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ORIGINAL ARTICLE

Additional contribution of phonophoresis and low-level laser therapy to exercise in the treatment of carpal tunnel syndrome: A clinical, electrophysiological, and ultrasonographic evaluation

Karpal tünel sendromunun tedavisinde fonoforez ve düşük seviyeli lazer tedavisinin egzersize ek katkısının klinik, elektrofizyolojik ve ultrasonografik olarak değerlendirilmesi

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Summary

Objectives: Carpal Tunnel Syndrome (CTS) is the most common peripheral nerve compression syndrome. This study aims to evaluate the additive contribution of phonophoresis and low-level laser therapy (LLLT) to tendon and nerve gliding exercises electrophysiologically, ultrasonographically, and clinically in the treatment of moderate CTS.

Methods: The sample consisted of 45 patients with moderate CTS, randomized into three groups. Group 1 received phonophoresis and exercise, Group 2 received LLLT and exercise, and Group 3 received exercise alone. Participants were evaluated electrophysiologically, clinically, and ultrasonographically before treatment and at the 6th and 12th weeks after the treatment.

Results: An improvement was observed in clinical parameters (Boston Functional Status Scale, Boston Symptom Severity Scale, visual analog scale at rest, and visual analog scale during activity) for all groups at the 6th and 12th weeks after the treatment ($p<0.05$). An improvement was also noted in the ultrasonographic parameter (cross-sectional area) for all groups at the 12th week after the treatment ($p=0.017$).

Conclusion: Phonophoresis and LLLT do not provide additional effects to exercise therapy. Exercise therapy alone may positively contribute to ultrasonographic and clinical outcomes in the treatment of moderate CTS.

Keywords: Carpal tunnel syndrome; electromyography; exercise; median neuropathy; nerve compression syndromes; pain; pain management; physical therapy modalities; ultrasonography.

Özet

Amaç: Karpal tünel sendromu (KTS), en sık görülen periferik sinir sıkışma sendromudur. Bu çalışma, fonoforez ve düşük seviyeli lazer tedavisinin (LLLT) orta dereceli KTS'nin tedavisinde tendon ve sinir kaydırma egzersizlerine ek katkısını elektrofizyolojik, ultrasonografik ve klinik olarak değerlendirmeyi amaçlamaktadır.

Gereç ve Yöntem: Örneklem, orta dereceli KTS'li 45 hastadan oluşmakta ve üç gruba randomize edilmiştir. Grup 1'e fonoforez ve egzersiz, Grup 2'ye LLLT ve egzersiz, Grup 3'e ise sadece egzersiz uygulandı. Katılımcılar tedavi öncesi ve tedavi sonrası 6. ve 12. haftalarda elektrofizyolojik, klinik ve ultrasonografik olarak değerlendirildi.

Bulgular: Tedavi sonrası 6. ve 12. haftalarda tüm gruplarda klinik parametrelerde (Boston Fonksiyonel Durum Skalası, Boston Semptom Şiddet Skalası, istirahat vizüel analog skalası ve aktivite vizüel analog skalası) düzelme saptandı ($p<0.05$). Tedavi sonrası 12. haftada tüm gruplarda ultrasonografik parametrede (kesit alanı) düzelme saptandı ($p=0.017$).

Sonuç: Fonoforez ve LLLT, egzersiz tedavisine ek bir etki sağlamamaktadır. Egzersiz tedavisi, orta derecede KTS'nin tedavisinde ultrasonografik ve klinik sonuçlara olumlu katkı sağlayabilir.

Anahtar sözcükler: Ağrı; ağrı yönetimi; elektromiyografi; egzersiz; fizik tedavi modaliteleri; karpal tünel sendromu; medyan nöropati; sinir sıkışması sendromları; ultrasonografi.

