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ORIGINAL ARTICLE

Effects of electrical stimulation program on trunk muscle strength, functional capacity, quality of life, and depression in the patients with low back pain: a randomized controlled trial

Dilek Durmus · Yesim Akyol · Gamze Alayli · Berna Tander · Yeliz Zahiroglu · Ferhan Canturk

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Abstract The aim of this clinical trial was to evaluate the effects of electrical stimulation (ES) program on trunk muscle strength, functional performance, quality of life (QOL) in the patients with chronic low back pain (CLBP). A total of 41 patients with definite CLBP were included in this study. These patients were randomized into two groups. Group 1 ($n = 21$) was given an ES program and exercises. Group 2 ($n = 20$) was accepted as the control group and given only exercises. Both the programs were performed 3 days a week, for 8 weeks in the out-patient department. The patients were evaluated according to pain, disability, functional performance, endurance, quality of life, depression. The muscle strengths were measured with a hand-held dynamometer. There were significant improvements for all the parameters in two groups after the treatment. Except depression and social function, the improvements for all the parameters were better in the ES group than in the control group. We observed that ES program was very effective in improving QOL, functional performance and isometric strength. In conclusion, we can say that ES therapy provides comfortable life functions by improving muscle strength, functional performance and QOL.

Keywords Electrical stimulation · Trunk muscle strength · Pain · Disability · Quality of life · Depression

D. Durmus (✉) · Y. Akyol · G. Alayli · B. Tander · Y. Zahiroglu · F. Canturk
Department of Physical Medicine and Rehabilitation, Medical Faculty, Ondokuz Mayis University, Samsun, Turkey
e-mail: drdilekdurmus@yahoo.com

Introduction

Chronic low back pain (CLBP) constitutes a major healthcare problem in industrialized countries. This condition is not only very common but also its treatment is difficult and time-consuming and it results disability in quality of life (QOL). The relationship between the patient's symptoms and the functional disability levels is too complex. It is known that psychological and social factors are important in low back pain and its chronicity. Extended pain duration affects the patient's daily functions [1].

Chronic low back pain has been found to be associated with certain postural, muscular, and mobility characteristics. Numerous etiologic factors have been linked to the condition: increased lumbar lordosis decreased abdominal muscle strength, imbalance between flexor and extensor trunk muscle strength, reduced spinal mobility. Trunk muscle strength has been extensively studied in relation to CLBP [2–4]. One investigation [5] noted that trunk muscle strength ratios of patients seeking hospitalization for chronic low-back disorders did not differ significantly from those of healthy subjects, whereas most of the researchers have found trunk muscle strength to be an important factor in CLBP [6, 7].

Exercise therapy aims at reduction of pain and disability. This is achieved through improvement of muscle strength, endurance, and aerobic capacity. Certainly, in patients with CLBP, regular exercise can improve pain control, proprioception, controlled strength, instability, and endurance, all of which improve functional independence [8, 9].

The mechanism of pain relief with electrical stimulation (ES) is explained by the gate-control theory developed by Melzac and Wall. ES causes facilitation in substantia gelatinosa at the level of medulla spinalis by stimulating A–C

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and A–D fiber, which do not transmit pain sense and reduces pain sense by inhibiting A–Δ and C fiber which transmit pain sense in presynaptic area. ES increases muscle strength, decreases joint stiffness and spasm in muscle as well [10].

The use of ES in the lower back has been used predominantly as a pain reduction modality [10–12]. To our knowledge ES usage in CLBP to improve trunk muscle strength, functional performance and QOL has not been reported previously. The aim of this clinical trial was to determine the effects of ES program on pain, disability, trunk muscle strength, functional performance, QOL and depression in the patients with CLBP.

Methods

A total of 46 female patients who had been experiencing low back pain for at least 3 months were enrolled in this study. Forty-one patients completed the study (3 patients in the ES group were out of contact, 2 from the control group did not come to the assessment after 8 weeks). A demographic data including age, body mass index (BMI) (kg/m^2), educational level and duration of symptoms were recorded. Subjects of both groups 1 and 2 were housewives or they were retired (they had been living a sedentary life and had no regular or irregular sports habits). A complete examination was performed by the same physician (YZ).

