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Full-Length Paper

Investigating the effects of neuromobilization in lateral epicondylitis

Kamil Yilmaz PT, PhD [a,*], Kezban Yigiter Bayramlar PT, PhD [b], Cigdem Ayhan PT, PhD [c], Osman Tufekci MD [d]

[a] Division of Physiotherapy and Rehabilitation, KTO Karatay University, School of Health Sciences, Konya, Turkey
[b] Division of Physiotherapy and Rehabilitation, Hasan Kalyoncu University, Faculty of Health Sciences, Gaziantep, Turkey
[c] Faculty of Physical Therapy and Rehabilitation, Hacettepe University, Ankara, Turkey
[d] Physical Medicine and Rehabilitation, Konya Farabi Hospital, Konya, Turkey

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ABSTRACT

Study Design: Randomized controlled study.
Introduction: Lateral epicondylitis (LE) causes pain and loss of function in the affected limb. Different exercises have been used for the treatment of LE. In recent years, the technique of neuromobilization has been frequently used to treat tendinopathy. However, there is no study that demonstrates the effects of neuromobilization techniques on patients with LE.
Purpose of the Study: The aim of the present study was to determine the effects of neuromobilization techniques on pain, grip strength, and functional status in LE patients and to compare them with conservative rehabilitation treatment.
Methods: A total of 40 patients (26 females and 14 males; age: 42.80 ± 8.91 years) with a history of LE participated in the study. The patients were randomly assigned to two groups: the neuromobilization group and the control group. The neuromobilization group completed a 6-week conservative rehabilitation and radial nerve mobilization program, whereas the control group received conservative rehabilitation therapy only. Both groups underwent a 7-day weekly conservative home rehabilitation program. Pain severity, grip strength, pinch strength, joint motions, and upper extremity functional level were assessed before treatment, at the third week after treatment, and at the sixth week after treatment.
Results: There was a significant decrease in all pain scores in favor of the neuromobilization group at week 6 after treatment (at rest: $P = .001$, effect size (ES) = 0.84; at night: $P = .001$, ES = 0.91 and during activity: $P = .004$, ES = 1.06). No significant differences were found for grip strength, pinch strength, joint motions, and functional level in the neuromobilization group, although trends toward better improvement were observed.
Conclusions: Radial nerve mobilization techniques are more effective on pain than conservative rehabilitation therapy in LE patients, and this effect continues after treatment.

Introduction

Lateral epicondylitis (LE) is a painful situation, which usually occurs due to the overuse of the wrist extensor muscles.[1,2] The prevalence of LE is 1 to 3% in both men and women, and it is highest in individuals aged >40 years.[3] Pain and tenderness over the lateral epicondyle of the humerus at the origin of the common extensor tendon are the main characteristics.[4,5] There is a history of excessive and repetitive stress straining the extensor tendons of the forearm.[6] There are many theories regarding the etiology of LE; however, it is commonly believed to be caused specifically by degeneration of the extensor carpi radialis brevis (ECRB) tendon.[7] LE causes pain and loss of function in the affected limb.[1] Moreover, 20% of LE cases persist for >1 year.[8] Therefore, LE has a great impact on the social and personal lives of patients, and its disease burden continues to increase annually.[1,9]

Different conservative treatment methods have been used for treating LE; however, no standard protocol has been documented in the literature.[10,11] Physiotherapy programs have focused on relieving pain, controlling inflammation, and increasing muscle strength and endurance.[11] The use of eccentric strengthening

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* Corresponding author. KTO Karatay Universitesi, 42020 Konya, Konya, Turkey.
E-mail address: fztkamilyilmaz@hotmail.com (K. Yilmaz).

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programs has been supported by current research.[7,12] Eccentric exercises have been demonstrated to reduce pain and increase function in patients with LE.[13,14] These exercises induce hypertrophy and increase the tensile strength of the muscle−tendon unit, thus consequently reducing tendon strain during movements.[15,16] As a result, eccentric exercises have become one of the most widely used traditional physiotherapy approaches and are often integrated into the physiotherapy program.

Recently, neuromobilization techniques have been employed in treating musculoskeletal problems and various compression syndromes.[17,18] These techniques aim to provide nerve gliding or lengthening via joint movements. Therefore, a therapist extends the nerve length in one joint while shortening the same in the adjacent joint or increases the distance between each end of the nerve,[19,20] and this neural elongation ability in patients with LE has already decreased.[21] Chronic inflammation of the extensor tendons may lead to reactive synovitis of the annulus ligament, which also involves the radial nerve. Furthermore, fibrosis and local edema resulting from overuse of the extensor tendons may increase the pressure over the nerves,[22] and fibrosis of the ECRB muscle may also compress the radial nerve before it enters the Frohse arcade.[23-26] Neuromobilization techniques may facilitate neural gliding, reduce adhesions between the nerve and its surrounding tissue, enhance neural vascularity, and improve axoplasmic flow.[19,20,27] Neuromobilization techniques have also been proposed to modulate central sensitization and peripheral pain mechanisms in musculoskeletal disorders. Given that central sensitization plays an important role in the increased nociceptive reflex and hyperalgesia in LE,[28-31] inducing hypoalgesia via neuromobilization techniques may provide pain relief in the long term. Beneciuk et al[32] demonstrated that a special median nerve-stretching technique has a rapid hypoalgesic effect on pain by inhibiting temporal summation of C-fiber-mediated pain. Researchers suggest that the thermal pain relief mechanism of neuromobilization may be due to inhibition in the dorsal horn. In some animal studies, neural mobilization has been shown to activate the inhibitor pain system, including serotoninergic and noradrenergic pathways in the spinal cord.[33]