Introduction

Carpal tunnel syndrome (CTS) is the most common peripheral nerve compression syndrome.[1] CTS develops as a result of compression of the median nerve in the carpal tunnel of the wrist for various reasons.[2] Risk factors include obesity, menopause, inflammatory rheumatic diseases, hypothyroidism, genetics, pregnancy, diabetes mellitus, and recurrent wrist

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activity.[1,3] It is most commonly seen in individuals aged between 40–60 years and is more prevalent in females than males. CTS is characterized by pain in the hand and numbness and tingling in the median nerve distribution area.[3] Symptoms tend to worsen at night.[2] Anamnesis and physical examination are beneficial for diagnosing CTS.[1,2] Physical examination often includes provocative tests, such as the Tinel sign and Phalen's test, which are positive. Sensory loss and, more rarely, motor loss and thenar atrophy may be seen on neurological examination.[2] Electrophysiological evaluations are the most sensitive method to determine damage to the median nerve. With these tests, the degree of demyelination and axonal loss can be defined. Therefore, nerve conduction studies are useful in the diagnosis of CTS and in determining the prognosis.[1] However, less invasive diagnostic options have come to the fore due to the invasiveness and electrophysiological false negative rates of traditional methods. With the widespread use of ultrasonography (US), ultrasonic examination has been shown to be useful in diagnosing CTS. The main advantages of US are that it is simple, fast, economical, and non-invasive.[4] Numerous conservative treatment options exist in the treatment of CTS. These include splinting, corticosteroid injection, oral medication, physical therapy agents, and exercise.[2,5] Low-level laser therapy (LLLT) and ultrasound are among the most commonly used physical modalities in the treatment of CTS.[6] Phonophoresis is a technique used to increase transdermal absorption of drugs into inflamed tissues by the application of ultrasound.[7] LLLT and phonophoresis involve methods that affect biological processes in the body. They are easy to apply, inexpensive, and non-invasive.[8] Tendon and nerve gliding exercises also reduce edema in the median nerve and surrounding tissues.[1] However, there is insufficient evidence in the literature about the effectiveness and superiority of these methods.[9]

The objective of this study was to clinically, electrophysiologically, and ultrasonographically evaluate the additional contribution of phonophoresis and LLLT to exercise in the treatment of moderate CTS.

Material and Methods

Institutional review board approval (Ethics Committee of the Celal Bayar University Medical Faculty, 180 - 06.05.2015) was obtained for this retrospective study. The study was registered at ClinicalTrials.gov PRS under Registration No. NCT05213819. Written informed consent was obtained from all patients.

A total of 45 patients (5 males, 40 females; mean age 50.2±10.0 years; range 26 to 69 years) with clinical and electrophysiologic findings of moderate CTS were examined. Inclusion criteria were as follows: age older than 18 years, positive Tinel's sign or positive Phalen's sign, pain or paresthesia in the median nerve course, pain or paresthesia aggravated at night, and moderate CTS according to the American Association of Electrodiagnostic Medicine (AAEM) guidelines.[10,11] Exclusion criteria included metabolic diseases (including diabetes mellitus, thyroid, and chronic kidney diseases), rheumatoid arthritis, wrist trauma, pregnancy, corticosteroid treatment in the last three months, and physical or medical treatment in the last month. Participants were allocated into three groups using random allocation software: Group 1 (phonophoresis combined with exercise, n=15), Group 2 (LLLT combined with exercise, n=15), and Group 3 (exercise only, n=15).

Interventions

Phonophoresis was administered to the course of the carpal tunnel for 8 minutes each session at a frequency of 3 MHz and an intensity of 1.0 W/cm^2, using pulsed mode (1:4) ultrasound with a transducer surface area of 1.4 cm^2 (Sonicator 730, Metler Electronics, USA). A 2.5% ketoprofen gel was used. Patients underwent this therapy five days a week for three weeks.

A Gal-Al-As diode laser device (Endolaser 476, Enraf Nonius, Netherlands) was used for LLLT, with a power output of 30 mW and a wavelength of 830 nm. The probe irradiated three points on the volar side at the wrist, with one minute of irradiation per point (three minutes in total) as the single dose of irradiation. The dose for every tender joint was 1.8 joules. The total and accumulated doses after 15 treatments were 5.4 and 81 joules, respectively. This therapy was applied five days a week for three weeks.

All individuals were instructed to complete nerve and tendon gliding activities as described by Totten and Hunter.[12] Additionally, a booklet explaining the activities was provided to all individuals.

Patients were contacted weekly by phone to check on and remind them about their exercises. For tendon gliding exercises, the fingers were moved into five separate positions: straight, hook, fist, table top, and straight fist. For median nerve-gliding exercises, placing the hand and wrist in six separate positions facilitated the mobilization of the median nerve. The neck and shoulder were kept in a neutral position, and the elbow in supination and 90 degrees flexion throughout these exercises. Each separate position was held for 5 seconds. The exercises were repeated in five sessions every day, with 10 repetitions of each exercise per session, lasting for three weeks.

