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The effectiveness of transcutaneous electrical nerve stimulation in the management of patients with complex regional pain syndrome: A randomized, double-blinded, placebo-controlled prospective study

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Abstract.
OBJECTIVE: To investigate the effect of transcutaneous electrical nerve stimulation (TENS) on clinical recovery in the management of patients with complex regional pain syndrome Type I (CRPS Type I).
MATERIAL AND METHOD: The study included 30 patients with stage 1 and 2 CRPS Type I in the upper extremities. The patients were randomly assigned into 2 groups, group 1 ($n = 15$) received conventional TENS therapy for 20 minutes, and group 2 ($n = 15$) received sham TENS therapy. The standard physical therapy program, which included contrast bath for 20 minutes; whirlpool bath for 15 minutes; assisted active and passive range of motion, and static stretching exercises up to the pain threshold, was also conducted in both groups. Therapy was scheduled for 15 sessions. A visual analogue scale (VAS) was used to assess spontaneous pain. The Leeds Assessment of Neuropathic Signs and Symptoms (LANSS) scale and the Douleur Neuropathique en 4 Questions (DN-4) were used to assess neuropathic pain. In addition, range of motion (ROM) was measured using a goniometer and volumetric measurements were taken to assess edema. Functional capacity was assessed using a hand dynamometer and the Duruöz Hand Index (DHI). All measurements were performed at baseline and after therapy.
RESULTS: Significant improvements were achieved in spontaneous and neuropathic pain scores, edema, ROM, and functional capacity in both groups ($p < 0.05$). However, improvement was found to be significantly greater in group 1 regarding pain intensity, neuropathic pain assessed using LANNS, edema, and in the 2^{nd}–3^{rd} finger ROM measurements ($p < 0.05$). No significant difference was detected between groups regarding improvements in 4^{th}–5^{th} finger and wrist ROM measurements, grip strength, and DN4 and DHI scores ($p > 0.05$).
CONCLUSION: The addition of TENS to the physical therapy program was seen to make a significant contribution to clinical recovery in CRPS Type 1.

Keywords: Complex regional pain syndrome, transcutaneous electrical nerve stimulation, pain, functional capacity

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1. Introduction

Complex regional pain syndrome (CRPS) accompanied by trauma history is characterized by severe pain, edema, changes in skin color and temperature at the involved sites, motor and sensorial disorders, and trophic changes [1,2]. Patients without nerve injury are classified as having CRPS Type I and those with nerve injury as CRPS Type II [3].

The annual incidence has been reported as 5.46–26.2/100000, and prevalence as 20.57/100000. There is female predominance with a female:male ratio of 3:1 [4]. Trauma is accepted as the most frequent predisposing factor, accounting for more than half of all cases [5]. Fractures are the most common etiologic factor related to trauma [6]. The incidence of CRPS Type I has been shown to vary from 8% to 25% after distal radius fractures [7]. Other etiologic factors include dislocation, ligament injuries, fasciitis, tendinitis, bursitis, arthritis, mastectomy, deep venous thrombosis or immobilization, nerve injuries that involve peripheral nerves or the dorsal root, brachial plexus lesions, postherpetic neuralgia, root lesions, tumors, and myocardial lesions [8]. Although the pathophysiology is unclear, it is thought that peripheral- and central neurogenic inflammation and micro-vascular dysfunction contribute to CRPS [8,9].

Complex regional pain syndrome generally manifests within a month of injury with burning ondermatomal pain, early swelling and edema, and increased heat and redness. Joint movements are usually restricted because of pain and edema in the early phases of the syndrome, which affects functional capacity. If not treated efficiently, fixed joint contractures may cause stiffness in range of motion (ROM) in later stages. There may be color and temperature changes and pseudomotor activity alterations with one hand red or pink, and hotter and sweatier than the other hand in the early phase [10]. The later stages are frequently characterized by skin, nail, and muscle atrophy, hypertrichosis, and bone demineralization [11].

In CRPS, the primary goals of treatment include relief of pain, prevention of contracture and deformities, and reduction of vascular stasis [12]. Treatment includes medical treatment, physical therapy and rehabilitation interventions, sympathetic nerve blockade, sympathectomy, spinal cord stimulation, surgery, and psychologic interventions [13,14]. In addition, a whirlpool bath, hot-cold packs, contrast bath, fluidotherapy, TENS, diadynamic current, interferential current and ultrasound (US), as well as an exercise program, massage, splinting, and elevation can be used in physical therapy [13,15]. The action of mechanism of the analgesic effects of TENS can be explained by the gate control theory as defined by Melzack and Wall, increased spontaneous opiate release, induction of local vasodilatation, and pain relief via stimulation of acupuncture points that could influence energy flow [13,16]. In CRPS management, TENS use can provide less painful exercise and functional activity during rehabilitation [17]. TENS can be safely and effectively used in the affected extremity because it has analgesic effects and helps to breakdown the vicious cycle of pain caused by the inhibitory effect of pain on extremity movements [18]. Studies have demonstrated the effectiveness of TENS therapy in acute musculoskeletal pain, postoperative pain control, and musculoskeletal disorders such as chronic low back and neck pain [19]. However, there is insufficient evidence of the effectiveness of TENS alone in the management of CRPS Type I [20]. Although some studies have indicated that conventional or acupuncture-like TENS interventions are beneficial in the treatment of neuropathic pain in CRPS, which is considered as one of the most common causes of neuropathic pain, there is no consensus regarding how TENS therapy should be used in CRPS [19,21–23].