Neuromobilization, which has been used in recent years, has been shown to be an effective technique in relieving pain in musculoskeletal disorders such as low back pain, carpal tunnel syndrome, and cervicobrachial neurogenic pain.[27] In the literature, there are no studies that demonstrate the effects of neuromobilization techniques on the functional status of patients with LE. The aim of the present study was to determine the effects of neuromobilization techniques on pain, grip strength, and functional status in LE patients and to compare them with conservative rehabilitation treatment. It was hypothesized that neuromobilization techniques might have additional benefits in patients with lateral epicondylitis in terms of improvements in pain, improve grip strength, and upper extremity functional status when compared to conservative treatment.

Methods

Participants

This randomized controlled study was performed on patients diagnosed with lateral epicondylitis admitted to Hacettepe University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Hand Surgery Rehabilitation Unit and Konya Farabi Hospital Physical Therapy and Rehabilitation Unit between May-December 2014 and approved by the Hacettepe University Clinical Research Ethics Committee (GO 14/95-01). Forty participants diagnosed with LE were included in this study. Patients aged >18 years with a symptom duration of >3 months were included. Patients were excluded if they had: (1) bilateral symptoms, (2) rheumatologic diseases affecting the elbow and the wrist, (3) musculoskeletal disorders due to connective tissue diseases, (4) diffuse pain syndrome, (5) cervical radiculopathy, (6) nerve compression syndromes involving the upper extremity, (7) undergone surgery on the affected arm, (8) received an LE treatment in the last 6 months, and (9) an inability to perform the exercises.

After the patients were informed about the purpose and the procedures of the study, the patients provided their written informed consent before participating in the study. Physiotherapy programs were performed by the first author (KY), and the assessments were completed by the fourth author (OT), who was blinded to the group allocation.

The participants were allocated to the control group and neuromobilization group by using a randomized sampling method by the first author. Envelopes were provided as many as the number of people determined by the power analysis method. The papers written by the neuromobilization group were placed in half of these sealed opaque envelopes, and the other papers by the control group were placed in the other half of sealed opaque envelopes. Then the envelopes were numbered and sealed, and respectively, placed in a box. Before the treatment, the sealed opaque envelopes drawn from the box by the patient were opened by the first author and treatment of the patients was started subject to the selected group.

The control group received a home program, whereas the neuromobilization group received a home program plus radial nerve mobilization. The home program included patient education and eccentric exercises. We chose eccentric exercises in the control group because they are one of the most recommended exercises in LE and are included in the standard rehabilitation program at our institution. The home program was administered three times daily for 6 weeks. In addition to the home program, the participants in the neuromobilization group underwent radial nerve mobilization for 3 days a week for 3 weeks. Furthermore, the patients in the neuromobilization group were asked to perform radial nerve mobilization exercises at home for 6 weeks. The patients in both groups were told to avoid exacerbating their condition and engaging in forceful activities and to rest intermittently during periods of intense pain.[14] The patients were instructed not to take any medications that provide pain relief throughout the study period.

Outcome measures

Assessments were performed at baseline, at the third week, posttreatment, and at the sixth week posttreatment. The patients in both groups were assessed in terms of pain severity, grip strength, pinch strength, range of motion (ROM) of the wrist, and functional status of the upper extremity.

Descriptive characteristics regarding sex, age, weight, height, dominant side, and affected side were recorded during the baseline assessment.

Pain severity was measured using a 10-cm visual analog scale, labeled from 0 (no pain) to 10 (the worst pain), at rest, at night, and during daily activities.[34]

Grip strength was measured using two different test methods: pain-free grip strength and maximum grip strength. Both tests were performed in the sitting position with the elbow flexed at 90° and in the standing position with the elbow extended at 0°.[35] In the sitting position, the upper extremity was positioned based on the instructions of the American Society of Hand Therapists with the shoulder adducted and neutrally rotated, elbow flexed at 90°, the forearm in a neutral position, and the wrist in 0°-30° extension and 0°-15° ulnar deviation position.[36] In the standing position, the shoulder is adducted, and the elbow is extended.[37] Both tests were performed using a calibrated hydraulic hand dynamometer (Jamar, Bolingbrook IL). The measurements of both extremities were repeated 3 times with a resting interval of 30 second between each measurement. The average of the three trials was recorded in kilograms (kg). To measure the pain-free grip strength, the participants were instructed to grip the dynamometer to the point where they felt discomfort, whereas, for the maximum grip strength, the participants were instructed to grip with their maximal effort beyond the pain threshold.

Tip pinch and key pinch were measured using the "Baseline Mechanical Pinch Gauge" (FEI, White Plains, NY).[38] Measurements were repeated 3 times with a resting interval of 30 second between each measurement. The average of the three trials was recorded in kg. The patients were positioned as described by the American Society of Hand Therapists.

Wrist active ROMs, including flexion, extension, and radial and ulnar deviation, were recorded in degrees by using a universal goniometer for each group.[39]

The functional status of the upper extremity was evaluated using the Turkish version of the DASH questionnaire.[40] The DASH questionnaire includes 30 items related to symptoms and activities of daily living. The total score is 100, and a higher score indicates a higher degree of disability.