Exclusion criteria were the following: (1) Subjects with acute radicular signs or symptoms, (2) those who had radiographic evidence of inflammatory disease affecting the spine, tumor, spondylolysis, spondylolisthesis, or sacroiliitis, (3) serious medical conditions for which exercise would be contraindicated, (4) neuromuscular or dermatologic disease that involves the lomber and abdominal area, (5) had exercise program that may cause increase of muscle strength within the previous months (6) implanted cardiac pacemaker or defibrillator, (7) contracture, (8) previous trauma.

These patients were randomized into two groups. Group 1 ($n = 21$) was given an ES program and exercises. Group 2 ($n = 20$) was accepted as the control group and was given only exercises. All patients came to the out-patient department for ES and exercise treatments. For ES group, 30-min duration ES therapy was applied. For both groups, 30-min duration exercise therapy was applied. Both of the programs were performed 3 days a week, for duration of 8 weeks. Patients were evaluated before and 2nd, 4th and 8th weeks of the therapy.

The patients were informed about the purpose of the study and gave their consent. The study was approved by the ethical committee of Ondokuz Mayis University.

Fig. 1 The placement of the electrodes of back on L2–L4 levels over the erector spinae muscles bulks motor points

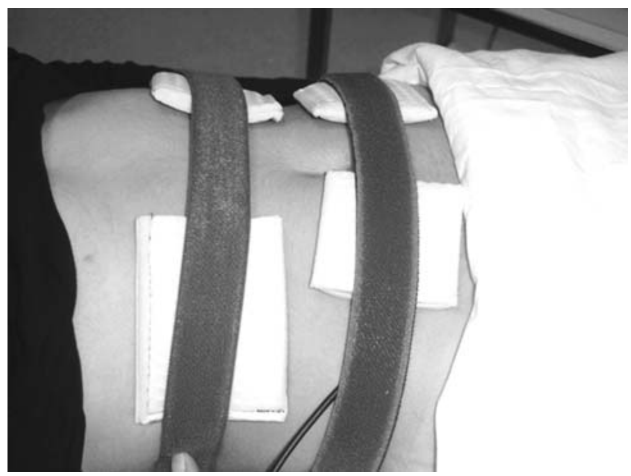

Fig. 2 The placement of the electrodes on obliquus externius abdominis muscles motor points

ES therapy

Electrical stimulation was administered with the subject in the prone (15 min) and supine position (15 min). The electrodes of prone position were placed on L2–L4 levels over the erector spinae muscles bulks motor points, and those of supine position were placed on obliquus externius abdominis muscles motor points (Endomed-CV 405) (Figs. 1, 2). The symmetric biphasic wave was applied with the frequency of 50 Hz and 50 ms of phase time. The intensity of the current was arranged separately one by one for each patient until apparent muscle contraction was established (70–120 mA). The stimulation was applied as 10 s of contraction and 10 s of relaxation [13, 14].

Exercise therapy

Exercises were taught by a physiatrist (YZ). The subjects in both groups were treated with a group-exercise programme composed of 20 min back and abdominal exercises with a warm up and cool down period of 5 min stretching exercises 3 days a week under the supervision of the same physiatrist (YZ) [14]. Both groups were given an exercise program which consisted of six exercises: motion, flexibility and back strengthening exercises of the cervical, thoracic, and lumbar spine; stretching of the erector spine muscle, hamstring muscles, pelvic muscles and abdominal muscles (1) Pelvic tilt (2) Knee to chest (3) Lower abdominal exercises (4) Cat and camel (5) Back extension exercises.

Clinical assessments

The patients were compared before and after the treatment, in accordance with pain, disability, functional performance, abdominal and extensor endurance, isometric trunk flexor and extensor muscle strength, quality of life, depression.

Pain and disability

The global pain of the patients was assessed by visual analogue scale (VAS) pain score (0–100 mm, with higher scores indicating more pain). Pain was measured before treatment and 2nd, 4th and 8th weeks of the therapy.

The Oswestry disability questionnaire (ODQ) and pain disability index (PDI) were used to assess pain and disability in the study group. ODQ has ten subgroups and these are evaluated with 0–5 scores. Subgroups are pain severity, self care, walking, sitting, standing, sexual function, traveling and social life. The maximum score in ODQ is 70, which means 100% disability [15, 16].

Pain disability index has eight subgroups. These are social activities, leisure activities, self care, job, sexual function, daily life activities. Each group is evaluated 0–50 scores. Higher score of the PDI reflects greater disability [16].

Functional performance

Objective assessment of functional performance was obtained by timing the patients walking as fast as they could for 50 m [13].