The aim of the present study was to investigate the effectiveness of TENS therapy on spontaneous and neuropathic pain, edema, ROM, and functional capacity in the management of patients with CRPS Type I.

2. Materials and methods

2.1. Patients

The study included 30 patients (16 women and 14 men) who presented at the Physical Therapy and Rehabilitation Outpatient Clinic of Antalya Education and Research State Hospital, and were diagnosed as having Stage I or II CRPS Type I in their upper extremities between 2012 and 2013. The CRPS diagnosis was made in accordance with the International Association for Study of Pain (IASP) consensus statement [24].

Diagnostic criteria recommended by IASP:

1. Presence of an initiating noxious event or a cause of immobilization.
2. Continuing pain, allodynia or hyperalgesia of which the pain is disproportionate to any inciting event.

3. Evidence of edema at some time, change in skin blood blow, or abnormal pseudomotor activity in the region of the pain.
4. The diagnosis is excluded by the existence of conditions that would otherwise account for the degree of pain and dysfunction.

Criteria 2–4 must be satisfied [24].

Exclusion criteria were as follows: 1) presence of peripheral nerve injury; 2) presence of comorbid disease that could cause neuropathic pain such as diabetic neuropathy; 3) presence of renal dysfunction; 4) presence of a chronic pain syndrome (e.g. fibromyalgia, phantom pain, rheumatoid arthritis); 5) conditions that cause disruption of skin and extremity integrity such as burns, large tissue defects or amputations; 6) mental retardation; 7) unwillingness for participation; and 8) any previous treatment for CRPS.

2.2. Therapeutic intervention

The study was designed as double-blinded, randomized, placebo-controlled study. Randomization was performed by a physician who did not participate in the study. Thirty cards with two distinct colors were prepared. The patients were asked to choose a card, which was then used to allocate the patient to one of the treatment groups. The patients and physicians were blinded to the randomization.

Group 1: TENS + contrast bath + whirlpool bath + exercise program
Group 2: Sham TENS + contrast bath + whirlpool bath + exercise program

TENS: Conventional TENS (CHATTANOGA Intelect Mobile Stim 2777) was conducted to the involved extremity with the following parameters: frequency, 100 Hz; pulse duration, 50–100 ms; and amplitude that did not cause discomfort to the patient or muscle contraction. Two carbon electrodes (6×8 cm in size) were placed on the involved extremity using wet pads, with the active electrode on the dorsal aspect of the forearm and the passive electrode on the dorsal aspect of hand.

Sham TENS: The electrodes were placed on the involved extremity ina similar manner. The TENS device was operated but no current was given.

Whirlpool bath: The involved upper extremity was immersed in a whirlpool tank containing hot water (37°C) for 15 minutes.

Contrast bath: The involved upper extremity was repeatedly immersed in hot water (38°C) for 4 minutes followed by cold water (4°C) for one minute, with an overall duration of 20 minutes.

Exercise program: The exercise program for the involved upper extremity included extension, flexion, ulnar and radial deviation exercises for the wrist and flexion, and extension exercises for the metacarpophalangeal joints and proximal and distal interphalangeal joints. Daily active, active assistive, and passive range of motion and also stretching exercises were scheduled in 3 sets of 10 repeats.

All interventions were used in 15 sessions. The patients were allowed to use paracetamol (maximum dose: 4 g per day) according to their pain status.

2.3. Assessment parameters

In all patients, baseline sociodemographic and clinical characteristics (age, sex, dominant hand, etiology, stage, extremity involved) were recorded. All patients underwent routine laboratory evaluations (complete blood count, erythrocyte sedimentation rate, C-reactive protein (CRP), rheumatoid factor (RF), glucose, aspartate aminotransferase (AST), alanine transferase (ALT), blood urea nitrogen (BUN), creatinine, alkaline phosphatase, Ca, P, and urinalysis), bilateral hand and wrist radiographs (anterior-posterior/lateral), and 3-phase bone scintigraphy. Spontaneous and neuropathic pain, edema, ROM, and functional capacity were assessed before and after treatment because these are the major targets in the treatment of CPRS.

2.4. Assessment of pain severity

Resting pain was assessed using the visual analogue scale (VAS; 0 = no pain, 10 = intractable pain). The VAS is one of the most commonly used and validated tools, and has been in use since the early part of the 20th century. It has been found to be a reliable and valid tool in the assessment of pain, and depression and anxiety [25]. When VAS was compared with other pain scales, a strong correlation was found between successive measurements of pain made with the use of VAS [26].

2.5. Assessment of neuropathic pain

The Leeds Assessment of Neuropathic Signs and Symptoms (LANSS) scale and Douleur Neuropathique en 4 Questions (DN-4) were used to assess the neuropathic component of pain. The LANSS scale included 7 domains that assessed pain characteristics and sen-

sation. A total score $\geqslant 12$ indicates neuropathic pain. The Turkish version of the LANSS scale has been validated [27,28].

There are 10 questions in the DN-4, including 7 questions related to pain quality and 3 questions that investigate the presence of tactile sensation, pinprick sensation, and allodynia. A total score $\geqslant 4/10$ indicates neuropathic pain [25]. The validation and reliability studies of the DN-4 Turkish version were performed by Ünal Çevik et al. [30].

2.6. Measurement of edema

The upper extremity was immersed in a volumeter (Baseline, USA) with the 3^{rd} finger touching the base of the volumeter. The patient was instructed not to move the extremity until the end of the water displacement test. The volume of displaced water was measured in milliliters.