Treatment protocol

Control group

The patients in the control group received education and eccentric strengthening exercises as part of a home program. These exercises were performed in the sitting position with the elbow extended, the forearm pronated, and the wrist fully extended. First, the patients fully extended their wrist (Fig. 1A). Second, they slowly moved their wrist from full wrist extension to full wrist flexion (Fig. 1B). Finally, they passively extended their wrist with the help of the other hand to the starting position (Fig. 1C). Patients were instructed to stop the exercises if they felt pain at any time during the exercises.[14]

After the patients were able to perform the exercises without discomfort or pain, strength training was progressed with the resistance exercises. The concept of ten-repetition maximum (10 RM) performance as proposed by DeLorme[41] was used for instrumenting the progress of the resistance exercises. Patients were advised to continue the previous exercises without weights when they felt pain during the resistance exercises.[14] The exercise was performed in both groups at home for 6 weeks, and three sets of 10 repetitions of progressive eccentric exercises of the wrist extensors were performed daily, with a 1-minute rest interval between each set. Patients visited the physiotherapist once every other week for a follow-up examination and to receive a progression of the exercises.

Neuromobilization group

The neuromobilization group underwent a physiotherapy program, which included radial nerve mobilization exercises performed by the physiotherapist for 3 weeks and a home program for 6 weeks. The patients in the neuromobilization group also performed self-neuromobilization exercises at home for 6 weeks.

The neuromobilization exercises were performed to improve radial nerve gliding throughout the surrounding tissues and to induce hypoalgesia.[32,33,42] The patients performed the radial nerve mobilization exercises in a supine position with the arms resting by the side. The physiotherapist holds the patient's arm and wrist while the patient reclined on his side (Fig. 2A). After depressing the patient's shoulder, the physiotherapist extended the elbow and then internally rotated the patient's arm. The patient's wrist, thumb, and fingers were all flexed, and the patient's ulnar was brought to deviation (Fig. 2B). Finally, the patient's position was maintained, and the arm was abducted (Fig. 2C). Also, with the rotation or lateral flexion movements of the head, the severity of tension was adjusted (Fig. 2D). The nerve was relaxed after each repetition.[20,42,43] Each tensioning position was maintained for 3 second. Radial nerve mobilization exercises were applied to the participants 3 days per week for a total of 3 weeks.[32,44] Three sets of 10 repetitions were performed during each treatment session with 2 minute of rest between sets.

Patients were instructed to perform self-neuromobilization exercises 10 times a day for 6 weeks. Each patient received a brochure describing the exercises with illustrations for their home therapy program at the first visit.[45] Self-neuromobilization exercises were performed in the standing position (Fig. 3A). With the elbows in extension, the patient was then asked to twist his/her wrist toward the ulnar deviation and to rotate his/her arm internally by depressing his shoulder. In the meantime, the patient was asked to turn his/her head toward his/her palm and stare at it for at least 3 second before returning to his/her initial position (Fig. 3B).

The participation rates of patients to weekly physiotherapy visits were over 80% in both groups. The patients answered the following question; "Did you do your daily exercises the way you were instructed?" The positive response to the question was 88.2% in the neuromobilization group and 80.6% in the control group, respectively.

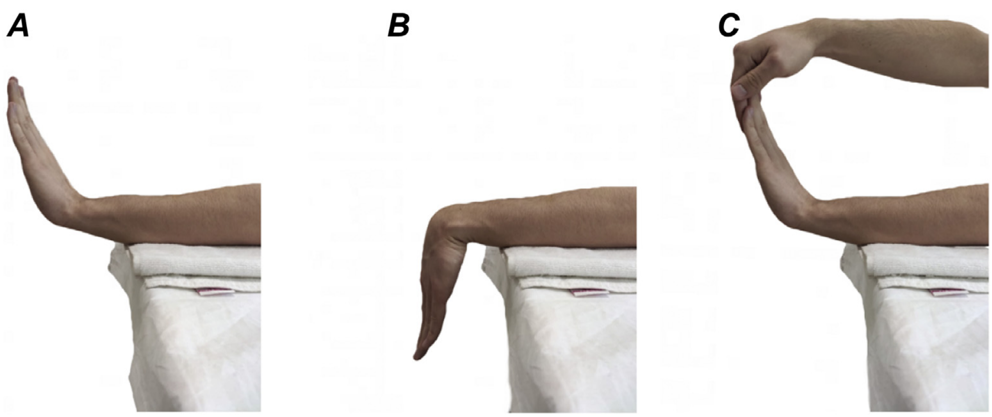

Fig. 1. Eccentric strengthening exercises. (**A**) Starting position, wrist in full extension. (**B**) The wrist is slowly moved from full extension to full flexion. (**C**) The wrist is passively extended to the starting position with the help of the other hand.

