Best Pract Res Clin Rheumatol. 2000;14(4):751-71.
12. Chou R, Huffman LH; American Pain Society; American College of Physicians. Nonpharmacologic therapies for acute and chronic low back pain: a review of the evidence for an American Pain Society/American College of Physicians clinical practice guideline. Ann Intern Med. 2007;147(7):492-504.
13. Kofotolis ND, Vlachopoulos SP, Kellis E. Sequentially allocated clinical trial of rhythmic stabilization exercises and TENS in women with chronic low back pain. Clin Rehabil. 2008;22(2):99-111.
14. Keller A, Hayden J, Bombardier C, van Tulder M. Effect sizes of non-surgical treatments of non-specific low-back pain. Eur Spine J. 2007;16(11):1776-88.
15. Deyo RA, Walsh NE, Martin DC, Schoenfeld LS, Rumamurthy S. A controlled trial of transcutaneous electrical nerve stimulation (TENS) and exercise for chronic low back pain. N Engl J Med. 1990;322(23):1627-34.

16. Melzack R, Vetepe P, Finch L. Transcutaneous electrical nerve stimulation for low back pain. A comparison of TENS and massage for pain and range of motion. Phys Ther. 1983;63(4):489-93.

17. Bertalanffy A, Kober A, Bertalanffy P, Gustorff B, Gore O, Adel S, et al. Transcutaneous electrical nerve stimulation reduces acute low back pain during emergency transport. Acad Emerg Med. 2005;12(7):607-11.

18. Ratajczak B, Hawrylak A, Demidasi A, Kuciel-Lewandowska J, Boerner E. Effectiveness of diadynamic currents and transcutaneous electrical nerve stimulation in disc disease lumbar part of spine. J Back Musculoskelet Rehabil. 2011;24(3):155-9.

19. Loney PL, Stratford PW. The prevalence of low back pain in adults: a methodological review of the literature. Phys Ther. 1999;79(4):384-96.

20. Can F, Tandogan R, Yilmaz I, Dolunay E, Erden Z. Rehabilitation of patellofemoral pain syndrome: TENS versus diadynamic current therapy for pain relief. Pain Clinic. 2003;15(1):61-8.

21. Cheing GL, Hui-Chan CW. Transcutaneous electrical nerve stimulation: nonparallel antinociceptive effects on chronic clinical pain and acute experimental pain. Arch Phys Med Rehabil. 1999;80(3):305-12.

22. Manheimer E, White A, Berman B, Forsey K, Ernst E. Meta-analysis: acupuncture for low back pain. Ann Intern Med. 2005;142(8):651-63.

23. Lisinski P, Zapalski W, Stryla W. Physical agents for pain management in patients with gonarthrosis. Ortop Traumatol Rehabil. 2005;7(3):317-21.

24. Biering-Sorensen F. Physical measurements as risk indicators for low back trouble over a one-year period. Spine (Phila Pa 1976). 1984;9(2):106-19.

25. Loeser JD, Melzack R. Pain: an overview. Lancet. 1999;353(9164):1607-9.

26. Carragee EJ. Psychological and functional profiles in select subjects with low back pain. Spine J. 2001;1(3):198-204.

27. Hancock MJ, Maher CG, Latimer J, Spindler MF, McAuley JH, Laslett M, et al. Systematic review of tests to identify the disc, SIJ or facet joint as the source of low back pain. Eur Spine J. 2007;16(10):1539-50.

28. Hsueh TC, Cheng PT, Kuan TS, Hong CZ. The immediate effectiveness of electrical nerve stimulation and electrical muscle stimulation on myofascial trigger points. Am J Phys Med Rehabil. 1997;76(6):471-6.

29. Petrofsky J, Laymon M, Lee H. The effect of transcutaneous electrical nerve stimulation and low-level continuous heat on non-specific low back pain: a randomized controlled trial. Gazzetta Medica Italiana Archivio per le Scienze Mediche. 2020;179(6):419-27.

30. Resende L, Merriwether E, Rampazo ŠP, Dailey D, Embree J, Deberg J, et al. Meta-analysis of transcutaneous electrical nerve stimulation for relief of spinal pain. Eur J Pain. 2018;22(4):663-78.

31. Wu LC, Weng PW, Chen CH, Huang YY, Tsuang YH, Chiang CJ. Literature review and meta-analysis of transcutaneous electrical nerve stimulation in treating chronic back pain. Reg Anesth Pain Med. 2018;43(4):425-33.

32. Knežević A, Kovaćević M, Klicov L, Pantić M, Vasin J, Spasojević T. Conditioned pain modulation assessment using contact heat as conditioning stimulus and two different test stimuli. Med Pregl. 2019;72(3-4):66-71.

33. Juković M, Koković T, Nikolović D, Ilić D, Tili V. Lower back pain: silent symptom of chronic infrarenal abdominal aeurysm rupture. Med Pregl. 2016;69(3-4):115-7.