2.7. Assessment of mobility

To assess mobility, the distance between the 2^{nd} and 5^{th} finger pulp and distal palmar line was measured in centimeters using a ruler. Wrist mobility was assessed by measuring active wrist flexion, extension, radial and ulnar deviation using the neutral zero method with a standard goniometer.

2.8. Assessment of functional capacity

2.8.1. Hand grip strength

Hand grip strength was measured using a hydraulic hand dynamometer (Baseline, USA). Three measurements were taken at 15-second intervals with the patient in a sitting position with the shoulder in abduction, the elbow at 90° flexion, and the wrist at 0–30° extension. The average of 3 measurements was used.

2.8.2. Duruöz Hand Index

The Duruöz Hand Index (DHI) is a functional disability scale that has been successfully used to assess functional disability in different hand problems [31]. It has been validated for the evaluation of hand dysfunction in rheumatoid arthritis, osteoarthritis, systemic sclerosis, patients receiving hemodialysis, stroke patients, and diabetic hand dysfunction [32]. This scale consists of 18 questions in 5 categories, including ability in the kitchen, dressing, personal hygiene, office tasks, and other activities. All questions are rated as follows: 0, no difficulty; 1, little difficulty; 2, some difficulty; 3, almost impossible; 4, impossible. The overall score is obtained by totaling the individual scores [31].

2.9. Statistical analysis

Descriptive statistics were expressed as mean, standard deviation, rate and frequency. Normal distribution was tested using the Kolmogorov-Smirnov test. Variance homogeneity was tested using the Levene test. The independent sample t- and Mann-Whitney tests were used in the analysis of quantitative data. Chi-square and Fischer's exact tests were used in the analysis of qualitative data when appropriate. Paired-sample t-test, Wilcoxon test, and McNemar test were used in repeated measurements. SPSS for Windows version 21.0 was used for all statistical analyses. A value of $p < 0.05$ was accepted as statistically significant.

3. Results

The total study population of 30 patients comprised 15 patients (9 women and 6 men) in group 1, and 15 patients (7 women and 8 men) in group 2. The mean age was 49.07 $\pm$ 10.26 years in group 1 and 45.20 $\pm$ 17.65 years in group 2. Stage 1 CRPS was determined in 11 patients and Stage 2 in 4 of group 1, and 10 patients had Stage 1 CRPS and 5 had Stage 2 in group 2. There was no statistically significant difference between groups 1 and 2 regarding age and sex distribution, dominant hand rate, and distribution of disease stage and extremities involved ($p > 0.05$). The sociodemographic characteristics of the patients are presented in Table 1.

In group 1, the etiologic factors included distal radius fractures (11 patients), radial corpus fracture (1 patient), excision of cystic mass from soft tissue (1 patient), and fracture in the 1^{st} metacarpal bone (1 patient). In group 2, the etiologic factors included distal radius fractures (10 patients), radial head fracture (1 patient), scaphoid bone fracture (1 patient), excision of cystic mass from soft tissue (1 patient), olecranon fracture and triceps tendon rupture (1 patient), and ligament injury in the 5^{th} proximal interphalangeal joint (1 patient).

3.1. Pain intensity

There was no significant difference between the groups in pretreatment VAS scores ($p > 0.05$). The VAS scores were significantly decreased in both groups after treatment ($p < 0.05$). However, the decrease in group 1 was significantly greater than in group 2 ($p < 0.05$) (Table 2).

Table 1
Comparison of sociodemographic characteristics of the patients

	Group 1	Group 2	p
Age (Mean ± SD)	49.07 ± 10.26	45.20 ± 17.65	0.471
Sex (N, %)			
Female	9 (60%)	7 (46.7%)	0.464
Male	6 (40%)	8 (53.3%)	
Dominant hand (N, %)			
Right	14 (93.3%)	15 (100%)	0.990
Left	1 (6.7%)	0 (0%)	
Stage I (N, %)	11 (73.3%)	10 (66.7%)	0.690
Stage II (N, %)	4 (26.7%)	5 (23.7%)	
Involved site (N, %)			
Right	12 (80%)	8 (53.3%)	0.121
Left	3 (20%)	7 (46.7%)	

$^{**}p < 0.01$; $^{*}p < 0.05$.

Table 2
Comparison of pre-and post-treatment VAS, DN4 and LANSS scores between groups

	Group 1	Group 2	p
VAS (0–100 mm)			
Pretreatment (Mean ± SD)	47.47 ± 13.20	35.33 ± 20.91	0.070
Posttreatment (Mean ± SD)	14.27 ± 10.10	23.27 ± 15.83	0.074
Change (Mean ± SD)	−33.20 ± 10.81	−12.07 ± 10.29	0.000**
P	0.000**	0.000**	
DN4			
Pretreatment (Mean ± SD)	4.40 ± 1.84	4.53 ± 1.13	0.813
Posttreatment (Mean ± SD)	2.20 ± 1.78	3.00 ± 1.41	0.184
Change (Mean ± SD)	−2.20 ± 1.47	−1.53 ± 0.92	0.148
P	0.000**	0.000**	
LANNS			
Pretreatment (Mean ± SD)	15.00 ± 5.92	11.53 ± 3.93	0.069
Posttreatment (Mean ± SD)	10.40 ± 6.27	9.47 ± 4.16	0.634
Change (Mean ± SD)	−4.60 ± 3.42	−2.07 ± 2.89	0.037*
P	0.000**	0.015*	

VAS: Visual Analogue Scale; DN-4: Douleur Neuropathique 4; LANSS: Leeds Assessment of Neuropathic Signs and Symptoms; $^{**}p < 0.01$; $^{*}p < 0.05$.