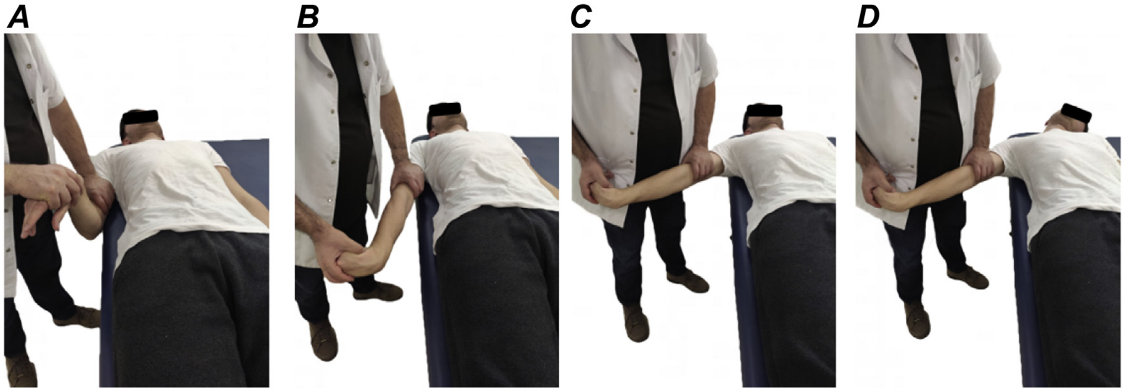

Fig. 2. Radial nerve mobilization technique. (**A**) Physiotherapist holds the patient's arm and wrist. (**B**) Physiotherapist depresses the patient's shoulder, extends the patient's elbow, and then internally rotates the arm. The patient's wrist, thumb and fingers are flexed, and the wrist is brought to ulnar deviation. (**C**) The shoulder is abducted while maintaining the patient's position. (**D**) The severity of the tension is adjusted by the rotation of the head or lateral flexion movements.

Statistical analysis

Statistical analysis was performed using SPSS Statistical Software Package 21.0 (SPSS Inc., Chicago, IL). The variables were expressed in terms of mean and standard deviation values.

The normality of continuous variables was analyzed using the Kolmogorov–Smirnov test. The independent *t*-test for parametric data or the Mann–Whitney *U* test for nonparametric data was used to compare the groups. If the normality and homogeneity of variance were obtained, a repeated-measures ANOVA was used to make comparisons of within-group measurements; otherwise, the Friedman test was used. The Bonferroni correction method was used to determine the parametric status, and the Wilcoxon signed-rank test was used to determine the nonparametric status in paired comparisons of repeated measurements within the groups. The required sample size power analysis results, three repeats in each of at least 20 individuals in total, were determined. In this case, 80.04% of the power test is expected to be obtained. A $P = .05$ was considered statistically significant in all analyses.

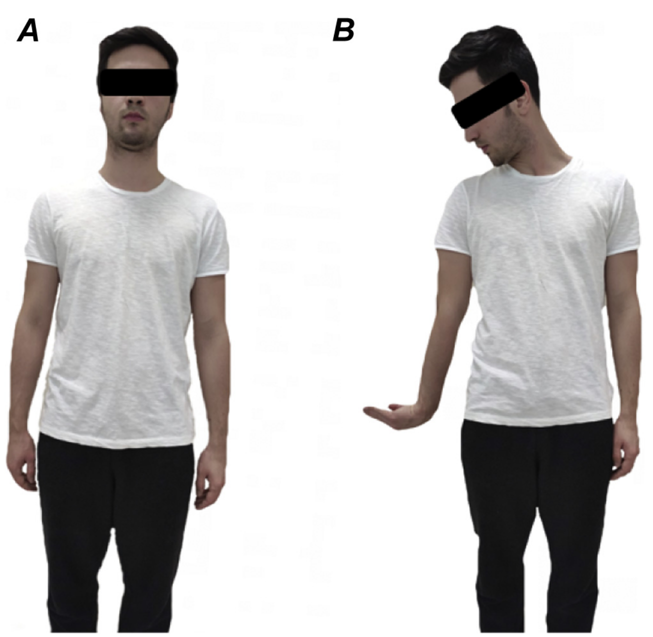

Fig. 3. Self-neuromobilization exercises. (**A**) Starting position. (**B**) The patient extends his elbow, turns his wrist toward the ulnar deviation, depresses his shoulder, rotates his arm internally, and looks at it for at least 3 s, turning his head toward his palm before returning to his starting position.

Results

Forty patients who met the inclusion criteria were included in the study, and patients were randomized to the neuromobilization group ($n = 20$) and the control group ($n = 20$). Three participants involved in the neuromobilization group, and two participants in the control group, did not participate in the assessments of the third-week, posttreatment and the sixth-week posttreatment. One of the participants in the neuromobilization group did not attend the sixth week of posttreatment assessment because of pain. The flow diagram in Figure 4 shows the study design. Table 1 shows the demographic data, including age, sex, body mass index, occupation, dominant side, affected side, education status, and complaint duration.

Intergroup comparison

Table 2 shows the data obtained from the intergroup comparison. All pain scores were lower in the neuromobilization group than the control group at week six after the treatment (VAS at rest: $P = .001$, effect size (ES) = 0.84; VAS at night: $P = .001$, ES = 0.91 and VAS during activity: $P = .004$, ES = 1.06). No statistically significant differences were found in pinch strength, painless, and maximum grip strengths in both elbow flexion and extension positions between the neuromobilization and control groups ($P > .05$).

In the intergroup comparison of normal joint movements, a significant difference was observed in the posttreatment and sixth-week posttreatment measurement values of the ulnar deviation angle ($P < .05$). No significant difference was found between the groups in terms of extension, flexion, and radial deviation angle values ($P > .05$).