Muscle strength

Trunk flexor muscle strength (FMS) and extensor muscle strength (EMS) (isometric muscle force of) were measured with a hand-held dynamometer [Baseline Push-Pull Dynamometer, Digital (LCD) hydraulic New York, USA] by the same tester (DD). FMS was measured with the subject in supine, arms resting at side, head mid-line. The end piece of the dynamometer was applied on the sternum at the center of the chest. Subject was asked to take 1 or 2 s to come to maximum effort and, then, tester pushed down body as forcefully as possible. EMS was measured with the subject in prone, arms resting at side, head mid-line. The end piece of the dynamometer was applied at the inferior angle of the scapulae on the center of the back between the shoulder blades. Subject was asked to take 1 or 2 s to come to maximum effort and, then, Tester pushed down body as forcefully as possible. The maximum force realized during a 3–5 s effort was recorded in kg. The test was performed three times with a 30-s interval and the average was recorded. Muscle strength was measured before treatment and 2nd, 4th and 8th weeks of the therapy (Figs. 3, 4).

Fig. 3 Measurement of extensor and flexor muscle strength

Fig. 4 Measurement of extensor and flexor muscle strength

Endurance

The subject is placed prone with the legs extended while holding the sternum off the floor. A small pillow is placed under the lower abdomen to decrease the lumbar lordosis. The subject is asked to maintain maximal flexion of the cervical spine, pelvic stability being maintained through gluteal muscle contraction. Subject is asked to maintain this position for as long as possible, to a maximum of 300 s. Endurance time (in s) is recorded by an examiner (extensor endurance test) [17].

The flexor endurance test required subjects to sit on the test bench and place the upper body against a support with an angle of 60° from the test bed. Both the knees and hips were flexed to 90°. The arms were folded across the chest with the hands placed on the opposite shoulder and toes were placed under toe straps. Subjects were instructed to lift their upper body away from the support and kept it parallel with the support (as instructed by the examiner). Subjects were instructed to maintain the body position as long as possible. The test ended when the upper body fell below the 60° angle and came in contact with the back support. Endurance time (in s) is recorded by an examiner [18].

Quality of life

Quality of life was assessed with short form 36 (SF-36). The SF-36 is a widely applied generic instrument for measuring health status and consists of eight dimensions: physical functioning, social functioning, physical role, emotional role, mental health, vitality, bodily pain and general health perceptions. Scores range from 0 (worst) to 100 (best) with higher scores indicating better health status [19].

Depression

Depression was assessed with Beck depression inventory (BDI). BDI is a 21-item test presented in multiple-choice format which purports to measure presence and degree of depression. Responses are made on a four-point, minimally anchored scale, ranging from 0 to 3, with 3 representing the most severe symptoms [20].

Statistical analysis

Statistical analyses were performed with SPSS 13.0 for windows. Descriptive data were presented as mean ± standard deviation (SD) or minimum–maximum (median) when needed according to the normal distribution of the parameters. The Shapiro–Wilk test was used to analyze normal distribution assumption of the quantitative outcomes. To compare two groups Mann–Whitney *U* test and Independent Samples *t* test were used when needed according to the normal distribution of the parameters. Wilcoxon's signed rank test or paired *t* test was used for within-group change. The sociodemographical characteristics of the groups were evaluated by Chi-square test. *P* values less than 0.05 were considered statistically significant.

Results

Demographical properties of the patients are shown in Table 1. There was no statistically significant difference for age, BMI, educational level and duration of symptoms between the groups ($P > 0.05$).

There was also no significant difference between the groups in terms of pain, disability, functional performance, trunk muscle strength, endurance, QOL and depression scores before treatment ($P > 0.05$). Both groups showed significant improvements in pain, disability, functional performance and endurance (Table 2). The improvements for all the parameters were better in the ES group than in the control group after treatment (Table 3).

There were no differences between the two groups for VAS, extensor and flexor muscle strength, before the therapy and 2nd weeks of the therapy ($P > 0.05$). At the 4th week of the therapy, there were significant differences between the groups at each parameters (respectively, $P < 0.01$, $P < 0.01$, $P < 0.01$) and these differences were more significant at the 8th week of the therapy (respectively, $P < 0.001$, $P < 0.001$, $P < 0.001$) (Figs. 5, 6, 7).