3.2. Assessment of neuropathic pain

There was no significant difference between the groups in pretreatment DN-4 scores ($p > 0.05$). The DN-4 scores were significantly decreased in both groups after treatment ($p < 0.05$). The decrease was similar in both groups ($p > 0.05$).

There was no significant difference between the groups in pretreatment LANSS scores ($p > 0.05$). The LANSS scores were significantly decreased in both groups after treatment ($p < 0.05$). However, the decrease in group 1 was significantly greater than in group 2 ($p < 0.05$) (Table 2).

3.3. Edema

There was no significant difference between groups 1 and 2 in pretreatment volumetric edema values ($p > 0.05$). Volumetric edema values were significantly decreased in both groups after treatment ($p < 0.05$). However, the decrease in group 1 was significantly greater than in group 2 ($p < 0.05$) (Table 3).

3.4. Mobility

There was no significant difference between groups 1 and 2 in the pre-treatment distance between the 2^{nd} and 5^{th} finger pulp and distal palmar line values ($p > 0.05$). After treatment, the distance between the 2^{nd} and 4^{th} finger pulp and distal palmar line values were significantly decreased in both groups ($p < 0.05$). In group 1, the distance between the 5^{th} finger pulp and the distal palmar line value was significantly decreased ($p < 0.05$); no significant difference was detected in group 2 ($p > 0.05$). After treatment, the decrease in the distance between the 2^{nd} and 3^{rd} finger pulp and distal palmar line values in group 1 were significantly greater than in group 2 ($p < 0.05$). No such difference was

Table 3
Comparison of pre- and post-treatment amounts of volumetric edema between groups

	Group 1	Group 2	p
Edema amount (mL)			
Pretreatment (Mean ± SD))	537.33 ± 55.25	523.00 ± 66.46	0.526
Posttreatment (Mean ± SD)	525.00 ± 53.59	520.00 ± 65.82	0.821
Change (Mean ± SD)	−12.33 ± 13.87	−3.00 ± 4.14	0.005**
p	0.004**	0.014*	

**$p < 0.01$; *$p < 0.05$.

Table 4
Comparison of pre- and post-treatment measurement of digital pulpa-palmar line distance between groups

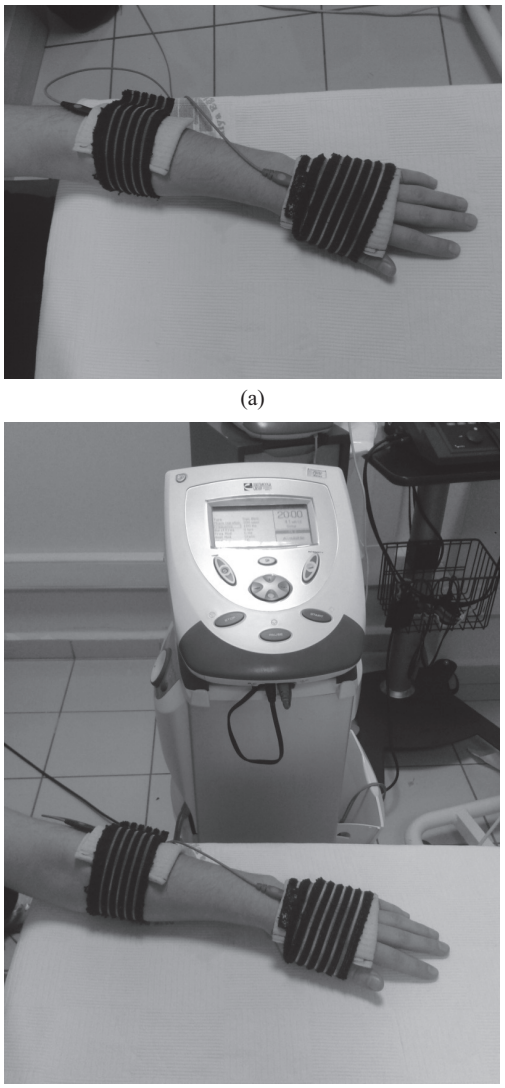
	Group 1	Group 2	p
2. digital pulpa-palmar line			
Pretreatment (Mean ± SD)	30.87 ± 14.04	26.60 ± 14.02	0.412
Posttreatment (Mean ± SD)	18.53 ± 11.65	19.60 ± 14.22	0.824
Change (Mean ± SD)	−12.33 ± 7.78	−7.00 ± 5.15	0.037*
p	0.000**	0.000**	
3. digital pulpa-palmar line			
Pretreatment (Mean ± SD)	31.13 ± 13.98	26.27 ± 13.31	0.337
Posttreatment (Mean ± SD)	18.07 ± 10.32	20.33 ± 13.09	0.603
Change (Mean ± SD)	−13.07 ± 8.69	−5.93 ± 5.43	0.012*
p	0.000**	0.001**	
4. digital pulpa-palmar line			
Pretreatment (Mean ± SD)	27.20 ± 11.95	25.67 ± 14.03	0.750
Posttreatment (Mean ± SD)	16.67 ± 9.27	19.47 ± 13.94	0.522
Change (Mean ± SD)	−10.53 ± 7.55	−6.20 ± 4.04	0.060
p	0.000**	0.000**	
5. digital pulpa-palmar line			
Pretreatment (Mean ± SD)	22.07 ± 11.82	22.07 ± 17.98	1.000
Posttreatment (Mean ± SD)	13.07 ± 7.99	18.20 ± 16.32	0.283
Change (Mean ± SD)	−9.00 ± 7.52	−3.87 ± 9.37	0.109
p	0.000**	0.132	