When the groups were compared as for DASH-T, the difference between them was not statistically significant, although there was more development in the neuromobilization group than in the control group ($P > .05$).

Intragroup comparison

Pain severity, grip strength, pinch strength, and functional level improved in both groups in all measurement periods compared with the baseline values ($P < .05$).

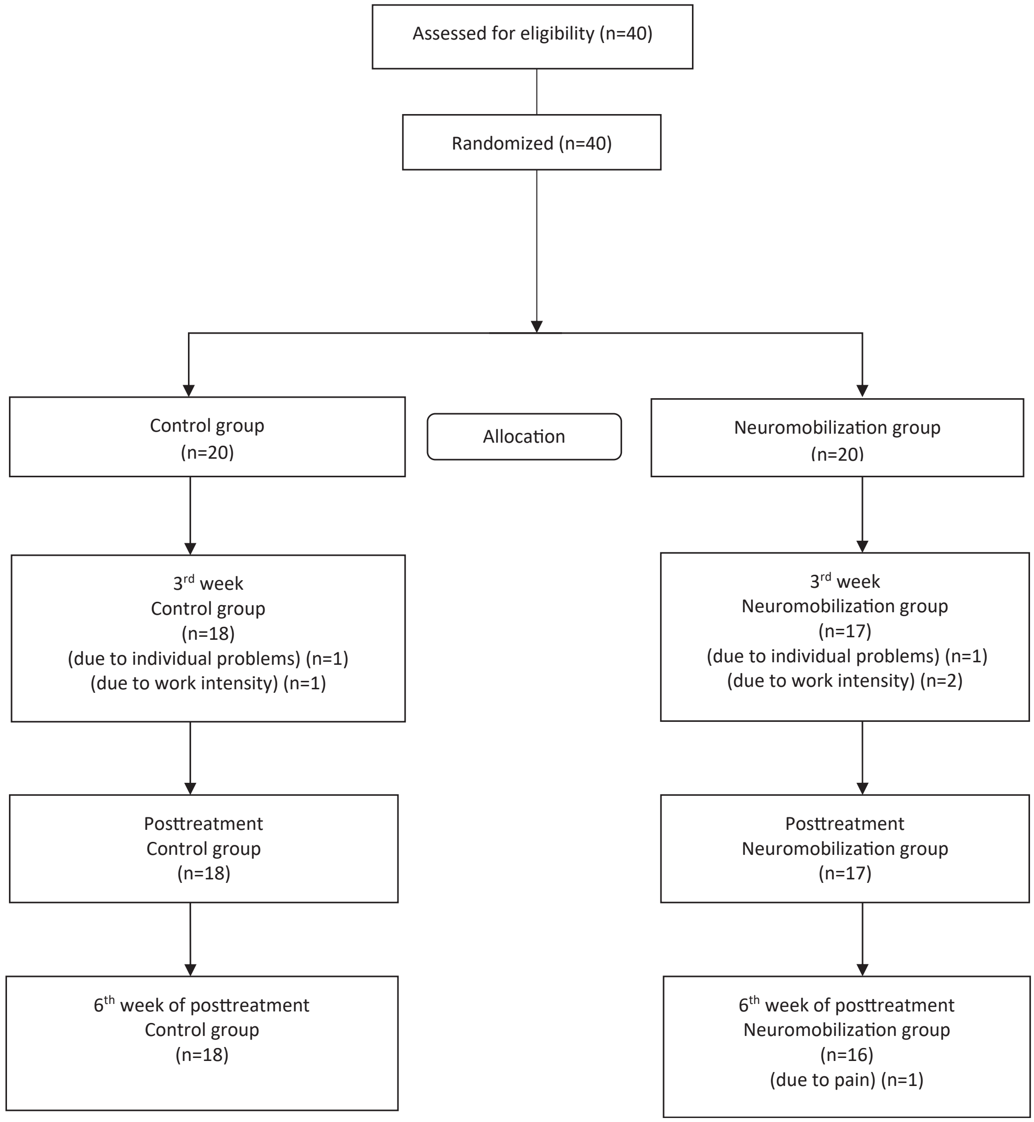

Fig. 4. Study flow diagram.

Flexion and radial deviation values increased in the third week in the neuromobilization group, whereas radial deviation values increased in the posttreatment and in the sixth-week of post-treatment in the control group ($P < .05$).

Discussion

In this study, neuromobilization techniques were found to be effective on pain, but its contribution to the grip strength and upper extremity functional level was not found.

Pain

Pain is one of the most frequent symptoms in patients with LE. Patients mostly complain about pain at the lateral epicondyle. The pain may also diffuse to the common extensor muscles. Tenderness is observed by palpating the ECRB tendon.[46] Wrist extension, middle finger extension against resistance, and passive wrist flexion aggravate the pain and tenderness on the lateral epicondyle.[47] This condition is more likely to occur in individuals who must do perform wrist flexion, extension, or forearm rotation in their daily activities.[48] Various rehabilitation modalities, including ultrasound, phonophoresis, electrical stimulation, manipulation, soft-tissue mobilization, neural stretching, friction massage, and stretching and strengthening exercises,[10] are used in LE treatment to reduce the pain.

