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Original Article

The effects of whirlpool bath and neuromuscular electrical stimulation on complex regional pain syndrome

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Abstract. [Purpose] The aim of the present study was to investigate and compare the effects of whirlpool bath and neuromuscular electrical stimulation on complex regional pain syndrome. [Subjects and Methods] Sixty outpatients (30 per group) with complex regional pain syndrome participated. They received 15 treatment 5 days per week for 3 weeks. The outcome measures were the visual analogue scale for pain, edema, range of motion of the wrist (flexion and extension), fingertip-to-distal palmar crease distance, hand grip strength, and pinch strength. All parameters were measured at baseline (week 0) and at the trial end (week 3). [Results] There were significant improvements in all parameters after therapy in both groups. The whirlpool bath group showed significantly better improvements in the visual analogue score, hand edema, hand grip strength, wrist range of motion (both flexion and extension), fingertip-to-distal palmar crease distance, and the three-point and fingertip pinch strengths than the neuromuscular electrical stimulation group; however, the lateral pinch strengths were similar. [Conclusion] Both whirlpool bath and neuromuscular electrical stimulation are effective in the treatment of complex regional pain syndrome, but the efficacy of the whirlpool bath treatment was better.

Key words: Complex regional pain syndrome, Whirlpool bath, Neuromuscular electrical stimulation

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INTRODUCTION

Complex regional pain syndrome (CRPS) is a condition characterized by severe pain in the affected extremities, autonomic vasomotor dysfunction, dystrophic changes in the skin and bone, impaired mobility, and psychological changes. Various traumatic or non-traumatic events, diseases, and medications may cause CRPS, but the initial event is usually a traumatic injury or major infectious disease[1)]. Cases of CRPS are classified as either type I or type II. CRPS type I does not have a specific pathology; however, CRPS type II is usually caused by peripheral nerve injuries that occur after trauma and cause burning pain[2)]. The diagnostic criteria are pain, allodynia, hyperalgesia, edema, and vasomotor and sudomotor changes[3)]. CRPS treatment requires a multidisciplinary approach. The main treatment method is physiotherapy; however, patients may additionally receive sympathetic ganglion block, electro-acupuncture, and, in cases of conservative treatment failure, they may undergo surgery[4, 5)]. One option is whirlpool bath treatment, which relaxes muscle tension and decreases pain[6)]. Another is neuromuscular electrical stimulation (NMES), which in addition to alleviating muscle contraction, also has analgesic effects. In clinical practice, NMES is used for pain control, muscle education, and venous stasis[7)]. We use NMES to treat CRPS due to its positive effects in reducing pain and edema, and its improvement of muscle performance[7)]. Notably, no other studies have evaluated the use of NMES in treating CRPS. In this study, we investigated and compared the effectiveness of the whirlpool bath and neuromuscular electrical stimulation in the treatment of CRPS.

SUBJECTS AND METHODS

A total 60 patients who were diagnosed with the first stage of CRPS type I in the upper extremity per the Budapest Criteria were enrolled[8)]. Patient complaints were recorded, and physical examinations, laboratory tests, and radiological examinations were carefully performed to determine a differential diagnosis, distinguishing CRPS cases from other diseases that may lead to edema, and sudomotor and vasomotor changes. Patients suffering from peripheral neuropathy or a nerve lesion, who had a history of hand fracture, who were diagnosed with systemic disease (such as diabetes mellitus, infection, or tumor), or who had an open hand wound were excluded from the study.

The demographic data of the patients were recorded, and the patients were randomized into two 30-patient groups. Patients in group 1 received 15 sessions distributed over 3

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weeks (5 days per week) of underwater ultrasound therapy, whirpool bath, and exercise therapy, while the group 2 patients received underwater ultrasound therapy, NMES, and exercise therapy. Range of joint motion (ROM) exercises and stretching exercises up to each patient's pain threshold were performed by both groups. Post-treatment assessment was performed on the last treatment day. Patients were only allowed to use paracetamol, 500 mg, three times daily for analgesia. This study was approved by the site Institutional Ethical Committee (IEC), and written consent was obtained from all the participants.

Ultrasound therapy was performed by placing the ultrasound probe 1–2.5 cm away from the hand and wrist underwater. The treatment intensity was 1.5 W/cm^2, and the probe was slowly moved parallel to the treatment area for 5 min[9].

A Chiron extremity caldron (Chirana Progress, Slovakia) was used for the whirlpool bath treatment. An electric motor creates eddies within the water. The water temperature was set at 40 °C and monitored with a thermometer. Hands and wrists were positioned in the most comfortable resting position that would not impede perfusion and placed in the water tank for 30 min[10].

A Cefar device (Cefar, European Union) was used to perform the NMES treatment. Symmetrical biphasic current pulses were applied at a 30 Hz frequency for 300 ms. Each muscle group (flexor and extensor muscle groups) was treated for 20 min, beginning with the flexor muscle group and finishing with the extensor muscle group of the hand[11].