Outcome Measures

Data including age, gender, body mass index (BMI), and disease duration (months) were recorded for all patients upon admission. In patients with bilateral CTS, the most symptomatic hand was included. Pain intensity at rest and during activity was assessed using the Visual Analog Scale (VAS), where individuals could specify their pain evaluation on a 10 cm scale, ranging from 0 (no pain) to 10 (the most intense pain).

The Boston Carpal Tunnel Questionnaire (BCTQ) is a self-administered tool that assesses symptom severity and functional status in CTS patients.[13] The BCTQ includes two subscales: the Boston Symptom Severity Scale (BSSS) consists of 11 questions, and the Boston Functional Status Scale (BFSS) has 8 questions. Each question is assessed on a 1-point (mildest pain) to 5-point (most intense pain) scoring system. The score for each scale is determined as the average of all items. The Turkish version of the BCTQ has been validated by Sezgin et al.[14]

Electrophysiologic examinations of all patients were performed at a room temperature of 22–24 °C using a 2-channel Dantec Keypoint Portable electromyography (EMG) device from Alpine Biomed Company (Natus Medical Incorporated, San Carlos, CA, USA). The band-pass filter settings were 20 Hz to 3 kHz, sweep speed was 2 ms/division, and gain was 10 μV/division. Electrophysiological studies were conducted according to AAEM guidelines.[10,11] The studies included an electromyographic investigation of the muscles of abductor pollicis brevis, adductor digiti minimi, and flexor carpi radialis, and the motor and antidromic sensorial conduction velocities of the median and ulnar nerves. The electrophysiological criteria for diagnosing CTS were determined as a median nerve's distal motor latency of >4.2 ms from the wrist to abductor pollicis brevis, and a separation between the median and ulnar sensorial distal latencies exceeding 0.5 ms.

CTS was electrodiagnostically categorized per the following criteria[15]: 1) Mild CTS: Elongation (absolute or relative) and/or decrease in sensory action potential (SNAP) amplitude in sensory or mixed distal latency (DL) (orthodromic, antidromic, or palmar). 2) Moderate CTS: In addition to the above, elongation in the median motor DL. 3) Severe CTS: Along with the prolongation of median motor and sensory latencies, failure to obtain sensory or mixed action potentials or low amplitude compound muscle action potential (CMAP), fibrillations, attenuation in full twitching in needle EMG, and changes in motor unit potentials. Patients diagnosed with moderate CTS by electrophysiological findings were included in the study.

Ultrasonographic studies were conducted using high-resolution ultrasound with a 12-3 MHz linear array transducer (Philips HDI Envisor; Philips Medical Systems, Bothell, WA, USA). Evaluations were made with all wrists in the neutral position, palms up and fingers semi-extended. The median nerve's full course was determined within the carpal tunnel in both transverse and sagittal planes. The median nerve's cross-sectional area (CSA), transverse, and anteroposterior diameters were evaluated at the pisiform bone level of the proximal carpal tunnel, and its CSA was determined by a tracking approach using electronic calipers. No measurements were taken at the distal carpal tunnel.[16] Three measurement repetitions were made, and the average of these values was determined for each wrist. The transverse diameter was divided by the anteroposterior diameter to calculate the flattening ratio (FR).

Researchers assessing ultrasonographic, electrodiagnostic, and clinical examinations were blinded to the assigned therapies and to each other's assessments. All these parameters were determined again at the 6th and 12th weeks after the initiation of treatment.

Table 1. Demographic characteristics of the patients

	Group 1 (n=15)	Group 2 (n=15)	Group 3 (n=15)	p
Age (years), Mean±SD	48.6±11.5	52.4±8.86	49.4±8.86	0.54*
Body mass index (kg/m^2), Mean±SD	31.4±6.4	29.2±5.0	29.6±5.4	0.52*
Duration of disease (months), Mean±SD	27.4±18.5	20.6±12.0	22±14.7	0.73*
Sex				0.79**
Female, n (%)	14 (93.3)	13 (86.7)	13 (86.7)	
Male, n (%)	1 (6.7)	2 (13.3)	2 (13.3)	

SD: Standard deviation; Group 1 (phonophoresis combined with exercise); Group 2 (low-level laser therapy combined with exercise); Group 3 (exercise alone); *: Kruskal-Wallis test; **: Chi-square test; a p-value of <0.05 is considered statistically significant.