Both groups showed significant improvements in QOL and depression (Table 4). The improvements for all the parameters were better in the ES group than in the control group after treatment except depression and social function (Table 5).

Table 1 Demographic properties of the patients

	Group I ($n = 21$) Mean ± SD	Group II ($n = 20$) Mean ± SD	*P*
Age (years)	46.80 ± 7.68	43.27 ± 10.27	>0.05
BMI (kg/m^2)	28.66 ± 4.99	27.77 ± 5.39	>0.05
Duration of symptoms (years)	6.47 ± 5.77	8.83 ± 6.33	>0.05
Job, *n* (%)			
Housewife	11 (26.8)	10 (24.4)	>0.05
Retired	10 (24.4)	10 (24.4)	
Education, *n* (%)			
Primary education	8 (19.5)	10 (24.3)	>0.05
Secondary education	5 (12.1)	3 (7.31)	
College	8 (19.5)	7 (17.0)	

$P < 0.05$ significant

Table 2 Baseline and the final results of clinical parameters of the patients

	Group 1			Group 2		
	BT	AT	P	BT	AT	P
ODQ (%) (mean ± SD)	36.66 ± 9.53	6.57 ± 5.83	**0.001**	37.22 ± 17.04	19.22 ± 13.99	**0.001**
AET (s) (mean ± SD)	98.00 ± 68.36	236.28 ± 99.0	**0.001**	104.05 ± 88.94	144.88 ± 90.02	**0.001**
50MWT (s) (mean ± SD)	40.71 ± 6.25	23.42 ± 4.01	**0.001**	39.22 ± 5.86	32.16 ± 5.30	**0.001**
EET (s) Med (min–max)	35 (10–225)	150 (40–358)	**0.001**	59.90 (4–139)	83.50 (10–258)	**0.001**
PDI Med (min–max)	19 (10–45)	4 (0–23)	**0.001**	22 (12–64)	9.50 (0–48)	**0.001**

ODQ The Oswestry disability questionnaire, *PDI* pain disability index, *50MWT* 50 m walking time, *EET* extensor endurance test, *AET* abdominal endurance test, *BT* before treatment, *AT* after treatment, *Med (min–max)* median (minimum–maximum), *Mean ± SD* mean ± standard deviation

$P < 0.05$ Significant

Table 3 Comparison of the final results of clinical parameters of the patients

	Group 1 AT	Group 2 AT	P
ODQ (%) (mean ± SD)	6.57 ± 5.83	19.22 ± 13.99	**0.001**
AET (s) (mean ± SD)	236.28 ± 114.08	144.88 ± 90.02	**0.007**
50MWT (s) (mean ± SD)	23.42 ± 4.01	32.16 ± 5.30	**0.001**
EET (s) med (min–max)	150 (40–358)	83.50 (10–258)	**0.003**
PDI med (min–max)	4 (0–23)	9.50 (0–48)	**0.013**

ODQ The Oswestry disability questionnaire, *PDI* pain disability index, *50MWT* 50 m walking time, *EET* extensor endurance test, *AET* abdominal endurance test, *BT* before treatment, *Med (min–max)* median (minimum–maximum), *Mean ± SD* mean ± standard deviation

$P < 0.05$ significant

Discussion

The present study was performed to investigate the efficacy of ES on pain, disability, functional performance, trunk muscle strength, endurance, all QOL subscales and depression in patients with CLBP. The results of this study showed greater improvements in pain, disability, functional performance, trunk muscle strength, endurance and QOL in the ES group than the control group.

Chronic low back pain is a common disorder in the general population, and mechanical factors are known to play an important role in its etiology. Chronic pain is described as a syndrome of five components, the “Five D Syndrome”: (1) drug: abuse or misuse; (2) dysfunction: a decrease in function, performance, or even the quality of life; (3) dis-

