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RESEARCH

Effect of electromyography biofeedback treatment on reaction time, pain, hand grip strength, and upper extremity functional status in patients with carpal tunnel syndrome.

Karpal tünel sendromlu hastalarda elektromyografi biofeedback tedavisinin reaksiyon süresi, ağrı, el kavrama gücü ve üst ekstremite fonksiyonel durum üzerine etkisi

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Abstract

Purpose: The aim of the study was to investigate the effect of electromyography biofeedback (EMG-BF), which in addition to conventional electrophysical therapy (EPT) commonly used in the symptomatic treatment of carpal tunnel syndrome (CTS), on motor parameters such as strength and reaction time and symptomatic functional parameters such as pain and function of the upper extremity.

Materials and Methods: Patients diagnosed with CTS were divided into two groups. The first group was the conventional EPT group only (control group, n=46 hands), and the second group was the group that received EMG-BF in addition to the conventional EPT treatment (research group, n=42 hands). The pain (VAS), hand grip strength (HGS), audio-visual reaction time (ART-VRT), and upper extremity disability (Quick DASH) of patients in both groups were assessed before and after the treatment program.

Results: After treatment, VRT, ART, HGS, and Quick DASH were significantly better in favor of the EPT +EMG- BF group. Before treatment, resting state (VASr), mobile state (VASm), and night state (VASn) VAS values were similar between the two groups. After training, the VAS -values were better in favor of the EPT +EMG- BF –group.

Conclusion: Although EPT applications provide effective results in the rehabilitation of CTS, EMG-BF applications together with EPT applications provide more meaningful results in the rehabilitation process.

Keywords: Carpal tunnel syndrome, electrophysical therapy, electromyography-biofeedback

Öz

Amaç: Çalışma Karpal Tünel Sendromu (CTS) semptomatik tedavisinde sıklıkla kullanılan konvansiyonel elektrofiziksel ajanlara (EPT) ek uygulanan Elektromyografi Biyo Feedback (EMG-BF)'nin kuvvet ve reaksiyon zamanı gibi motorik parametreler ve ağrı, üst ekstremite fonksiyonu gibi semptomatik-fonksiyonel parametrelere etkisini incelemeyi amaçlamıştır.

Gereç ve Yöntem: CTS tanısı alan hastalar iki gruba ayrıldı. Birinci grup sadece konvansiyonel EPT grubu (kontrol grubu, n=46 el), ikinci grup konvansiyonel EPT'ye ek EMG-BF uygulanan grup (araştırma grubu, n=42 el) olarak belirlendi. Her iki grupta hastaların tedavi programı öncesi ve sonrası ağrı (VAS), Hand Grip Strenght (HGS), görsel-işitsel reaksiyon zamanı (VRT-ART) ve üst ekstremite dizabilite (Quick DASH) durumu değerlendirildi.

Bulgular: Tedavi sonrasında VRT, ART, HGS ve Quick DASH skorları EPT+EMG-BF grubu lehine anlamlı düzeyde daha iyiydi. Tedavi öncesinde dinlenik (VASr), hareketli (VASm) ve gece (VASn) VAS skorları iki grup arasında benzerdi. Egzersiz sonrasında VAS skorları EPT+EMG-BF grubu lehine daha iyiydi.

Sonuç: Araştırmamızda; CTS rehabilitasyonunda EPT uygulamaları etkin sonuçlar vermesine rağmen, EPT uygulamalarıyla birlikte kullanılan EMG-BF uygulamaları rehabilitasyon sürecinde daha anlamlı sonuçlar verdiği tespit edilmiştir.

Anahtar kelimeler: Elektromiyografi biofeedback, elektrofiziksel tedavi, karpal tünel sendromu.