Table 2. Changes in clinical and electrophysiological parameters at different time points

Variable	Groups	Baseline Mean±SD	6th week Mean±SD	12th week Mean±SD	Group p	Time p	Group × Time interaction p
BSSS	Group 1	3.32±0.75	2.44±0.50	2.68±0.38	0.792	<0.001	0.047*
	Group 2	3.25±0.57	2.57±0.55	2.58±0.79			
	Group 3	3.26±0.67	2.52±0.57	2.20±0.75			
BFSS	Group 1	3.31±0.80	2.41±0.54	2.58±0.49	0.358	<0.001**	0.559
	Group 2	3.34±0.59	2.60±0.49	2.57±0.82			
	Group 3	3.23±0.71	2.35±0.63	2.18±0.61			
MDL	Group 1	5.10±0.79	5.16±0.87	4.67±1.31	0.512	0.013	0.051*
	Group 2	4.56±0.71	4.71±0.94	4.64±0.87			
	Group 3	4.73±0.66	4.88±0.79	4.73±0.69			
MA	Group 1	8.73±2.57	9.86±3.46	9.50±3.83	0.935	0.794	0.389
	Group 2	9.65±2.74	8.53±2.44	9.06±3.21			
	Group 3	8.90±3.35	9.93±3.43	9.21±2.60			
SNV	Group 1	30.53±6.95	29.00±3.31	29.18±4.11	0.657	0.554	0.736
	Group 2	31.30±7.06	31.33±6.90	28.07±9.92			
	Group 3	32.53±9.30	27.00±9.86	30.54±6.94			
SDL	Group 1	3.04±0.53	3.19±0.38	3.14±0.35	0.694	0.244	0.546
	Group 2	3.03±0.64	3.02±0.70	3.00±0.58			
	Group 3	3.20±0.56	3.20±0.71	3.00±0.55			
SA	Group 1	10.15±2.57	13.81±6.22	11.27±6.21	0.969	0.276	0.208
	Group 2	10.53±4.15	12.16±6.50	12.69±6.87			
	Group 3	12.10±5.92	10.83±4.19	12.18±5.63			

SD: Standard deviation; Group 1 (phonophoresis combined with exercise); Group 2 (low-level laser therapy combined with exercise); Group 3 (exercise alone); BSSS: Boston Symptom Severity Scale; BFSS: Boston Functional Status Scale; MDL: Motor Distal Latency; MA: Motor Amplitude; SNV: Sensory Nerve Velocity; SDL: Sensory Distal Latency; SA: Sensory Amplitude; p: Repeated measures ANOVA test. *: p<0.10 and **: p<0.05 statistically significant.

Statistical Analysis

The posthoc power analysis was conducted using G*Power version 3.1.9.2 software. The study power was calculated as 0.80 for α=0.05, with a sample size of 15 in each study group. Quantitative data were presented as mean, standard deviation, median, minimum, and maximum values, and categorical data as frequency and percentages. The normality assumption for the quantitative data was verified using the Shapiro-Wilk test. Time-dependent changes in relevant variables in the phonophoresis, laser, and exercise groups were analyzed using the Repeated Measures ANOVA method for variables with normal distribution, and the Brunner-Langer method (F1-LD-

Table 3. Changes in clinical and ultrasonographic parameters at different time points