The effects of exercise approaches on pain have been demonstrated in the literature. In a systematic review, Ortega-Castillo and Medina-Porqueres[49] reported that pain decreased significantly with eccentric exercises in 11 studies and that this decrease was more than that in the control group in five studies. Neuromobilization exercises have been one of the most frequently used exercises in treating orthopedic problems in recent years. These exercises aim to maintain the balance between neural tissues and the relevant movements of the mechanical interface nearby. Neuromobilization exercises may affect a range of optimum physiological functions by allowing internal pressure to decrease in neural tissues.[20] In literature, there have been studies showing that these exercises relieve pain. In a study in which he studied the neuromobilization effect in carpal tunnel syndrome, Manchanda[45] found a significant difference for the neuromobilization group in terms of pain level. Oskay et al[50] applied neurodynamics onto the ulnar

Table 1
Demographic data

Variable	Control group $n = 20$	Neuromobilization group $n = 20$	t	*P*
Age (y) (mean ± SD)	42.90 ± 10.27	42.70 ± 7.57	−0.70	.944
(Min-max)	22-59	28-57		
Sex *n* (%)				
Female	12 (%60)	14 (%70)		
Male	8 (%40)	6 (%30)		
BMI (kg/m^2) (mean ± SD)	29.10 ± 5.61	27.61 ± 4.97	−0.89	.380
(Min-max)	20.40-39.60	18.70-37.80		
Occupation *n* (%)				
Housewife	8 (%40)	7 (%35)		
Technician	2 (%10)	2 (%10)		
Servant	2 (%10)	4 (%20)		
Others	8 (%40)	7 (%35)		
Dominant side *n* (%)				
Right	17 (%85)	18 (%90)		
Left	3 (%15)	2 (%10)		
Affected side *n* (%)				
Right	17 (%85)	15 (%75)		
Left	3 (%15)	5 (%25)		
Education status *n* (%)				
Primary school	10 (%50)	11 (%55)		
Secondary school	3 (%15)	1 (%5)		
High school	4 (%20)	3 (%15)		
University	1 (%5)	4 (%20)		
Postgraduate	2 (%10)	1 (%5)		
Complaint duration (month) (mean ± SD)	29.25 ± 32.80	30.45 ± 34.55	0.11	.911
(Min-max)	3-144	3-132		

SD = standard deviation; BMI = Body Mass Index.

nerve of seven patients with cubital tunnel syndrome in a long-term follow-up study (12 months). It was reported that there was a significant decrease in pain level after the application. However, no study has assessed the efficiency of neuromobilization exercises in patients with LE in literature.

In our study, the pain level was evaluated at different situations because pain is a significant symptom in patients with LE. As described in the literature, neuromobilization exercises were more efficient in terms of resting, activity, and night pain control in our study. Pain severity decreased quicker during the third week of evaluation in the neuromobilization group. At the sixth-week posttreatment evaluation, it was seen that the resting and night pain disappeared completely in the patients of the neuromobilization group. However, in the control group, the pain gradually increased again posttreatment, and the efficiency of the therapy decreased. Activity pain decreased significantly in the neuromobilization group, and its efficiency was maintained as observed in the sixth week of posttreatment evaluation. There was a decrease in the extension ability of the radial nerve in patients with LE.[21] The chronic inflammation of the common extensor tendons in the elbow may cause the reactive synovitis of the annular ligament involving the radial nerve and cause fibrosis owing to the excessive use of tendons; hence, local edema may increase the pressure on the nerve.[22,51] Therefore, we proposed that the mobilization of the radial nerve may increase the gliding ability of the nerve, which may have positive effects on pain with increased neural vascularity.

Grip strength

One of the main complaints of LE is the decrease in grip strength. It was reported that both maximum and painless grip strength decreased in the patients with LE.[52] A study on motor stimulation of wrist extensor muscles using transcranial magnetic stimulation has shown that cortical organization can be maladaptive in individuals with lateral elbow tendinopathy.[53] The activation in sensory and motor functions in patients with LE may cause a decrease in grip strength. Individuals frequently tend to grip with the wrist in flexion.[54,55] Studies have shown that a painless grip strength measurement method offers a precise clinical measurement.[52] Studies have determined the effect of eccentric training on grip strength. Peterson et al[56] investigated the efficiency of eccentric and concentric exercises in 120 patients with chronic tennis elbow and found that the eccentric exercise group showed a higher muscle strength increase. In the systematic review by Ortega-Castillo and Medina-Porqueres,[49] nine studies considered the effect of different parameters on strength, including isometric strength, painless grip strength, and painless isometric strength. In the intragroup comparison, the strength in the eccentric exercise group significantly improved in seven studies. However, in the intergroup comparison, the eccentric group was more efficient than the concentric group regarding some strength parameters.

We proposed that neuromobilization exercises could increase grip ability because of both the positive effects on pain and the mechanical effects. Villfane et al[42] reported that radial nerve mobilization in 60 patients with thumb carpometacarpal osteoarthritis caused an increase in fingertip grip strength; however, there were no significant differences between the first and second month of follow-ups. In this study, however, it was observed that there were no differences between the groups concerning grip and pinch strength, although an increase in all considerations was obtained in painless grip strength, maximum grip strength, and pinch grip strength during intragroup comparisons. The grip strength can decrease secondarily to pain in patients with LE.[57] Increased by neuromobilization exercises, nerve mobilization can increase the grip strength via peripheral effect by increasing neural vascularity and axoplasmic transport. Another possible mechanism is that it increases motor ignition at a central level, supporting the restoration of maladaptive cortical reorganization in these patients. Long-term follow-up studies in which objective measurements have been used are needed to test these hypotheses.