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INTRODUCTION

Carpal tunnel syndrome (CTS) is the compression of the median nerve at the level of the wrist and the most common entrapment neuropathy of the upper extremities[1]. Althought it is more common in decades, a female-to-male ratio of 3/1 has been reported. The incidence is 149/52 per 100000 in women/men. While the prevalence is 3-3.4% in women, it is 0.6-2.7 in men[2]. The etiology of CTS is multifactorial. Causes leading to a decrease in tunnel volume, an increase in the volume of intracanal structures or the presence of additional structures, neuropathic changes, inflammatory causes, clinical conditions leading to changes in fluid balance, and external pressures are the most common etiologic factors[1-3]. In more severe cases, atrophy of the thumb joint and weakness of the abductor pollicis brevis and opponens pollicis muscles are observed[1-4]. The diagnosis of CTS is made using clinical and laboratory tests, provocation tests such as Tinel, Phalen, and Durkan tests, and electrodiagnostic tests during physical examination. The sensitivity of clinical tests varies from 60-90%[4,5]. Nerve conduction studies using electroneuromyography (ENMG) are used in the diagnosis of entrapment neuropathies because of their high specificity and sensitivity and are used in addition to clinical and physical examination in the diagnosis of CTS[6]. Treatment of CTS can be conservative or surgical. Conservative treatment is often preferred for patients with mild to moderate symptoms. Conservative methods include corticosteroids, oral and transvenous steroids, vitamins B6 and B12, nonsteroidal anti-inflammatory drugs (NSAIDs), yoga, carpal mobilization and hand splints, and conventional electrophysical agents. Patients have been shown to benefit significantly from conservative treatment, even in the short term[7].

One of the alternative treatments that can be used at CTS is EMG-BF. EMG-BF converts the myoelectric signals inside the muscle into audiovisual values and provides re-education of the muscles. Visual and auditory images of muscle activity are created using the surface EMG electrode[8]. EMG-BF measures the electrical activity that accompanies muscle contraction. This activity is shaped to decrease or increase muscle response. For this reason, muscle relaxation and muscle reeducation are the main goals[9-11].

Another motor feature that may be associated with CTS is reaction time. Reaction time can be simply defined as the time between stimulus and muscle response[12]. Reaction time is an indicator of muscle performance and a parameter that can be used in rehabilitation assessments[12]. In the clinic, reaction time can be tested visually and acoustically in a practical manner. Possible involvement in entrapment neuropathies such as CTS should be considered and evaluated. It has been established that good reaction time is only possible when the central nervous system and the musculoskeletal system work in synchrony[13]. From this contrast, there is a need for new studies on this topic. Regarding the effects on reaction time, no study was found in the available literature. Based on the information in the literature, the hypothesis of this study is that in CTS rehabilitation, EMG-BF applications provide more effective results on VAS, HGS, VRT-ART and Quick DAS scores when used together with EPT. For this reason, the aim of this study was to investigate the effects of EMG-BF on motor parameters such as strength and reaction time, and on symptomatic functional parameters such as pain and upper extremity function, in addition to the conventional electrophysical agents commonly used in the symptomatic treatment of CTS.

MATERIALS AND METHODS

The Ethics Committee of the Faculty of Health Sciences of Bandırma Onyedi Eylül University approved the study with registration number 2022/49. The study was carried out on individuals diagnosed with CTS in Bandırma Training and Research Hospital, Physical Therapy and Rehabilitation Outpatient Clinic and service. Participants were informed about the tests to be performed as part of the study. The study was conducted in accordance with the principles of the Declaration of Helsinki. Participants were informed in detail about the study and their written informed consent was obtained.

Sample

In the study conducted by Paker et al. examining joint range of motion and HGS results of women with CTS, the mean HGS of women with CTS = 15.32±7.27 kg, and the mean HGS of the control group = 40.40±7.80 kg.[14]. In the power analysis performed according to the results of this study (α=0.05 1-β(power)=0.95, actual power=95.2) and the effect size was taken as 0.8, it was determined that

there should be at least 35 subjects for each group in our study.