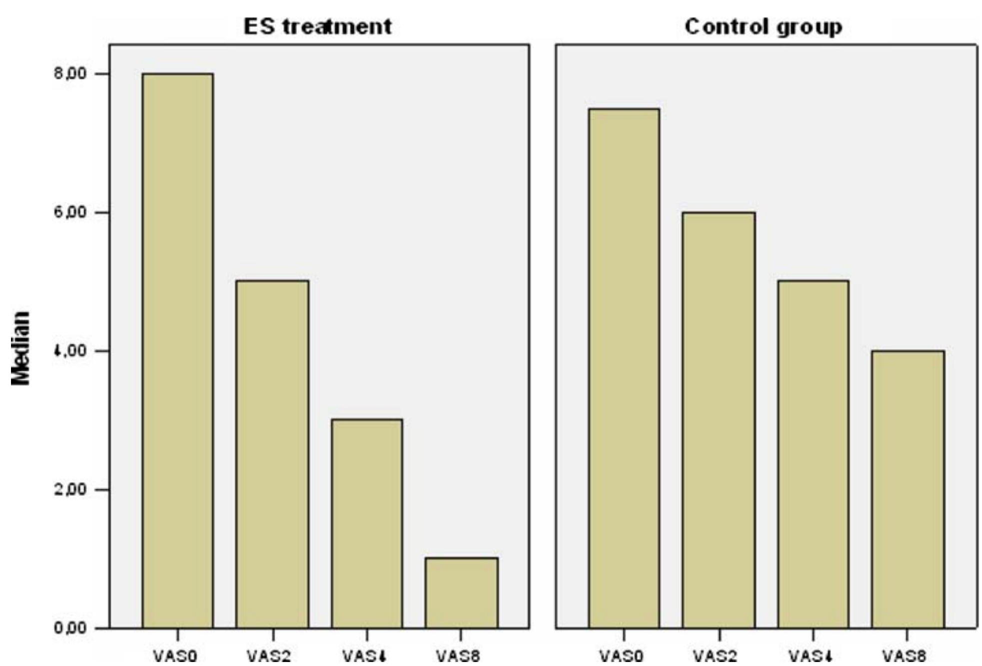

Fig. 5 Comparison of the results of VAS scores of the patients. *VAS0* VAS before treatment, *VAS2* VAS 2nd week, *VAS4* VAS 4th week, *VAS8* VAS 8th week

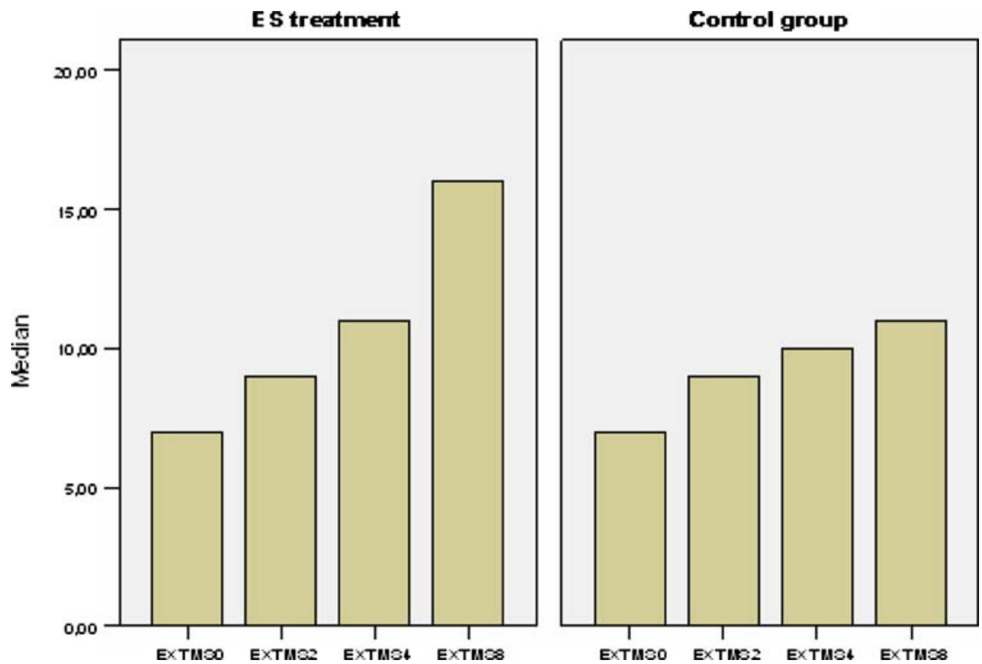

Fig. 6 Comparison of the results of extensor muscle strength measures of the patients. *EXTMS0* Extensor muscle strength before treatment, *EXTMS2* extensor muscle strength 2nd week, *EXTMS4* extensor muscle strength 4th week, *EXTMS8* extensor muscle strength 8th week