Range of motion

Wrist extension, flexion, and ulnar and radial deviation activities may be affected in patients with LE. It has been reported that there is a loss of approximately 5°-15° in the wrist extension range in patients with chronic LE.[58] Neuromobilization exercises cause an increase in the sensitivity of neurotendinous organs. This causes an increase in muscle relaxation and pain tolerance, allowing more ROM. In a randomized controlled study, Nunes et al[59] explained the reason for the increase in elbow extension with the restoration by the neural mobilization ability of muscle skeleton structures, which were innerved by the nervous system itself and its motion. In our study, a statistically significant difference was observed in the posttreatment and sixth week posttreatment evaluations between two groups regarding the wrist ulnar deviation angle. Ulnar deviation angles in the neuromobilization group were noted to be much higher than those in the control group in both evaluation periods. However, we think that this difference between groups occurred due to the decrease in the ulnar deviation angle in the control group. Also, when the results within the group were analyzed, no significant change was observed in the ulnar deviation angle in both groups. It was found that there was a significant difference between the average beginning flexion angle and the third-week values in the neuromobilization group. An increase in the flexion angle was observed when the therapy started. We hypothesize that the mobilization of the wrist by positioning in the flexion direction during neuromobilization caused an increase in the ROM of the

Table 2
Intergroups comparison of pain severity, grip strength, pinch strength, joint motions , and upper extremity functional level

Variables	Baseline (mean ± SD)			3rd week (mean ± SD)			Posttreatment (mean ± SD)			6th week of posttreatment (mean ± SD)		
	C (n = 20)	N (n = 20)	P/Effect size[c]	C (n = 18)	N (n = 17)	P/Effect size[c]	C (n = 18)	N (n = 17)	P/Effect size[c]	C (n = 18)	N (n = 16)	P/Effect size[c]
VAS rest pain level (cm)	2.78 ± 2.42	4.50 ± 1.85	0.016[a,d] 0.80[c]	1.72 ± 2.26	1.59 ± 1.87	0.850[a] 0.06[c]	0.61 ± 1.04	0.56 ± 1.26	0.894[a] 0.04[c]	1.06 ± 1.73	0	0.001[b,d] 0.84[c]
VAS night pain level (cm)	3.58 ± 2.55	4.70 ± 3.11	0.218[a] 0.39[c]	2.28 ± 2.28	1.26 ± 1.86	0.161[a] 0.49[c]	0.86 ± 1.11	0.74 ± 1.60	0.788[a] 0.09[c]	1.19 ± 1.79	0	0.001[b,d] 0.91[c]
VAS activity pain level (cm)	6.03 ± 1.94	7.23 ± 1.74	0.046[a,d] 0.65[c]	4.19 ± 3.03	3.06 ± 3.07	0.279[a] 0.37[c]	2.69 ± 2.19	1.62 ± 1.95	0.135[a] 0.52[c]	2.56 ± 2.55	0.50 ± 0.84	0.004[b,d] 1.06[c]
Painless grip strength when elbow in flexion (kg-force)	27.59 ± 11.80	26.29 ± 9.01	0.698[a] 0.12[c]	31.10 ± 13.75	32.14 ± 10.16	0.801[a] 0.09[c]	31.42 ± 13.02	33.09 ± 7.88	0.651[a] 0.15[c]	32.18 ± 13.78	32.98 ± 9.61	0.849[a] 0.07[c]
Maximum grip strength when elbow in flexion (kg-force)	31.13 ± 13.23	30.49 ± 9.66	0.861[a] 0.06[c]	33.79 ± 15.14	33.69 ± 9.92	0.981[a] 0.01[c]	34.12 ± 14.63	34.94 ± 8.40	0.314[b] 0.07[c]	34.41 ± 15.27	34.50 ± 9.26	0.361[b] 0.01[c]
Painless grip strength when elbow in extension (kg-force)	29.58 ± 12.29	29.17 ± 10.62	0.911[a] 0.04[c]	33.40 ± 15.33	32.00 ± 9.19	0.541[b] 0.11[c]	33.64 ± 14.64	32.92 ± 7.69	0.373[b] 0.06[c]	34.70 ± 14.78	33.56 ± 9.20	0.490[b] 0.09[c]
Maximum grip strength when elbow in extension (kg-force)	33.46 ± 13.40	32.12 ± 11.08	0.732[a] 0.11[c]	35.82 ± 14.66	33.44 ± 8.98	0.570[a] 0.19[c]	36.17 ± 14.98	35.19 ± 8.60	0.520[b] 0.08[c]	36.98 ± 16.18	35.00 ± 8.62	0.605[b] 0.15[c]
Key pinch grip strength (kg-force)	6.24 ± 2.56	6.16 ± 1.82	0.892[b] 0.04[c]	6.56 ± 2.57	6.74 ± 1.58	0.298[b] 0.08[c]	6.83 ± 2.27	6.73 ± 1.38	0.692[b] 0.05[c]	6.82 ± 2.16	6.67 ± 1.44	0.743[b] 0.08[c]
Tip pinch grip strength (kg-force)	4.46 ± 1.97	4.55 ± 1.64	0.865[a] 0.05[c]	5.12 ± 2.52	5.20 ± 1.24	0.146[b] 0.04[c]	5.15 ± 2.29	5.34 ± 1.05	0.142[b] 0.11[c]	5.36 ± 2.07	5.26 ± 1.22	0.512[b] 0.06[c]
Normal joint motion extension angle (°)	69.70 ± 7.28	70.80 ± 8.73	0.668[a] 0.14[c]	71.17 ± 6.00	74.06 ± 6.49	0.180[a] 0.46[c]	69.67 ± 4.07	72.24 ± 6.01	0.146[a] 0.50[c]	70.72 ± 4.17	71.81 ± 5.08	0.497[a] 0.24[c]
Normal joint motion flexion angle (°)	68.55 ± 6.54	67.10 ± 5.26	0.445[a] 0.24[c]	70.94 ± 8.99	72.59 ± 5.58	0.987[b] 0.22[c]	66.67 ± 9.02	71.41 ± 5.71	0.311[b] 0.62[c]	67.56 ± 8.97	72.56 ± 5.74	0.115[b] 0.66[c]
Normal joint motion radial deviation angle (°)	19.10 ± 3.06	19.35 ± 3.33	0.806[a] 0.08[c]	20.61 ± 3.33	21.00 ± 3.20	0.727[a] 0.12[c]	21.11 ± 2.85	20.53 ± 3.00	0.560[a] 0.20[c]	21.56 ± 2.38	20.50 ± 2.61	0.226[a] 0.43[c]
Normal joint motion ulnar deviation angle (°)	29.05 ± 5.60	31.60 ± 3.76	0.099[a] 0.53[c]	29.56 ± 5.29	31.71 ± 3.16	0.157[a] 0.49[c]	28.33 ± 5.54	32.59 ± 2.06	0.009[b,d] 1.01[c]	28.56 ± 6.01	32.25 ± 1.81	0.015[b,d] 0.81[c]
Functionality level DASH-T score	32.83 ± 14.09	39.20 ± 13.71	0.155[a] 0.46[c]	26.48 ± 16.00	20.49 ± 12.51	0.228[a] 0.42[c]	15.65 ± 9.78	12.79 ± 9.98	0.399[a] 0.29[c]	11.62 ± 12.22	5.36 ± 4.56	0.063[a] 0.66[c]