**$p < 0.01$; *$p < 0$.

Table 5
Comparison of pre- and post-treatment wrist ROM values between groups

	Group 1	Group 2	p
Flexion			
Pretreatment (Mean ± SD)	50.47 ± 20.33	41.20 ± 24.50	0.269
Posttreatment (Mean ± SD)	67.00 ± 15.45	61.00 ± 18.34	0.341
Change (Mean ± SD)	16.53 ± 9.69	19.80 ± 18.12	0.543
P	0.000**	0.001**	
Extension			
Pretreatment (Mean ± SD)	41.67 ± 19.24	33.67 ± 23.94	0.322
Posttreatment (Mean ± SD)	55.67 ± 17.82	50.20 ± 19.94	0.435
Change (Mean ± SD)	14.00 ± 10.56	16.53 ± 14.77	0.593
P	0.000**	0.001**	
Radial deviation			
Pretreatment (Mean ± SD)	14.00 ± 6.04	10.60 ± 6.64	0.153
Posttreatment (Mean ± SD)	18.00 ± 4.55	16.33 ± 4.81	0.338
Change (Mean ± SD)	4.00 ± 3.38	5.73 ± 5.51	0.308
P	0.003**	0.002**	
Ulnar deviation			
Pretreatment (Mean ± SD)	21.33 ± 9.15	17.27 ± 8.71	0.223
Posttreatment (Mean ± SD)	27.13 ± 5.32	24.00 ± 6.04	0.143
Change (Mean ± SD)	5.80 ± 5.44	6.73 ± 7.29	0.694
P	0.007**	0.005**	

**$p < 0.01$; *$p < 0.05$.



(a) (b)

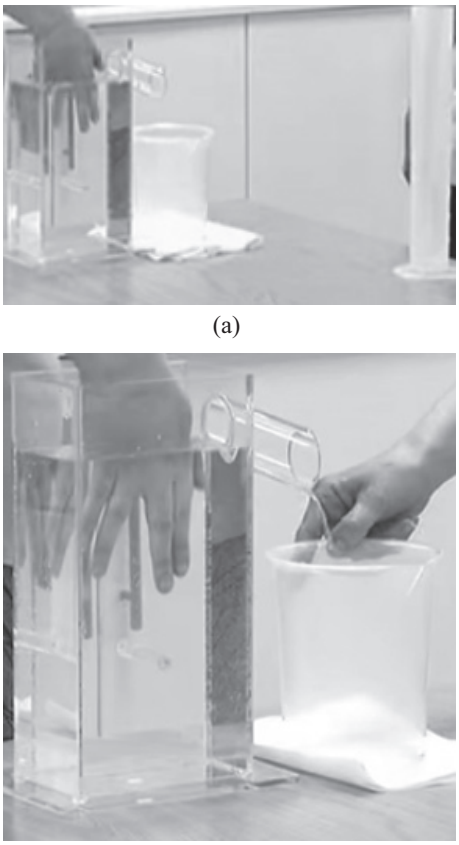
Fig. 1. (a) and (b): Transcutaneous electrical nerve stimulation.

detected in the distance between the 4^{th} and 5^{th} finger pulp and distal palmar line values ($p > 0.05$) (Table 4).

There was no significant difference between groups 1 and 2 in the pre-treatment wrist ROM measurements ($p > 0.05$). The wrist ROM values were significantly increased in both groups after treatment ($p < 0.05$). The increase was similar in both groups ($p > 0.05$) (Table 5).

3.5. Functional capacity

There was no significant difference between groups 1 and 2 in pretreatment grip strength values ($p > 0.05$).



(a) (b)

Fig. 2. (a) and (b): Measurement of hand edema with volumeter.

Grip strength values were significantly increased in both groups after treatment ($p < 0.05$). The increase was similar in both groups ($p > 0.05$) (Table 6).

3.6. Duruöz Hand Index

There was no significant difference between groups 1 and 2 in pretreatment DHI scores ($p > 0.05$). DHI scores were significantly decreased in both groups after treatment ($p < 0.05$). The decrease was similar in both groups ($p > 0.05$) (Table 6).

4. Discussion

In this study, significant improvements were achieved in spontaneous and neuropathic pain scores, edema, ROM and functional capacity using TENS and sham TENS therapies used together with contrast bath, whirlpool bath, and an exercise program. The improvements in pain severity, neuropathic pain measured us-

Table 6
Comparison of pre- and post-treatment grid strength and scores of Duruöz Hand Scale

	Group 1	Group 2	p
Grid strength (kg)			
Pretreatment (Mean ± SD)	7.60 ± 7.25	10.53 ± 9.32	0.344
Posttreatment (Mean ± SD)	14.47 ± 9.20	13.93 ± 9.71	0.878
Change (Mean ± SD)	6.87 ± 5.34	3.40 ± 3.92	0.052
P	0.000**	0.005**	
DHS scale			
Pretreatment (Mean ± SD)	48.67 ± 23.58	46.07 ± 20.31	0.749
Posttreatment (Mean ± SD)	17.80 ± 13.20	21.40 ± 14.11	0.476
Change (Mean ± SD)	−30.87 ± 16.06	−24.67 ± 13.67	0.265
P	0.000**	0.000**	

DHS: Duruöz hand scale; $^{**}p < 0.01$; $^{*}p < 0.05$.

Fig. 3. Measurement of hand grip strength using hydraulic hand dynamometer.

ing LANSS, edema, and ROM of the 2–3$^{\mathrm{rd}}$ fingers were found to be significantly greater in the TENS group. However, no significant differences between the groups were determined in terms of neuropathic pain measured using DN4, and function and ROM of the wrist.