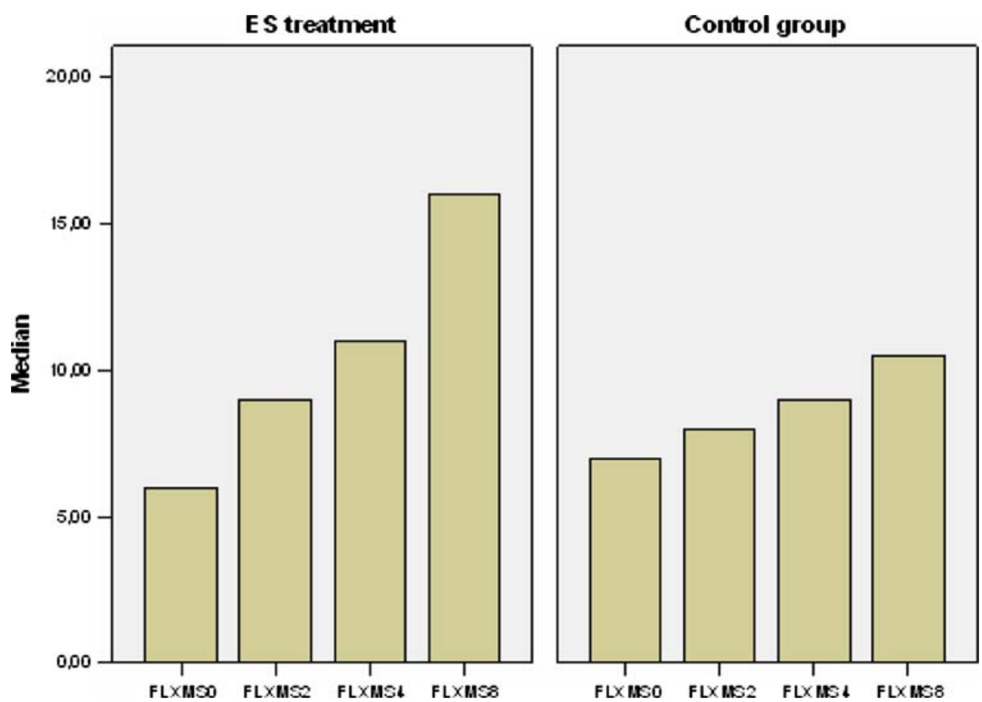

Fig. 7 Comparison of the results of flexor muscle strength measures of the patients. *FLXMS0* Flexor muscle strength before treatment, *FLXMS2* flexor muscle strength 2nd week, *FLXMS4* flexor muscle strength 4th week. *FLXMS8* flexor muscle strength 8th week

use: loss of flexibility, strength, and endurance; (4) depression: with significant loss, real or fantasized, reactive depression may result; and (5) disability: inability to perform activities of daily living [21]. The dysfunction, disability, QOL and depression components of this syndrome especially seem to be related to the aim of this study.

Weak trunk muscle and decreased endurance have been identified as significant risk factors in the development and incidence of low back problems. It is widely accepted that exercises play an important role in improving the trunk strength, endurance, QOL and function, treatment and prevention of low back pain [22–24].

Although there are many reports about the effectiveness of ES in patients with knee osteoarthritis (OA), studies showing the effectiveness of ES treatment are limited in patients with CLBP. Previous studies have showed that ES increases the muscle strength and the functional performance, decreases the pain in knee OA [13, 25–27].

Table 4 Baseline and the final results of quality of life, depression of the patients

	Group 1			Group 2		
	BT	AT	*P*	BT	AT	*P*
Depression (mean ± SD)	12.09 ± 7.03	2.80 ± 2.67	**0.001**	8.50 ± 5.76	3.33 ± 2.37	**0.001**
SF-36						
Physical function (mean ± SD)	0.61 ± 0.17	0.92 ± 0.09	**0.001**	0.58 ± 0.19	0.73 ± 0.17	**0.001**
Mental health (mean ± SD)	0.63 ± 0.15	0.82 ± 0.13	**0.001**	0.65 ± 0.12	0.70 ± 0.12	**0.001**
Pain (mean ± SD)	0.50 ± 0.17	0.87 ± 0.11	**0.001**	0.49 ± 0.19	0.64 ± 0.16	**0.001**
General health (mean ± SD)	0.52 ± 0.11	0.76 ± 0.11	**0.001**	0.56 ± 0.17	0.64 ± 0.16	**0.001**
Social function Med (min–max)	0.44 (0.22–0.65)	0.55 (0.44–0.77)	**0.004**	0.44 (0.33–0.55)	0.44 (0.33–0.66)	**0.006**
Physical role lim. Med (min–max)	0.5 (0.25–0.75)	1 (0.50–1)	**0.001**	0.5 (0.25–1)	0.65 (0.25–1)	**0.005**
Emotional role lim. Med (min–max)	0.50 (0–1)	1 (0.66–1)	**0.001**	0.66 (0.33–1)	0.82 (0.33–1)	**0.005**
Energy Med (min–max)	0.6 (0.30–0.80)	0.85 (0.50–1)	**0.001**	0.6 (0.25–0.70)	0.7 (0.25–0.90)	**0.001**

