

# Contralateral versus ipsilateral neural mobilization of median nerve in patients with unilateral carpal tunnel syndrome

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## ABSTRACT

**Objective:** The purpose of this study was to compare the effect of contralateral neural mobilization, ipsilateral neural mobilization of the median nerve and conventional treatment on (CTS).

**Methods:** forty-five patients from both genders diagnosed as unilateral mild or moderate CTS were randomly assigned into three equaled study groups, each one included 15 patients, each group received conventional treatment in the form of TENS, U.S and infra-red. The first group received contralateral neural mobilization in the form of upper limb tension test 1 (ULTT-1) plus conventional treatment, the second group received ipsilateral neural mobilization in the form of (ULTT-1) plus conventional treatment and the third group received only conventional treatment. Treatment in all groups was conducted for 3 sessions per week for 2 weeks. Pain level and functional level were measured by visual analogue scale (VAS) and Upper Extremity Functional Scale (UEFS), respectively.

**Results:** The comparison between pretreatment and post-treatment results in all groups reported significant differences within each group and non-significant differences among the 3 groups.

**Conclusions:** conventional treatment (TENS, U.S and infra-red) has the upper hand in treating CTS symptoms and both ipsilateral and contralateral neural mobilization have only a complementary effect to the conventional treatment effect.

**Keywords:** Neural mobilization, carpal tunnel syndrome, contralateral, ipsilateral, median nerve

## Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy. It is caused by compression of the median nerve at the wrist level [1].

It is evaluated that one of every five patients having upper limb pain and numbness has the finding of CTS. CTS additionally represents 90% of all known entrapment neuropathies [2].

One of the recent techniques for treating CTS is neural mobilization. Neural mobilization (NM) is a piece of manual treatment that is considered to be a good treatment for specific conditions [3], including carpal tunnel disorder [4].

Neural mobilization has a potential impact on autonomic function; improves blood flow speed inside the radial artery [5] and the diminished skin temperature of the hand has been observed during (NM) exercises [6]. In addition, (NM) exercises have been recommended to take a part in lessening intraneural swelling and circulatory stasis by adjusting intraneural pressure going with these methods [7].

Recognizing the pathogenesis of CTS might be essential in proving the efficacy of neural mobilizing techniques. The accompanying three etiologies which are recommended to cause CTS by evoking pressure of the neurovascular framework as it goes through the carpal tunnel, are: (1) ischemia, (2) a diminishing longitudinal excursion of the median nerve, and (3) mechanical pressure or damage to included carpal structures. CTS caused by ischemia might be decidedly influenced by treatment with neural mobilization techniques. Nerves are sensitive to delayed ischemic states because of the bad need for the circulating oxygen. Neural mobilizing techniques may decrease ischemic pain by adding to the conveyance of oxygenated blood to the median nerve at its distal site inside the wrist and hand [8].

### Access this article online

Website: [www.japer.in](http://www.japer.in)

E-ISSN: 2249-3379

**How to cite this article:** Mahmoud S. Asal, Mohamed H. Elgendy, Olfat I. Ali, and Amira A. Labib. Contralateral versus ipsilateral neural mobilization of median nerve in patients with unilateral carpal tunnel syndrome. J Adv Pharm Edu Res 2018;8(1):17-22.

**Source of Support:** Nil, Conflict of Interest: None declared.

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[9, 10, 11, 12] used neural mobilization as a method in treating CTS, they reported good results in decreasing CTS patients' symptoms.

Contralateral movements can be utilized as a part of mechanical diagnosis and treatment. Treatment with the contralateral procedure can be defended in some conditions, particularly if the procedure creates an improvement and can be incorporated into whatever is left of patient management [13].

Recently many researchers have made studies using the contralateral limb to treat ipsilateral limb, for example, [14] made neural mobilization of the sound side in stroke patients and found a change in the electrical signal of spasticity of biceps brachii in the hemiplegic side. Also, [15] found that neural mobilization of the lower extremity has the ability to increase the hamstring muscle length on the contralateral limb in which neural mobilization was not applied.

The nervous system is a continuum both structurally and functionally. It is unknown if neural mobilization of the contralateral side of CTS can influence affected side or not, so this study was designed to investigate the effect of contralateral neural mobilization on ipsilateral hand with CTS and compare it with ipsilateral neural mobilization. This will give us another tool in treating CTS patients, especially if the patients have a difficulty in executing neural mobilization in the ipsilateral hand.

## Patients and Methods

### Design of the study

This study is a randomized controlled trial. It included 3 groups of patients. Group one received contralateral neural mobilization plus conventional treatment. Group two received ipsilateral neural mobilization plus conventional treatment. Group three received only the conventional treatment.