The study started with 85 patients, but 9 patients were excluded from the study due to early discontinuation of treatment. 76 patients (88 hands) aged 18-65 years who volunteered to participate in the study, were diagnosed at CTS, and met the inclusion criteria were included. Those who had already undergone upper extremity surgery, were pregnant, had undergone upper extremity physiotherapy, other conservative treatment techniques or regular exercise program in the last 1 year, metabolic diseases such as concomitant diabetes, thyroid diseases, patients with systemic upper extremity musculoskeletal diseases (radiculopathy, brachial plexopathy, etc.), traumatic injuries such as fractures were excluded from the study.

Procedure

In the study, all patients completed the treatment and evaluation, which lasted a total of 3 weeks. The study was conducted in the Polyclinic of Physical Medicine and Rehabilitation. Patients diagnosed by electrodiagnostic tests (electroneuromyography-ENMG) as having CTS were randomized by lottery. Group 1 was defined as the group receiving only conventional electrophysical therapy (EPT) (control group, n=46 hands), and group 2 as the group in which EMG-BF was used in addition to conventional EPT (research group, n=42 hands).

Participants' demographic data were recorded. Age (year), height (cm), body weight (kg), body mass index (BMI) (kg/cm2) were obtained. Height was determined using a stadiometer accurate to 0.1 cm, and body weight was determined using the Tanita BC Segmental Body Analysis System (model: BC 418, Tanita Corporation, Tokyo, Japan). BMI was calculated using the formula weight (kg)/height*height (m^2)[15].

Pain, HGS, audiovisual reaction time (VRT-ART), and upper extremity disability were assessed before and after the treatment program. EPT was used 5 days per week (15 sessions) for 3 weeks. In the group in which EMG-BF was applied in addition to EPT, 15 sessions (3 weeks * 5 days) per week were performed.

Pain analysis

The Visual Analog Scale (VAS) was used to assess pain in the affected upper extremity. At VAS, the scale is a 10-cm ruler with a starting point at 0 = no pain and an end point at 10 = unbearable pain. Patients were asked to mark the degree of pain on this ruler, and the degree of pain was measured with a tape measure from the starting point. Pain ratings were made sEPTrately according to the degree of pain at rest (VAS -r), during movement (VAS -m), and at night (VAS -n)[16].

Evaluation of upper extremity function

The patient's upper extremity functional level (Quick Disability of the Arm, Shoulder, and Hand) was assessed using the Quick DASH scale. Quick DASH is an abbreviated version of DASH for measuring physical function and symptoms in patients with upper extremity musculoskeletal disorders. In the test administered to assess upper extremity function with 11 different questions, each activity is rated as '1=not at all difficult' and '5=I cannot do this at all'. The Turkish validity and reliability of the scale were determined by Doğan et al[17].

Hand grip strength (HGS)

HGS was measured with a Jamar hand dynamometer (Lafayette Instrument Company, USA) in the seated position, the standard position recommended by the American Association of Hand Therapists (ASHT), with the subjects' shoulders in 0° abduction and neutral rotation, elbows in 90° flexion, and forearms in neutral pronation/supination. The best value was expressed in kilograms (kg) by taking 3 measurements 1 minute apart. Validity and reliability study of HGS measurement using the Jamar hand dynamometer by Bohannon et al[18].

Audio-visual reaction time

VRT and ART measurements were performed using the Hubbard Scientific Reaction Timer (model: 6027, USA). Measurements were performed in a soundproofed, daylight-illuminated room. The reaction timer device operates on the principle of an audible and an illuminated visual warning signal. Participants were asked to place the hands of the affected side on the table in front of them. The button they were to press when the warning was detected was located 10 cm from the timer. When an audible or visual warning was given with the command "Ready," they were to press the button in front of them as quickly as possible. Each participant performed 10 trials each with sound stimuli for ART

and light stimuli for VRT. The mean of the last five trials was accepted as RT[19].