Pain and hyperalgesia are the most commonly encountered symptoms in patients with CRPS, despite variable symptomatology [33]. In general, the severity of pain is inappropriately high given the severity of the injury or disease causing the pain [34]. The primary goals in the management of CRPS should be pain relief, vascular stasis, and contracture prevention. The vicious cycle of pain and immobility can be broken with pain relief, which prevents its previous inhibitory effect on movement. There is insufficient evidence regarding the effectiveness of TENS use alone in the management of CRPS Type 1. Several studies have compared physical therapy programs containing TENS with other therapies [35,36], compared TENS therapy with other therapies [17,37], and have investigated standard therapies containing TENS [23,37,39]. However, to the best of our knowledge, no studies have compared the different techniques of TENS therapies or investigated the effectiveness of TENS therapy in the management of CRPS Type 1. In the available studies, information is lacking regarding parameters such as current intensity [17,36,40], current frequency [36, 40,41], duration [36,42], electrode type [36,39–42] or application site [37].

In 2 case reports, recovery from CRPS Type 1 was reported with the use of TENS therapy [40,42]. Kesler et al. found improvement in symptoms and signs of CRPS using TENS therapy in a study on a pediatric population [41]. In a study by Hazneci et al., patients with Stage 1–2 CRPS were randomly assigned into two groups and one group received contrast bath therapy and an exercise program with TENS or intermittent ultrasound therapy (US) on the stellate ganglion. Improvements were reported in spontaneous pain intensity, edema, mobility and hand grip strength in both groups, although significantly greater improvements were found in pain and hand grip strength in the TENS group [17]. Similarly, in the current study, although there were marked improvements in spontaneous pain intensity, edema, mobility, and hand grip strength in both groups, the improvements in pain intensity, edema, and 2$^{\mathrm{nd}}$–3$^{\mathrm{rd}}$ finger ROM measurements were greater in the TENS group than in the sham TENS group. Improved parameters in both groups could be related to the analgesic and anti-edematous effects of the contrast bath, whirlpool bath, and exercises that were conducted in combination with TENS therapies. ROM is greater in the 4–5$^{\mathrm{th}}$ fingers because

the synovial sheaths of the flexor tendons are longer. In the current study, 2^{nd}–3^{rd} ROM measurements were found to be more limited. After treatment, the increase in 2^{nd}–3^{rd} finger ROM was greater in the TENS group when compared with the sham TENS group.

CRPS is characterized by neuropathic pain during the disease course. The pain may be burning, throbbing, squeezing or tingling [43]. Somers et al. [23] induced CRPS Type 2 in rats by sciatic nerve injury and assessed thermal and mechanical allodynia thresholds by applying TENS therapy at various frequencies to lumbar paravertebral or acupuncture points [23]. In their study, the best improvement was achieved using high-frequency TENS on skin overlying the paraspinal muscles in mechanical allodynia, and with low-frequency TENS to acupuncture points in thermal allodynia [23]. In another study on patients with diabetes and neuropathic pain, improvement was greater in patients who received TENS therapy compared with those who received placebo. A similar effect was detected when TENS therapy was given to the patients with failure in the placebo group [39]. Norrbrink et al. [45] also assessed the effectiveness of low- and high-frequency TENS therapy in 24 patients with neuropathic pain after spinal cord injury. A significant improvement was demonstrated in the global pain recovery scale in 29% of the patients using high-frequency TENS therapy and in 38% with low-frequency TENS therapy [45]. The results of the current study are in agreement with above-mentioned studies. However, neuropathic pain was evaluated using both LANNS and DN-4 scales. In the validation study for the Turkish version of DN-4 by Çevik et al., the authors concluded that although the DN-4 scale seems more sensitive, LANSS scores would be more sensitive in patients with CRPS because of skin colorization, which is more frequently seen in these patients [30]. In the current study, it was thought that TENS was effective in the treatment of the neuropathic component of pain in CRPS Type, based on the finding that there were significantly greater improvements in neuropathic pain scores assessed using LANSS in the TENS group of this study.

Distal edema, which is seen in 80% of patients with CRPS, may lead to limitations in ROM and hand function [46,47]. Outcomes regarding edema assessment are contradictory in the management of CRPS [17,47]. In a study by Hazneci et al. [17] in which TENS and US therapies on stellate ganglion were compared, no significant improvement was found in either group. It is possible to fail to detect any improvement in edema, when there is pre-treatment edema and atrophic hand and forearm muscles, which then undergo hypertrophy due to the exercise during treatment. In the current study, although an improvement was detected in both groups in edema using volumetric analysis, the improvement was significantly greater in the TENS group.

In this study, the Duruöz Hand Index was used to assess hand function in addition to measurements of hand grip strength. There was improvement in the DHI scores in both groups after treatment, although no significant difference was detected between the groups. This could be due to the limited sample size. In addition, it may have been difficult for patients to understand the DHI due to the low sociocultural level of the study population. As sensorial recovery and coordination may be delayed when compared with improvements in ROM and muscle strength, long-term follow-up is recommended in terms of functional recovery.

The main limitation of this study was the limited sample size. In addition, only short-term follow-up results were evaluated with assessments performed at baseline and after treatment. No long-term results were available. Moreover, the response to treatment of patients at different stages of the disease could not be compared because the study included a limited number of patients with Stage 1 or 2 disease. Finally, TENS therapy alone was not compared with sham TENS therapy because of ethical concerns; therefore, all patients also received a therapy program including contrast bath, whirlpool bath, and exercise.