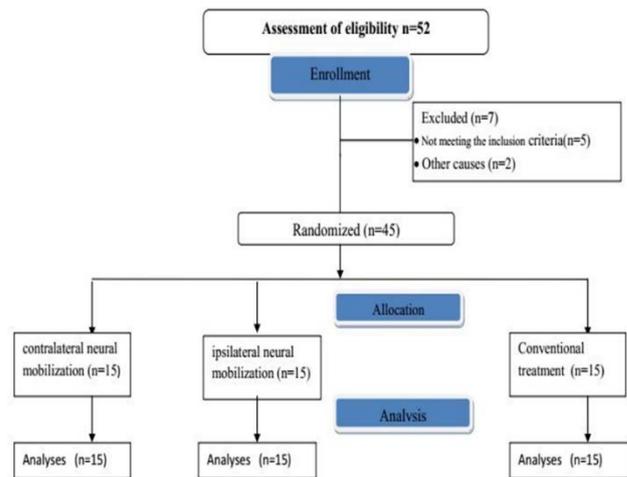
Outcome measures were the pain and function which were measured before and after treatment in each group.

### Patients

The study was done in South Valley university hospitals in the period between June 2015 until June 2017. Forty-five patients, aged 30 to 48 years, from both genders, diagnosed as unilateral mild or moderate CTS referred to us, randomly assigned to three study groups of equal number, each one included 15 patients as shown in the flowchart, in (figure 1). Before beginning the procedures, the patients were asked to sign an institutionally affirmed and informed consent.

Each group received conventional treatment in the form of TENS, ultrasound and infra-red. The first group received contralateral neural mobilization in the form of upper limb tension test 1 (ULTT-1) plus conventional treatment, the second group received ipsilateral neural mobilization in the form of upper limb tension test 1 (ULTT-1) plus conventional treatment, and the third group received only the conventional treatment. Treatment in all groups conducted for 3 sessions per week for 2 weeks. The patients participated in this study had the following inclusion criteria: Mild and moderate cases of unilateral CTS, and positive electro diagnosis findings. Patients were excluded if they

had one of the following criteria: Patients who were suffering from any orthopedic or neurogenic disorder of the neck or the upper limb as cervical radiculopathy, pronator teres syndrome, double crush syndrome, Sever degree of CTS and pregnant women.



**Figure 1:** Flowchart for the screening process and random assignment of the study participants

### Evaluative procedures

Pain level and Functional level were measured by visual analogue scale (VAS) and Upper Extremity Functional Scale (UEFS) respectively before and after treatment.

### Visual analogue scale (VAS)

VAS is a common, valid and reliable scale used for pain assessment [23]. It consists of a 10 cm line, with one end represents no pain and the other end represents the high level of pain that patient can suffer.

### Upper extremity functional index (UEFI)

The Upper Extremity Functional Index (UEFI) is a self-report questionnaire that is formed of 20 items that are rated on a 5-point scale (0-4). Total scores will range from 0 (the lowest functional status) to 80 (the highest functional status). The purpose of the questionnaire is to ask about the patients' current upper extremity functional status in a variety of activities. This assessment will be of a good value with individuals with any upper extremity of musculoskeletal dysfunction like shoulder, elbow, wrist, or hand deficits. The required time to use is short, it is less than five minutes, approximately thirty seconds to finish the scoring. The UEFI was found to have good validity, excellent test-retest reliability, and internal consistency [16].

### Procedures (intervention)

Each group received 5 minutes U.S OF 1 MHz, 1.0 W/cm<sup>2</sup>, 20 minutes TENS and 15 minutes Luminous near-infrared radiation infrared at distance of 50 cm in each session [17,18,19]. The first and second group received neural mobilization exercises either contralateral or ipsilateral as follows:

The patient was in supine lying position, arms by the sides, shoulders flush with the edge of the plinth, no pillow if permissible, and body straight. The therapist was stride standing, faced the patient's head and parallel to the patient with the near hip approximating the bed. The near foot is placed forward.

The therapist's near hand presses above the patient's shoulder, using the knuckle as a fulcrum to prevent scapular elevation and distal hand fingers wrap around the patient's fingers, distal to the patient's metacarpophalangeal joints Fig. 2.



Figure 2: Starting position

**Movements**

1. Glenohumeral abduction as possible, up to 90 -110 ° in the frontal plane
2. Glenohumeral external rotation to the allowable range.
3. Forearm supination and wrist and finger extension.
4. Elbow extension: the therapist pushes the patient's arm by his near thigh whilst his knee and hip are slightly flexed.
5. The neck is moved into contralateral lateral flexion <sup>[13]</sup> (Fig. 3, 4, 5).
6. Neural mobilization has been provided for roughly 10 minutes for every session including 30 sec hold and one-minute rest. The whole treatment was given for 6 sessions.



Figure 3: Glenohumeral abduction and external rotation. Forearm supination and wrist and finger extension.



Figure 4: Elbow extension: the therapist pushes the patient's arm by his near thigh whilst his knee and hip are slightly flexed.



Figure 5: The neck is moved into contralateral lateral flexion.

**Results**

The purpose of this study was to investigate the effects of contralateral versus ipsilateral neural mobilization on electrodiagnostic changes of the median nerve in patients with unilateral carpal tunnel syndrome.