Electrophysical therapy protocol

In the protocol EPT; 20 min of transcutaneous electrical stimulation (TENS) (asymmetric biphasic waveform and burst modulation, 10-60 mm, 60-120 Hz) (Compex Theta MI Pro), ultrasound application (3 min, 3MHz, 1.0W/) in the area of the affected wrist (Intelec Mobil, Hixon, Chatanooga, TN), and 20-min superficial heating (Hot Pack) in continuous mode on an area of 5 cm^2 with a density of cm^2. The treatment protocol was applied over 15 sessions (3 weeks*5 days).

EMG-BF therapy

The Neurotrac Myoplus Pro device (Verity Medical, UK) was used for the EMG-BF application. The device was connected to the computer using Neurotrack EPT 4.00 software, and all data were recorded. On the device, the application EMG-BF was selected, and the work-rest mode was chosen, in which electrical signals were sent at 10-second intervals and rested for 10 seconds. For the assessment, the screen scale was used as visual feedback, and the increasing or decreasing beep with changing muscle activity was used as sensory feedback. Before starting the treatment, the goal that the patient wanted to achieve was set. The device's "set target" function was used to examine tension and relaxation for 10 seconds and determine the average target. Then, the target was created by determining the percentage of this determined target. The determined target was displayed at the top of the screen above the bar graph in μV (microvolts). Since the target in this study was relaxation, the patient was asked to decrease the value on the graph during the session[20].

Statistical analysis

IBM SPSS Statistics 25.0 for Windows was used for statistical analysis. The compatibility of the data with normal distribution was tested using the Kolmogorov-Smirnov test, and it was found that the data were not normally distributed. The median (mean), minimum (min), and maximum (max) values of the data that did not have a normal distribution were reported. Pairwise comparisons of the variables age, height, weight, and BMI, VRT, ART, HGS, Quick DASH, and VAS between participants in the study and control groups were performed with Mann Whitney U analysis. The Wilcoxon test was applied to the data to compare VRT, ART, HGS, VAS -r, VAS -m, VAS -n, and Quick DASH before and after treatment. The effect sizes of the data were determined using Cohen's D formula. In this context, the resulting effect size of 0.2 was accepted as small, 0.5 as medium, and 0.8 as large[21]. The significance level in the study was set at 0.05.

RESULTS

The median (min-max) values of the variables age, height, weight, and BMI of the patients participating in the study, as well as the results of the Mann-Whitney-U analysis, are shown in Table 1. According to the results of the analysis, it was found that there was no statistically significant difference between EPT+EMG- BF and EPT groups in terms of age, height, weight and BMI variables ($p > 0.05$).

Table 1. Age, height, weight and BMI variables

Parameters	EPT+EMG-BF (n= 42)	EPT (n= 46)	p
Age (year)	47 (29-65)	53 (27-66)	.068
Height (cm)	166 (150-186)	165 (150-186)	.716
Weight (kg)	74 (48-110)	74 (50-97)	.866
BMI (kg/m^2)	26 (18.3-34.5)	26 (18.3-32.8)	.683

EPT: Electrophysical Therapy, EMG-BF: Electromyography Bio Feed Back, BMI: Body Mass Index

Table 2. VRT, ART, HGS and Quick DASH scores before and after treatment

Parameters	EPT+EMG-BF (n= 42) (PT)	EPT (n= 46) (PT)	p	EPT+EMG-BF (n= 42) (AT)	EPT (n= 46) (AT)	p
VRT	39.2 (22.2-74)	38.9 (17.8-82.4)	.955	25.6 (11.8-56,6)	36 (19-81.4)	.000
ART	36 (20.2-60)	33.4 (19.8-76.6)	.687	23.8 (11.4-47)	29.8 (17.6-75.8)	.000
HGS	25 (10-47)	20 (10-70)	.119	31 (14-65)	21,5 (10-65)	.002
Quick DASH	71 (35-91)	66 (55-77)	.091	36 (11-65)	49.5 (15-80)	.001