Variable	Groups	Baseline Med. (Min–Max)	6th week Med. (Min–Max)	12th week Med. (Min–Max)	Group p	Time p	Group × Time interaction p
VASr	Group 1	6.00 (4.00–9.00)	4.00 (1.00–6.00)	5.00 (2.00–7.00)	0.849	<0.001*	0.291
	Group 2	6.00 (3.00–9.00)	4.00 (2.00–7.00)	4.00 (1.00–8.00)			
	Group 3	6.00 (4.00–9.00)	4.00 (3.00–6.00)	3.50 (2.00–9.00)			
VASa	Group 1	8.00 (4.00–10.00)	4.00 (2.00–6.00)	5.00 (3.00–8.00)	0.648	<0.001*	0.144
	Group 2	8.00 (5.00–10.00)	5.00 (3.00–8.00)	5.00 (2.00–8.00)			
	Group 3	8.00 (6.00–10.00)	5.00 (3.00–7.00)	4.00 (2.00–9.00)			
CSA	Group 1	0.17 (0.14–0.29)	0.16 (0.14–0.29)	0.17 (0.14–0.3)	0.056	0.011*	0.224
	Group 2	0.16 (0.12–0.22)	0.15 (0.13–0.20)	0.15 (0.13–0.20)			
	Group 3	0.16 (0.11–0.27)	0.16 (0.13–0.21)	0.14 (0.07–0.21)			
FR	Group 1	3.23 (2.36–5.42)	3.38 (1.83–5.15)	3.48 (2.53–5.05)	0.471	0.391	0.288
	Group 2	3.63 (2.03–5.43)	3.38 (2.73–4.50)	3.64 (2.73–4.78)			
	Group 3	3.47 (2.50–4.94)	3.65 (2.00–5.17)	3.55 (2.41–5.00)			

Med: Median; Min: Minimum; Max: Maximum; Group 1 (phonophoresis combined with exercise); Group 2 (low-level laser therapy combined with exercise); Group 3 (exercise alone); VASr: Visual Analog Scale at rest; VASa: Visual Analog Scale on activity; CSA: Cross-Sectional Area; FR: Flattening Ratio; p: Brunner-Langer test; a p-value of <0.05 is considered statistically significant (indicated with*).

F1 design) for variables without normal distribution. When the time-dependent change across the groups was found to be dissimilar (when the interaction was significant), the groups were compared using a one-way ANOVA method at baseline and by calculating the difference between baseline and other time points. If the result of the one-way ANOVA was significant, pairwise comparison results of the groups were reported with Bonferroni correction. When the interaction was significant, intragroup comparisons were conducted using the Repeated Measures ANOVA method.

Statistical analyses were performed using IBM SPSS Statistics 25.0 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) and the R 3.5.2 software package (R software, version 3.5.2, package: nparLD, R Foundation for Statistical Computing, Vienna, Austria; http://r-project.org). A p-value of <0.05 was considered statistically significant in all analyses (p<0.10 was considered for interaction).

Results

Forty-five patients with moderate CTS constituted the study population. The data of two patients (one from Group 1 and one from Group 3), who did not complete their control visits in the 12th week after treatment, were also included in the study. The study was concluded with 43 patients who regularly attended their follow-up after treatment. A single wrist with moderate CTS was included, and evaluations were made based on this wrist. In patients with bilateral moderate CTS, the side with the most complaints was evaluated.

No significant differences were found between the general characteristics of patients (p>0.05) (Table 1) and between the groups in clinical, electrophysiological, and ultrasonographic parameters except for BSSS and MDL parameters before treatment, at the 6th and 12th week after treatment (p>0.05) (Table 2, 3).

Time-dependent progression was similar in all groups for BFSS, VASr, VASa, and CSA parameters (group × time interaction p>0.10) (Fig. 1–4). In all three treatment groups, significant differences were found in BFSS, VASr, VASa, and CSA values measured before treatment, at the 6th and 12th weeks after treatment (Table 2, 3).

In each group, two in-group time points were compared. Table 4 demonstrates the comparison of two time points in all three treatment groups. A statistically significant improvement in all three groups was determined in the BFSS, VASr, and VASa values obtained at the post-treatment 6th and 12th week controls compared to the pre-treatment values. However, no significant changes were found in the BFSS, VASr, and VASa values of the patients at the 12th week

Table 4. Comparison of in-group binary time points in all three groups

Comparison	BFSS p	VASr p	VASa p	CSA p
D0-6	<0.001*	<0.001*	<0.001*	0.151
D0-12	<0.001*	<0.001*	<0.001*	0.017*
D6-12	1.000	0.889	1.000	0.525

BFSS: Boston Functional Status Scale; VASr: Visual Analog Scale at rest; VASa: Visual Analog Scale on activity; CSA: Cross-Sectional Area; D0-6: Time differences between baseline and week 6; D0-12: Time differences between baseline and week 12; D6-12: Time differences between week 6 and week 12; p: Bonferroni test; a p-value of <0.05 is considered statistically significant (indicated with *). These p-values are given for all 3 groups.