SD = standard deviation; C = Control group; N = Neuromobilization group; VAS = Visual Analog Scale.

[a] Independent two group t-test.

[b] Mann–Whitney U test.

[c] Effect size was calculated using Cohen's d formula.

[d] Statistically significant (P < .05).

wrist. That the wrist extensor muscles are collectively affected by the pain in LE may cause spasm in the muscles, and in time, some decreases in the flexion angle. The pain that is experienced in the wrist flexion during this ailment may cause a decrease in motion function, as well as a decrease in ROM. In our study, we reason that not making passive measurements causes constraints in analyzing this parameter.

Upper extremity functional status

The pain and loss of grip strength in patients with LE may adversely affect the upper extremity functionality. DASH is one of the most commonly used outcome measurement in upper extremity problems. In our study, there was no difference between the neuromobilization and control groups. Similarly, Martinez-Silvestrini et al[7] did not find significant improvements in the DASH scores of patients with LE in whom they studied the effects of stretching, concentric strengthening exercises, and eccentric strengthening exercises. However, several studies have demonstrated significant improvements in the upper extremity function following eccentric training.[49] Oskay et al[50] also showed that ulnar nerve mobilization exercises resulted in decreased DASH-T scores at the 12th month. We concluded that the follow-up period might be too short for showing the effects of the radial nerve mobilization exercises on upper extremity function. Moreover, it was suggested that a disease-specific outcome measurement, such as patient-rated tennis elbow evaluation, might accurately address the difficulties in daily living activities compared with region-specific measures.

Study limitations

One of the limitations of our study is the short follow-up period. We consider that a long-term follow-up is better for understanding the efficiency of neuromobilization applications. Moreover, some intergroup differences that did not occur in the short-term follow-up may occur at the end of the long-term follow-up period. We also believe that the low number of samples included in the study may have affected the results. Another limitation is that we only considered the active motion angle, not the passive motion angle, in ROM consideration. We assume that there will be objective effects of passive motion angle consideration on the results. Considering that active motion can change according to the psychology, pain, and fatigue level of the individual at that time, this can directly affect the results.

Conclusion

It was seen that neuromobilization techniques had positive effects on pain in lateral epicondylitis. It is also understood that this effect lasts longer than conservative rehabilitation treatments that include eccentric strengthening exercises. However, no additional contribution of neuromobilization to the grip strength, pinch strength, joint motions, and functional level of the upper extremity was found. Further studies with a larger sample size and longer follow-up times would enlighten the effectiveness of neuromobilization techniques.

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1. The study design is
   a. retrospective cohort
   b. prospective cohort
   c. RCTs
   d. case series

2. The radial nerve mobilization techniques
   a. were referred to, but not described in sufficient detail to teach readers how to perform them
   b. were presented in sufficient detail to teach readers how to perform them
   c. were many and varied
   d. left up to therapists to select their preferred method

3. Outcome measures included
   a. function
   b. pain
   c. grip
   d. all of the above

4. All subjects were
   a. post-op for ECRB release
   b. treated by nerve gliding in the clinic
   c. given a traditional home exercise program
   d. taught nerve gliding techniques to be performed at home

5. The authors conclude that radial nerve mobilization is more effective than traditional therapy in managing LE
   a. false
   b. true

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