BT Before treatment, *AT* after treatment, *SF-36* Short Form 36, *Med (min–max)* median (minimum–maximum), *Mean* ± *SD* mean ± standard deviation, *Physical role lim* physical role limitation, *Emotional role lim* emotional role limitation

P < 0.05 significant

Table 5 Comparison of the final results of quality of life, depression scores of the patients

	Group 1 AT	Group 2 AT	*P*
Depression (mean ± SD)	2.80 ± 2.67	3.33 ± 2.37	>0.05
SF-36			
Physical function (mean ± SD)	0.92 ± 0.09	0.73 ± 0.17	**0.001**
Mental health (mean ± SD)	0.82 ± 0.13	0.70 ± 0.12	**0.006**
Pain (mean ± SD)	0.87 ± 0.11	0.64 ± 0.16	**0.001**
General health (mean ± SD)	0.76 ± 0.11	0.64 ± 0.16	**0.012**
Social function Med (min–max)	0.55 (0.44–0.77)	0.44 (0.33–0.66)	>0.05
Physical role lim. Med (min–max)	1 (0.50–1)	0.65 (0.25–1)	**0.001**
Emotional role lim. Med (min–max)	1 (0.66–1)	0.82 (0.33–1)	**0.010**
Energy Med (min–max)	0.85 (0.50–1)	0.7 (0.25–0.90)	**0.001**

AT After treatment, *SF-36* Short Form 36, *Med (min–max)* median (minimum–maximum), *Mean* ± *SD* mean ± standard deviation, *Physical role lim* physical role limitation, *Emotional role lim* emotional role limitation

P < 0.05 significant

ES causes an increase in the muscle strength with the changing in the muscle fibers and the capillary system. It also prevents the muscle atrophy due to the prolonged immobilization [28]. Besides improving the muscle strength, ES also decreases the pain and increases the functional performance due to the gate-control theory of Melzack and Wall [25, 28].

Kahanovitz et al. [14] performed a study to show the effectiveness of ES on normal trunk muscle strength and endurance in women. In this study, low-frequency ES (35 Hz, biphasic symmetrical balanced rectangular pulse) was compared with medium high-frequency ES (50–300 Hz, monophasic modified spike wave). The trunk muscle strength and endurance were evaluated before and after 20 training sessions (5 days a week for 4 weeks). There was a significant increase in isokinetic strength and endurance in the participants receiving low-frequency ES. We applied biphasic symmetrical balanced rectangular pulse ES in 50 Hz frequency on erector spina muscles and obliquus externius abdominis muscles and exercises for 24 training sessions (3 days a week for 8 weeks) in patients with CLBP. The trunk muscles strength and pain were evaluated before treatment and 2nd, 4th and 8th weeks of the therapy. Although there was no significant difference in pain and muscle strength between two groups at the 2nd week of therapy, there was significant difference between two groups at the 4th and 8th weeks of therapy.

In the literature there are limited studies about the effects of ES on trunk muscle strength, endurance, physical performance and QOL in patients with CLBP. We determined that ES was effective in patients with CLBP. We observed not only a decrease in pain, but also an increase in trunk muscle strength and improvement in physical function, functional performance and QOL. A recent study on the topic has found that the health related quality of life of patients with low back pain depended on functional status and psychological factors more than simple physical impairment [29]. In our study, the improvement of QOL and psychological status may be related to decreasing pain, increasing muscle strength and functional performance.

Selective training with ES or a combination of ES and exercises can be used to obtain optimal clinical results. ES may, therefore, become a valuable treatment modality for patients with CLBP before the exercise and conditioning programs. In addition, we can recommend ES treatment for the patients who have difficulty in or contraindications to perform an exercise program.

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