EPT: Electrophysical Therapy, EMG-BF: Electromyography Bio Feed Back, PT: Pre-Therapy, AT: After Theraphy, VRT: Visual Reaction Time, ART: Audio Reaction Time, HGS: Hand Grip Strenght, Quick DASH: Quick Disability of the Arm, Shoulder, and Hand

The median (min-max) values of the pre-treatment VRT, ART, HGS and Quick DASH scores of the patients participating in the study and the Mann Whitney U analysis results are given in Table 2. According to the results of the analysis, it was determined that there was no statistically significant difference between the EPT+EMG-BF and EPT groups in terms of VRT, ART, HGS and Quick DASH scores (p>0.05).

The median (min-max) values of VRT, ART, HGS and Quick DASH scores and Mann Whitney U analysis results of the patients who participated in the study are given in Table 3. According to the results of the analysis, there was a statistically significant difference in favor of the EMG-BF group in terms of VRT, ART, HGS and Quick DASH scores between the EPT+EMG-BF and EPT groups (p<0.05).

Table 3. Patients' pre- and post-treatment VAS scores

Time	Parameters	EPT+EMG-BF (n= 42)	EPT (n= 46)	p
VAS-Pre Therapy	VAS-r	5 (2-8)	5 (1-9)	.729
	VAS-m	8 (3-9)	7 (3-9)	.054
	VAS-n	7 (1-9)	6 (3-9)	.193
VAS-Post Therapy	VAS-r	3 (0-7)	5 (2-9)	.000
	VAS-m	4 (1-8)	6 (3-9)	.000
	VAS-n	4 (0-7)	7 (2-9)	.000

EPT: Electrophysical Therapy, EMG-BF: Electromyography Bio Feed Back, PT: Pre Theraphy, AT: After Theraphy, VAS: Vizuel Analog Scala, VAS-r: Vizuel Analog Scala-in Rest, VAS-m: Vizuel Analog Scala During Movement, VAS-n: Vizuel Analog Scala-in Night

Table 4. Analysis results of VRT, ART, HGS, VAS rest, VAS movement, VAS night and Quick DASH scores before and after treatment

Groups	VRT	ART	HGS	VAS-r	VAS-m	VAS-n	Quick DASH
EPT+EMG-BF (n= 42)	.000	.000	.000	.000	.000	.000	.000
EPT (n= 46)	.002	.002	.009	.416	.080	.251	.002

EPT: Electrophysical Therapy, EMG-BF: Electromyography Bio Feed Back, PT: Pre-Therapy, AT: After Theraphy, VRT: Visual Reaction Time, ART: Audio Reaction Time, HGS: Hand Grip Strenght, Quick DASH: Quick Disability of the Arm, Shoulder, and Hand, VAS: Vizuel Analog Scala, VAS-r: Vizuel Analog Scala-in Rest, VAS-m: Vizuel Analog Scala During Movement, VAS-n: Vizuel Analog Scala-in Night

The median (min-max) VAS -r, VAS -m, and VAS -n scores of the patients participating in the study before and after treatment and the results of the Mann Whitney U analysis are shown in Table 4. According to the results of the analysis, there was a statistically significant difference between the groups EPT+EMG- BF and EPT, in favor of the group EMG-BF, between the scores for rest, exercise and night VAS after treatment ($p < 0.05$).

The Wilcoxon test was applied to the data to compare the VRT, ART -, HGS-, VAS is-, VAS -movement-, VAS -night-, and Quick DASH -scores of patients in the EPT+EMG- BF and EPT groups before and after treatment. According to the results of the analysis, in the EPT+EMG- BF group, there was a statistically significant difference between the VRT, ART, HGS, VAS -r, VAS -m, VAS -n and Quick DASH scores before and after treatment ($p < 0.05$). In the EPT group, there was a statistically significant difference between the values for VRT, ART, HGS, and Quick DASH ($p < 0.05$).