Patients were evaluated using the visual analogue scale (VAS) for pain. Patients were also assessed for edema, ROM of the wrist (flexion and extension), fingertip-to-distal palm crease distance (FT-PCD), hand grip strength (HGS), and pinch strength before and after treatment.

Hand grip strength (HGS): HGS was measured using a hand dynamometer (Jamar, USA) in the standard position recommended by the American Society of Hand Therapists. Patients sat with the shoulder in adduction and neutral rotation, 90° elbow flexion, forearm in mid-rotation, and the wrist in a neutral position. Three measurements were taken with 1-min intervals between each, and the mean value was recorded. The HGS was measured in kilogram-force[12, 13].

Visual analogue scale (VAS): VAS is a subjective assessment of an individual's pain. Numbers from zero to 10 were marked on a 10-cm line, with zero representing no pain and 10 representing the worst pain. Patients were asked to indicate their pain by pointing to the corresponding number on the line[14].

Pinch strength: The pinch strength was measured in kilograms using a manual pinch meter (Jamar, Sammons Preston, Inc. Bolingbrook, IL, USA). Patients were asked to grip the pinch meter at maximum strength in three basic grip positions: the fingertip grip (FGS), three-point grip (TPGS), and lateral grip (LGS). Pinch strengths were recorded while patients sat with the shoulder in adduction and neutral rotation, the elbow in 90° flexion, forearm in mid-rotation, and the wrist in a neutral position. Three measurements were performed in each position, and the mean value was calculated[15].

Table 1. The demographic data of the patients in each group and the significance of the difference between groups

	Whirpool bath (n=30)	NMES (n=30)
Age (years)	38.86±9.76	40.20±9.08
Gender (female/male) (%)	18/12 (60/40)	17/13 (56.66 /43.33)
Dominant hand/ Non-dominant hand (%)	22/8 (73.33/26.66)	19/11 (63.33/36.66)
BMI (kg/m^2)	28.13±1.13	27.63±0.98
Disease duration (weeks)	5.46±0.73	5.11±0.73

* Significant at $p < 0.05$, BMI: Body-mass index, Subject characteristics: Age, gender, dominant and non-dominant hand of subject. Values are represented as mean ± SD

Edema assessment: Edema was assessed using a hand volumetric device. Patients placed each extremity into the volumetric container, which was completely filled with water, and the amount of water overflow was measured in cubic millimeters. Edema was calculated based on the difference in the volume of water overflow between the affected and non-affected extremities[16].

Range of joint motion (ROM): The ranges of wrist flexion and wrist extension were measured with a hand goniometer[17]. Finger-to-palm crease distance (FT-PCD): The distance between the fingertip of the third finger and the distal palmar crease was measured in centimeters[5].

All analyses were performed using the SPSS version 16.0 statistical software program. Normal distribution of the continuous variables was determined by the Kolmogorov-Smirnov test. Student's t-test was used to compare normally distributed data, and the Mann-Whitney U test was used to compare non-normally distributed data. The χ^2 test was used to compare qualitative parameters. For all tests, a p-value less than 0.05 was considered statistically significant. To evaluate the changes in the post-treatment outcomes in each group, the percent rate of change in each parameter was calculated and compared between the groups using the following formula: Variable x: (x after treatment − x before treatment)/x before treatment × 100.

RESULTS

All patients were aged between 26 and 58 years (mean age: 39.53 ± 9.37 years). The patient demographic data is summarized in Table 1. There were no significant differences between the groups ($p > 0.05$). Etiological factors were as follows: in the first group, 16 patients (53.33%) had experienced a distal radius fracture, 4 patients (13.33%) had experienced a metacarpal fracture, and 10 patients (33.33%) had experienced a tendon injury. In the second group, 17 patients (56.66%) had experienced a distal radius fracture, 5 patients (16.66%) had experienced a metacarpal fracture, and 8 patients (26.66%) had experienced a tendon injury.

Before treatment, none of the measured parameters was significantly different between the groups ($p>0.05$). After

Table 2. Comparison of pre and post-treatment measurement values

	Pre-treatment		Post-treatment		
	Group 1	Group 2	Group 1	Group 2	
Hand edema (ml)	33.30±3.33	32.23±3.14	10.83±1.68	15.63±1.49	*
Hand grip strength (kg)	12.54±2.00	13.20±1.93	21.32±2.15	19.65±2.60	*
Range of wrist flexion	35.23±4.82	34.76±4.24	51.13±3.94	46.43±4.39	*
Range of wrist extension	22.7±3.16	24.33±3.45	42.90±3.55	37.20±3.30	*
Visual analogue scale	6.65±1.22	6.56±1.30	3.16±0.64	3.81±0.86	*
Fingertip-to-distal palm crease distance (kg)	5.29±0.64	5.07±0.53	1.19±0.20	2.00±0.28	*
Lateral pinch strength (kg)	6.32±0.91	6.08±0.69	9.46±0.84	9.05±0.81	
Fingertip pinch Strength (kg)	3.88±0.96	3.52±0.62	6.61±0.73	6.25±0.53	*
Three-point pinch Strength (kg)	4.35±0.72	3.98±0.77	7.31±0.45	7.05±0.45	*