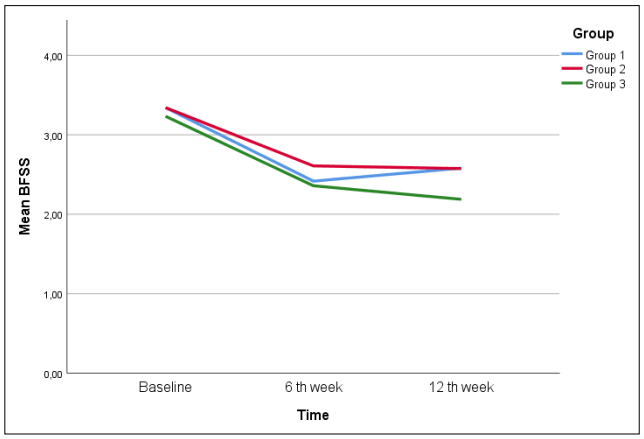

Figure 1. Simple line mean of BFSS (Boston Functional Status Scale) by time by group.

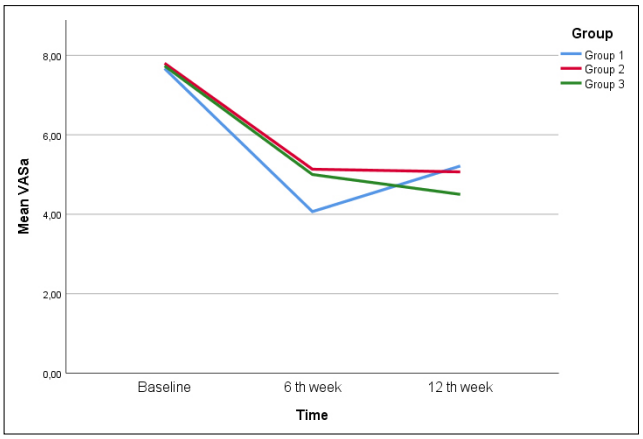

Figure 3. Simple line mean of VASa (Visual Analog Scale on activity) by time by group.

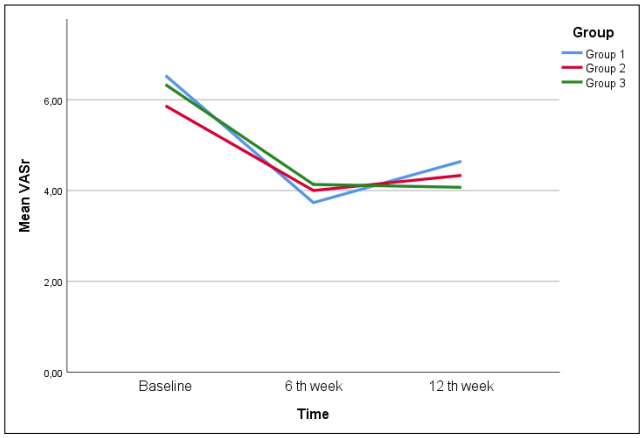

Figure 2. Simple line mean of VASr (Visual Analog Scale at rest) by time by group.

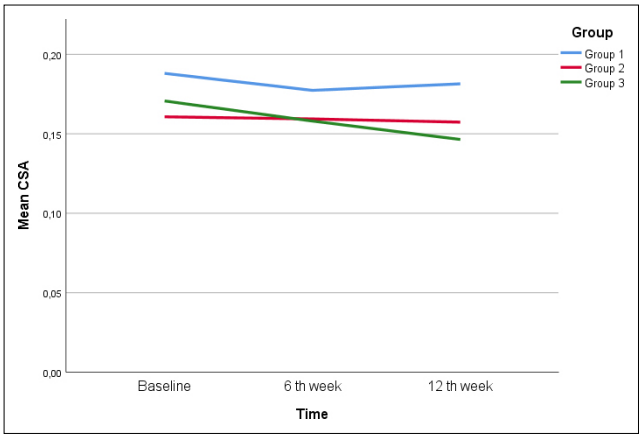

Figure 4. Simple line mean of CSA (Cross-Sectional Area) by time by group.

follow-up compared to the post-treatment 6th week. A statistically significant improvement in all three groups was determined in the CSA values obtained at the post-treatment 12th-week control visits compared to the pre-treatment values (Table 4).