DISCUSSION

As a result of our research, it was found that there is a significant difference between EPT application in CTS patients and EPT+EMG- BF application in favor of EPT+EMG- BF application. In CTS patients; EPT+EMG- BF application, VRT, ART, HGS, VAS -r, VAS -m, VAS -n and Quick DASH scores were found to be significantly different. Although there was a significant difference between VRT, ART, HGS, and Quick DASH scores when EPT was used alone, a higher significance level was found in favor of the EPT+EMG- BF group. As far as we know, this is the first study comparing only EPT application and EPT+EMG- BF application in CTS patients. When the results of our research are evaluated in this context, it is concluded that EPT+EMG- BF application provides more effective results in the rehabilitation of CTS.

CTS patients; they complain of pain in the hand, decreased sensation, functional impairment, and loss

of strength[22]. Reaction time is a method to determine the movement time of the muscle and thus to determine the loss of function. At the same time, it provides important information for evaluating the effectiveness of the applied movements during the rehabilitation process[12]. In the study conducted by Turhanoğlu and Beyazova, no difference was found between the reaction times of patients with mild, moderate, and severe CTS[23]. After evaluating the results of this study, it is believed that the reaction time is shortened in patients with CTS regardless of the severity of CTS. CTS is defined as an acute or chronic compressive lesion of the median nerve at the wrist[24]. This compressive lesion of the median nerve also negatively affects hand grip strength. In Lowe's study, it was found that the grip strength of individuals with CTS decreased to some degree[25].

Although the goal of the rehabilitation process in CTS patients is to eliminate functional losses such as handgrip strength and reaction time, this process can be performed more actively if the degree of pain felt during rehabilitation movements is known and limb functions are assessed. Koldas Dogan et al. concluded that the Quick DASH scale is a reliable and valid method for assessing symptoms and functional limitations in CTS patients [17]. In the study of Karcioglu et al.; comparing different scales for determining pain intensity, it was concluded that VAS provides more valid and reliable results than other methods[26].

CTS is classified as mild, moderate, or severe at diagnosis. Although the rehabilitation process and duration applied to CTS patients of different degrees vary, the treatment method applied is almost the same for all degrees. Treatments such as massage, manual therapy, therapeutic ultrasound, electrophysical treatments (TENS etc.), EMG-BF, iontopheresis, splinting, acupuncture are commonly used in CTS rehabilitation. Some studies have compared different treatment modalities. Koca et al. In the study conducted by CTS, patients diagnosed with CTS were treated with interferential current (IFC), transcutaneous electrical nerve stimulation (TENS), and splint therapy, and it was found that the IFC treatment protocol showed greater improvement in CTS patients[27]. In the study conducted by Oztas et al. concluded that the clinical situation in the treated group improved after ultrasound treatment in patients with CTS[28]. In the study by Bakhtiary and Rashidy-Pour, ultrasound and laser therapy were applied to CTS patients, and it was concluded that laser therapy provided more effective results[29]. In the study of Duarte-Moreira et al. concluded that the use of EMG-BF is limited in improving motor functions in individuals with peripheral nerve injuries (facial paralysis, acute ischiatitis, and CTS)[30]. However, when examining the results of our research, we conclude that EMG-BF and EPT applications are more effective in CTS rehabilitation when used together. In this case, we believe that the EMG-BF application should be used together with EPT applications instead of using them alone.

In conclusion, examination of the literature reveals that different methods are used in CTS rehabilitation. Many academic studies have been conducted to find out which method provides the most effective results in CTS rehabilitation. According to the results of our study, the application of EPT+EMG- BF has a positive effect on auditory and visual reaction time, handgrip strength, upper extremity pain score and upper extremity functions. When evaluated in this context, it is recommended that physical therapists include EMG-BF in the rehabilitation process in addition to EPT applications. It is also believed that EMG-BF applications can be used for various motor disorders. In these studies, it is recommended that the results of our research be used as a reference.

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