In conclusion, the addition of TENS to a physical therapy program can improve the effectiveness of treatment on spontaneous pain, neuropathic pain, edema, and ROM in the management of CRPS Type 1. However, there is a need for further randomized, placebo-controlled studies with greater patient numbers and longer follow-up to investigate the effectiveness of TENS therapy alone.

Conflict of interest

None to report.

References

[1] Fischer GL, Perez SGM, Nouta J, Zuurmond WA, Scheffer PG. Oxidative Stress in Complex Regional Pain Syndrome (CRPS): No Systemically Elevated Levels of Malondialdehyde, F2-Isoprostanes 80 HdG in a Selected Sample Of Patients. İnt. J. Mol. Sci. 2013; 14: 7784-7794.

[2] Harden RN, Bruehl SP. Diagnosis of complex regional pain syndrome: signs, symptoms, and new empirically derived diagnostic criteria. Clin J Pain 2006; 22: 415-9.
[3] Harden RN, Bruehl SP. Proposed new diagnostic criteria for complex reginal pain syndrome. PainMed 2007; 8: 326-31.
[4] Mos M, Bruijn AG, Huygen FJ, Dieleman JP, Stricker BH, Sturkenboom MC. The incidence of complex regional pain syndrome: A population-based study. Pain 2007; 129: 12-20.
[5] Buschnell TG, Cobo-Castro T. Complex Regional Pain Syndrome: Becoming More or Less Complex? Manuel Therapy 1999; 4: 221-22.
[6] Birklein F, Handwerker HO. Complex regional pain syndrome: How to resolve the complexity? Pain 2001; 94: 1-6.
[7] Herlyn P, Müller-Hike B, Wendt M, Hecker M, Mittlmeir T, Gradl G. Frequencies of Polymorphisms in Cytokines, Neurotransmitters and Adrenergic Receptors in Patients With Complex Regional Pain Syndrome Type I After Distal Radial Fracture. Clin J Pain 2010; 26: 175-181.
[8] Akman MN, Atalay A. Kompleks bölgesel ağrı sendromu. Türkiye Klinikleri J intMedSci 2006; 5: 64-72.
[9] Ofluoğlu D, Akyüz G. Kompleks bölgesel ağı sendromu tip 1: genel klinik yaklaşım. Türk Fiz Tıp Rehab Derg. 2008; 54: 112-5.
[10] Field J. Complex regional pain syndrome: a review. J Hand Surg Eur 2013 Jul; 38(6): 616-26.
[11] Inchiosa Jr. MA. Phenoxybenzamine in complex regional pain syndrome: potential role and novel mechanisms. Anesthesiol Res Pract. 2013: 978615. doi: 10.1155/2013/978615. Epub 2013 Dec 19.
[12] Kozanoğlu ME, Sur S. Refleks Sempatik Distrofi Sendromu. T Klin J PM &R 2001; 1: 189-196.
[13] Dinçer K. Kompleks Bölgesel Ağrı Sendromu. In: Beyazova M, Kutsal YG, editors. Fiziksel Tıp ve Rehabilitasyon. Ankara: Güneş Tıp Kitabevi, 2011; 2143-2157.
[14] Tran De QH, Duong S, Bertini P, Finlayson RJ. Treatment of complex regional pain syndrome: A review of the evidence. Can J Anesth/J Can Anesth 2010; 57: 149-166.
[15] Eskiyurt N, Karan A. Üst Ekstremite Ağrıları. In: Oğuz H, Dursun E, Dursun N, editors. Tıbbi Rehabilitasyon. İstanbul: Nobel Tıp Kitabevleri 2004; 1126-1130.
[16] Melzack R, Wall PD. Pain Mechanisms: A New Theory. Sciense 1965; 150: 971-979.
[17] Hazneci B, Tan K, Özdem T, Dinçer K, Kalyon TA. Refleks sempatik distrofi sendromu tedavisinde transkutanöz elektrostimülasyon ve ultrasonun etkileri. Türk Fiz Tıp Rehab Derg. 2005; 51(3): 83-89.
[18] Koyuncu H, Karacan İ. Temel elektroterapi. In: Oğuz H, Dursun E, Dursun N, editors. Tıbbi Rehabilitasyon. İstanbul: Nobel Tıp Kitabevleri 2004; 427-9.
[19] Alper S. Transkütan Elektriksel Sinir Stimülasyonu. In: Beyazova M, Kutsal YG, editors. Fiziksel Tıp ve Rehabilitasyon Ankara: Güneş Tıp Kitabevi 2000; 790-798.
[20] Perez RS, Zollinger PE, Dijkstra PU, Thomassen-Hilgersom IL, Zuurmond WW, Rosenbrand KCJ, et al. Evidence based guidelines for complex regional pain syndrome type 1. BMC Neurology 2010; 1-14.
[21] Claydon LS. Neuropathic pain: An evidence-based update. Journal of Physiotherapy 2009; 38: 68-74.
[22] Akyüz G. Transkütan Elektriksel Sinir Stimülasyonu. In: Tuna N, editors. Elektroterapi. İstanbul: Nobel Tıp Kitabevi 2000; 163-176.
[23] Somers DL, Clemente FR. Transcutaneous Electrical Nerve Stimulation for the Management of Neuropathic Pain: The Effects of Frequency and Electrode Position on Prevention of Allodynia in a Rat Model of Complex Regional Pain Syndrome Type II. Phys Ther 2006; 86: 698-709.
[24] Merskey H, Bogduk N. Classification of chronic pain: Descriptions of chronic pain syndromes and definition of terms. Seattle: IASP press 1994: 41-42.
[25] Ho K, Spence J, Murphy MF. Review of pain-measurement-tools. Ann Emerg Med 1996; 27: 427-432.
[26] McCormack HM, Home DJ, Sheather S. Clinical applications of visual analogue scales: A critica lreview. Paychol Med 1988; 18: l007-1019.
[27] Bennet M. The LANSS Pain Scale: The Leeds assesment of neuropathic symptoms and signs. Pain 2001; 92: 147-157.
[28] Yücel A, Şenocak M. Results of the Leeds assessment of neuropathic symptoms and signs pain scale in Turkey: A validation study. Pain 2004; 5(8): 427-432.
[29] Bouhassira D, Attal N, Alchaar H, Boureau F, Brochet B, Bruxelle J, et al. Comparison of Pain Syndromes Associated With Nervous or somatic lesions and development of a new neuropathic pain diagnostic questionnaire (DN4). Pain 2005; 114: 29-36.
[30] Unal-Çevik İ, Sarıoğlu-Ay S, Evcik D. A Comparison of the DN4 and LANSS Questionnaires in the Assesfment of Neuropathic Pain: Validity and Reliability of the Turkish Version of DN4. The Journal of Pain 2010; 11: 1129-1135.
[31] Duruöz MT, Poiraudeau S, Fermanian J, et al. Development and validation of a rheumatoid hand functional disability scale that assesses functional handicap. J Rheumatol. 1996; 23: 1167-1172.
[32] Turan Y, Duruöz MT, Aksakalli E, Gürgan A. Validation of Duruöz Hand Index for diabetic hand dysfunction. J Investig Med. 2009; 57(8): 887-91.
[33] Correll GE, Maleki J, Gracely EJ, Muir JJ, Harbut RE. Subanesthetick etamine in fusion therapy: A retrospective analysis of a novel therapeutic approach to complex regional pain syndrome. Pain Med 2004; 5: 263-75.
[34] Rho RH, Brewer RP, Lmer TJ, Wilson PR. Complex Regional Pain Syndrome. Mayo Clin. Proc. 2002; 77: 174-180.
[35] Oerlemans HM, Oostendorp RA, Boo T, Goris RJ. Pain and reduced mobility in complex regional pain syndrome I: Outcome of a prospective randomised controlled clinical trial of adjuvant physical therapy versus occupational therapy. Pain 1999; 83: 77-83.
[36] Lee BH, Scharff L, Sethna NF, McCarthy CF, Scott-Sutherland J, Shea AM, et al. Physical therapy and cognitive-behavioral treatment for complex regional pain syndromes. J Pediatr 2002; 141: 135-40.
[37] Robaina FJ, Rodriguez JL, Vera JA, Martin MA. Transcutaneous electrical nevre stimulation and spinal cord stimulation for pain relief in reflex sympathetic dystrophy. Stereotact Funct Neurosurg 1989; 52: 53-62.
[38] Aşkın A. Kompleks Bölgesel Ağrı Sendromlu Hastalarda Düşük ve Yüksek Dozda Uygulanan Terapötik Ultrason Tedavisinin Klinik İyileşme ve Sempatik Disfonksiyon Üzerine Etkisinin Araştırılması. Süleyman Demirel Üniversitesi Tıp Fakültesi, Fiziksel tıp ve Reahabiliasyon Kliniği Tıpta Uzmanlık Tezi. Isparta, 2010.
[39] Şahin F, Yılmaz F, Kotevoglu N, Kuran B. Efficacy of salmoncalcitonin in complex regional pain syndrome (type 1) in addition to physicaltherapy. Clinical Rheumotology 2006; 25: 143-148.
[40] Bodenheim R, Bennet JH. Reversal of a Sudeck's Atrophy by the Adjunctive Use of Transcutaneous Electrical Nerve Stimulation A Case Report. Phys Ther. 1983; 63: 1287-1288.