The interaction was found to be significant for the BSSS and MDL parameters (Table 2), and the difference between times in each group was examined. For BSSS, a statistically significant difference was found between pre-treatment and the post-treatment 6th and 12th weeks in each group (p<0.05). However, no statistically significant difference was found between the 6th and 12th weeks (p>0.05). Only for MDL, there was a statistically significant difference between the 6th and 12th weeks in Group 1 (p=0.049).

A significant difference was observed between the groups in the change from the 6th week to the 12th week for the BSSS parameter (p=0.007). This difference was determined between Groups 1 and 3 and in favor of Group 3 (p=0.006). A significant dif-

ference was observed between the groups in the change from pre-treatment to the 12th week after the treatment for the MDL parameter (p=0.032), and this difference was between Group 1 and Group 2 (p=0.042). There was a significant difference between the groups in the change from the 6th week to the 12th week for the MDL parameter (p=0.048), but no significant difference was determined due to Bonferroni correction in binary group comparisons.

Within all three groups, no significant differences were found in MA, SNV, SDL, SA, and FR values before treatment and at the 6th and 12th weeks (Table 2, 3).

Discussion

In the current study, we demonstrated clinically, electrophysiologically, and ultrasonographically that phonophoresis and Low-Level Laser Therapy (LLLT) did not contribute significantly beyond exercise alone. In all groups, post-treatment improvements were observed in symptom severity score, functional capacity scores, and pain both at rest and during activity. Significant improvements were found in Cross-Sectional Area (CSA) values of all groups, one of the ultrasonographic parameters, compared to pre-treatment. No significant changes were observed in any of the electrophysiological findings, excluding Median Distal Latency (MDL), compared to pre-treatment in all three treatment groups. In Group 1, the MDL value at the 12th week decreased compared to the 6th week.

Ultrasound is used to facilitate regeneration following hand tendon and nerve injuries. Phonophoresis involves using ultrasound to enhance the absorption of various anti-inflammatory drugs through the skin.[7] In our study, phonophoresis treatment was applied at a 1 W/cm^2 dose, with 1 MHz frequency, in a 1:4 intermittent mode,[17–19] using 2.5% ketoprofen gel, consistent with other studies in the literature. Cagnie et al.[20] reported that 2.5% ketoprofen is better absorbed with 1 MHz, 1.5 W/cm^2, 5 minutes intermittent mode ultrasound compared to continuous mode and demonstrated ketoprofen's efficacy in reducing pain and inflammation. Similar to our study, there are very few studies involving ketoprofen phonophoresis for CTS. Soyupek et al.[21] compared the effectiveness of splinting, corticosteroid phonophoresis, and non-steroidal anti-inflammatory (diclofenac diethyl ammonium) phonophoresis treatments in CTS patients. They evaluated patients by clinical, ultrasonographic, and electrophysiological parameters three months after initiating treatment. A significant decrease in the anteroposterior diameter and CSA of the median nerve was found in the corticosteroid phonophoresis group compared to pre-treatment. However, no significant changes were observed in the other groups in terms of ultrasonographic parameters. They reported that non-steroidal anti-inflammatory phonophoresis improved some clinical parameters but did not alter ultrasonographic and electrodiagnostic findings. Boonhong et al.[22] compared phonophoresis of piroxicam, phonophoresis of dexamethasone sodium phosphate, and non-drug ultrasound therapy in patients with CTS and demonstrated that these treatments did not improve electrophysiological parameters. Clinical symptoms and functional status improved in all three groups. No statistically significant difference was found between phonophoresis and drug-free ultrasound at MHz frequency and 1.0 W/cm^2 intensity of ultrasound waves.

LLLT is commonly used in the treatment of CTS due to its anti-inflammatory and analgesic effects. Potential anti-inflammatory effects include improvement of vascular supply, nerve reconstruction, and increased myelin production in the median nerve.[6] Many studies in the literature evaluate the efficacy of laser in treating CTS, but laser treatments at different doses and wavelengths have been applied, leading to conflicting results.[23–25] However, in none of these studies was exercise applied similarly to our study. In a placebo-controlled study by Shooshtari et al.[23] on CTS, it was found that laser treatment provided significant improvement in symptoms, nerve conduction studies, and handgrip strength, while no difference was determined in the placebo group except for symptoms. Chang et al.[24] included 36 patients with mild and moderate CTS in a placebo-controlled study. Low-intensity laser (830 nm, 9.7 J/cm^2, 10 sessions) was applied to the treatment group. They reported no decrease in VAS scores for pain, no functional improvement, no increase in hand and finger strength, and no difference in electrophysiological measurements after treatment and in the second week. Contrary to these studies, there are also studies comparing laser treatment with placebo and finding laser treatment ineffective. For ex-

ample, Irvine et al.[25] found that low-intensity laser therapy (860 nm, 6 J/cm^2, 15 sessions) in CTS was not superior to placebo in terms of symptomatic and functional improvement.