* Significant at $p < 0.05$, Group 1: Whirlpool bath, Group 2: Neuromuscular electrical stimulation

treatment, statistically significant improvements were observed in all parameters in both groups according to intra-group comparisons ($p < 0.001$). The outcomes before and after treatment in each group and the significance level of the differences between the groups are shown in Table 2. The improvements in edema, flexion and extension ROM, FT- PCD, VAS, HGS and lateral pinch strength were significantly better among the patients treated with the whirlpool. However, the change in fingertip and three-point pinch strength was similar in both groups (Table 3). No treatment-associated complications were observed in either group.

Table 3. The percentage rates of change of the outcome measure of each group, and the significance level of the differences between the two groups

	Whirlpool bath	NMES	
Edema	−67.5 ± 3.15	−49.4 ± 4.9	*
Range of wrist extension	91.2 ± 20.5	54.1 ± 11.4	*
Range of wrist flexion	46.3 ± 9.9	34.1 ± 6.2	*
FT-PCD	−76.8 ± 6.1	−59.3 ± 7.3	*
VAS	−52.2 ± 5.5	−46.8 ± 4.6	*
HGS	70.1 ± 12.8	56.9 ± 14.6	*
LPS	51.1 ± 10.6	43.0 ± 8.2	*
FGS	76.5 ± 26.2	69.3 ± 15.1	
TPGS	70.7 ± 25.4	66.4 ± 17.2	

* Significant, $p < 0.05$, FGS: Fingertip grip strength, TPGS: Three point grip strength, LPS: Lateral pinch strength, VAS: Visual analogue scale, FT-PCD: Finger-to-palm crease distance

DISCUSSION

The exact prevalence of CRPS is unknown. Gender, race, and geographic location have no effect on the occurrence of CRPS. In general, CRPS is more frequent in females and during the fourth decade of life. There is no significant difference in the involvement of the dominant and nondominant extremities, but upper extremity involvement and fracture etiologies are more frequent[1]. In this study, the incidence of disease according to age, gender, and etiological factors were consistent with prior reports.

Pain associated with CRPS increases sufferers' resistance to moving the extremities, and joint stiffness continues to worsen[18]. The sudomotor and vasomotor changes cause edema and variable skin discoloration in patients with CRPS[19]. CRPS is somewhat difficult to treat because its physiopathology remains unclear. As a result, an ideal therapy has not been determined despite the multiple treatment options available. Whirlpool, a physiotherapy modality, is one treatment option[20]. Clinical studies have shown that whirlpool bath treatment improves regional perfusion, nutrition, and oxygen to the tissues, and softens the skin; as a result, it is used to reduce pain and edema in CRPS[21, 22]. A previous study conducted of whirlpool treatment also revealed an analgesic effect[23]. In another study, whirlpool bath treatment decreased pain and stiffness in patients with knee osteoarthritis[10]. In a case report, CRPS symptoms occurring after Herpes Zoster infection significantly improved following whirlpool bath treatment[20].

Neuromuscular electrical stimulation is another treatment option for CRPS, and it induces muscle contractions which compress the venous and lymphatic vessels. This mechanical effect helps resolve edema[24] and has been used to treat hand edema, with significant improvement noted[25]. Studies conducted by Faghri et al. and Man et al.[26, 27] revealed that NMES was effective in the treatment of hand edema in patients with cerebrovascular disease and ankle edema in patients who remained standing for longer than 30 min. In previous studies, significant improvements in the shoulder ROM and a decrease in shoulder pain were reported in stroke patients treated with NMES[28, 29]. In our study, both the whirlpool bath and NMES treatments significantly improved pain and hand edema in the patients, but the improvements were significantly better in the whirlpool bath group than in the NMES group.

Previous studies have demonstrated that NMES improves voluntary hand movement, HGS, and functional skills[30]. A study conducted on patients suffering from an immobile knee demonstrated that NMES had benefical effects, preventing muscular atrophy and improving muscle performance[31]. Lin et al.[32] showed that NMES induced repetitive muscle contractions and meaningful movement of the affected upper limb, significantly improving its motor

function. Borrell et al.[33] found that whirlpool bath treatment was effective at relieving pain and improving hand function. Similarly, in a study of patients with hand osteoarthritis, Uçar et al.[34] reported that whirlpool bath treatment increased HGS.

Consistent with the literature, the present study found that both treatment regimens increased the grip strength, pinch strength (three-point and fingertip pinch strengths), and ROM of the wrist joints after treatment. However, these improvements were better in the whirlpool bath group. The difference between the groups in lateral pinch strength improvement was not significant.

In conclusion, based on the present findings, both whirlpool bath and NMES treatments are effective for pain control, reduction of edema, increasing the grip strength, and improving the hand function of CRPS patients. Furthermore, these improvements were better in the patients receiving whirlpool bath treatment.

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