[41] Kesler RW, Saulsbury FT, Miller LT, Rowlingson JC. Reflex Sympathetic Dystrophy in children: Treatment With Transcutaeous Electrical Nerve Stimülation. Pediatrics 1988; 82: 728-732.
[42] Stilz RJ, Carron H, Sanders DB. Case History Number 96 Reflex Sympathetic Dystrophy In a 6-Year-Old: Successful Treatment by Transcutaneous Nerve Stimulation. Anesthesia and Analgesia 1977; 56: 438-442.
[43] Schattschneider J, Binder A, Siebrecht D, Wasner G and Baron R. Complex Regional Pain Syndromes: The Influence of Cutaneous and Deep Somatic Synpathetic Innervation on Pain. Clin J Pain 2006; 22: 240-244.
[44] Kumar D, Marshall HJ. Diabetic Peripheral Neuropathy: Amelioration of Pain With Transcutaneous Electrostimulation. Diabetes Care 1997; 20: 1702-1705.
[45] Norrbrink C. Transcutaneous electrical nevre stimulation for treatment of spinal cord injury neuropathic pain. Journal of Rehabilitation Research & Development 2009; 46(1): 85-94.
[46] Gürsoy S. Gizemli Bir Hastalık: Kompleks Bölgesel Ağrı Sendromu. Türkiye Klinikleri J Neurol-Special Topics 2010; 3(4): 107-13.
[47] Bear-Lehman J, Abreu BC. Evaluating the Hand: Issues in Reliability and Validity. Phys Ther. 1989; 69: 1025-1033.