Tendon and nerve gliding exercises are often employed in the conservative treatment of Carpal Tunnel Syndrome (CTS). These exercise therapies improve symptoms by stimulating venous return, preventing adhesions between the median nerve and tendons, reducing pressure in the carpal tunnel, and reducing tenosynovial edema.[2] Seradge et al.[26] demonstrated a reduction in carpal tunnel pressure with intermittent active wrist and finger flexion-extension exercises. Schmid et al.[27] reported that exercise therapy led to a reduction in intraneural edema, as evidenced in magnetic resonance imaging studies. Akalin et al.[28] investigated the efficiency of splint and nerve and tendon glide exercises in CTS through clinical parameters and Boston symptom severity and functional status scores. In their study, splinting treatment was applied to the first group for four weeks, and nerve and tendon glide exercises were added to the second group in addition to splinting treatment. Significant improvement was found in both groups' clinical parameters at the one-month evaluation. Rozmaryn et al.[29] included 197 CTS patients in their study and found that nerve and tendon glide exercises contributed to the recovery of symptoms and decreased the surgery rate at follow-up of up to 23 months. In our study, we observed improvements in BCTQ and VAS scores, which are clinical parameters, and CSA values, which are ultrasonographic parameters, in the exercise group. CSA measurements have been demonstrated to be reliable in diagnosing CTS.[30] In a study by Sançmış et al.,[31] the importance of BCTQ was emphasized, stating that symptom severity and functional status scores of BCTQ are reliable methods in monitoring patients post-CTS operations.

In our research, electrodiagnostic studies were fundamental for diagnosing CTS and for patient follow-up. Similarly, many studies in the literature have utilized electrodiagnostic examinations for post-treatment follow-up in CTS.[24,25] In our study, we also performed pre- and post-treatment ultrasonographic evaluations, in addition to electrodiagnostic examinations. Many studies, akin to ours, have used ultrasonography (USG) to monitor CTS disease.[16,18] In the study by Koyuncuoğlu et al.,[32] the CTS diagnosis was confirmed by nerve conduction studies in 260 (81.5%) of 319 wrists diagnosed clinically, while the diagnosis of CTS could not be established in the remaining 59 patients (18.5%). In 30.5% of these 59 patients with clinically diagnosed CTS but negative nerve conduction study results, the median nerve Cross-Sectional Area (CSA) value measured from the pisiform bone level was found to be over 10.5 mm^2. They reported that USG is a helpful diagnostic technique in CTS patients with negative nerve conduction study results. In diagnosing CTS, an increase in the median nerve CSA value measured at the level of the pisiform bone (carpal tunnel inlet) has been shown to have the highest sensitivity and specificity.[30,33] Our findings indicate that ultrasonography, combined with clinical parameters, is a useful tool for monitoring improvements in CTS treatment. Further studies are needed to ascertain the sensitivity of electrophysiological and ultrasonographic evaluations in the follow-up of CTS treatment.

The limitations of the current study include the absence of a placebo group and a small sample size. The absence of a placebo group limited our ability to make a more precise interpretation of treatment modalities. A placebo group was not included in our study due to ethical reservations.

Conclusion

In conclusion, our study results suggest that tendon and nerve gliding exercises may be effective in improving clinical and ultrasonographic outcomes of patients with a diagnosis of moderate CTS. The addition of phonophoresis and LLLT to the exercise regimen, five days a week for three weeks, did not provide additional benefits. Nonetheless, long-term, large-scale, randomized controlled studies are required to evaluate the efficacy of this treatment method more comprehensively.

Ethics Committee Approval: The Celal Bayar University Clinical Research Ethics Committee granted approval for this study (date: 06.05.2015, number: 180).

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