**General characteristics of the subjects**

There was no significant difference between the three groups in the mean age, weight, height, BMI and sex ( $P > 0.05$ ), as shown in Table 1.

Table 1: Comparison of the mean age, weight, height, BMI and sex distribution between the three groups (I, II, and III)

	Group I $\bar{x} \pm SD$	Group II $\bar{x} \pm SD$	Group III $\bar{x} \pm SD$	F-value	p-value
Age (years)	40.93 ± 3.39	40.86 ± 3.2	39.66 ± 2.91	0.75	0.47*
Weight (kg)	77.2 ± 6.64	75.46 ± 6.09	77.8 ± 6.47	0.53	0.58*
Height (cm)	170 ± 6.41	171.46 ± 6.78	171.06 ± 6.34	0.2	0.81*
BMI (kg/m <sup>2</sup> )	26.73 ± 2.09	25.74 ± 2.52	26.6 ± 2	0.88	0.42*
Sex	Male	3 (20%)	2 (13%)	3 (20%)	$\chi^2 = 0.1$
	Female	12 (80%)	13 (87%)	12 (80%)	

$\bar{x}$ , Mean; SD, Standard deviation; MD, Mean difference;  $\chi^2$ , Chi squared value; p value, Probability value; \*, Non significant.

**The effect of treatment and time on vas and functional score**

**iii. Effect of treatment on vas**

**Group i**

There was a significant decrease in the mean value of VAS post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was 5 and the percent of change was 69.44 as shown in Table 2

**Group ii**

There was a significant decrease in the mean value of VAS post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was 4.74 and the percent of change was 69.7 as shown in Table 2.

**Group iii**

There was a significant decrease in the mean value of VAS post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was 4 and the percent of change was 60.6 as shown in Table 2.

**Table 2: Mean of VAS and functional score pre and post treatment in group I, II and III**

	Group I			Group II			Group III		
	Pre	Post	p value	Pre	Post	P value	Pre	Post	P value
VAS	7.2 ± 2.21	2.2 ± 1.89	0.001**	6.8 ± 1.01	2.06 ± 1.86	0.001**	6.6 ± 1.59	2.6 ± 1.91	0.001**
Functional score	53.93 ± 8.18	70.93 ± 6.14	0.001**	54.8 ± 5.33	68.8 ± 8.23	0.001**	57.66 ± 6.29	65.73 ± 6.44	0.001**

$\bar{x}$ , Mean; SD, standard deviation; p-value, level of significance; \* Non significant; \*\* Significant

**Comparison between groups**

Multiple pairwise comparisons showed that there was no significant difference in the mean values of VAS pretreatment between groups ( $P = >0.999$ ). Also, there was no significant difference in the mean values of VAS post-treatment between groups ( $P = >0.999$ ), as shown in Table 3

**The effect of treatment on functional score**

**Group i**

There was a significant increase in the mean value of functional score post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was -17 and the percent of change was 31.52 as shown in Table 2.

**Group ii**

There was a significant increase in the mean value of functional score post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was -14 and the percent of change was 25.54 as shown in Table 2.

**Group iii**

There was a significant increase in the mean value of functional score post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was -8.07 and the percent of change was 13.99 as shown in Table 2.

**Comparison between groups**

Multiple pairwise comparisons showed that there was no significant difference in the mean values of functional score pretreatment between groups ( $p > 0.05$ ). Also, there was no significant difference in the mean values of functional score post-treatment between groups ( $P > 0.05$ ), as shown in Table 3

**The effect of treatment on functional score**

**Group i**

There was a significant increase in the mean value of functional score post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was -17 and the percent of change was 31.52 as shown in Table 2.

**Group ii**

There was a significant increase in the mean value of functional score post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was -14 and the percent of change was 25.54 as shown in Table 2.

**Group iii**

There was a significant increase in the mean value of functional score post-treatment compared with pretreatment ( $P = 0.0001$ ). The mean difference was -8.07 and the percent of change was 13.99 as shown in Table 2.

**Comparison between groups**

Multiple pairwise comparisons showed that there was no significant difference in the mean values of functional score pretreatment between groups ( $p > 0.05$ ). Also, there was no significant difference in the mean values of functional score post-treatment between groups ( $P > 0.05$ ), as shown in Table 3.

**Table 3: Mean of VAS and functional score post treatment in group I, II and III:**

	Group I	Group II	Group III	Group I vs II	Group I vs III	Group II vs III
	$\bar{x} \pm SD$	$\bar{x} \pm SD$	$\bar{x} \pm SD$	p value	p value	p value
VAS	2.2 ± 1.89	2.06 ± 1.86	2.6 ± 1.91	1*	1*	1*
Functional score	70.93 ± 6.14	68.8 ± 8.23	65.73 ± 6.44	1*	0.14*	0.71*

$\bar{x}$ , Mean; SD, standard deviation; p-value, level of significance; \* Non significant

**Discussion**

This study was done to compare the effect of contralateral neural mobilization, ipsilateral neural mobilization and conventional treatment on CTS patients. It was found that there was a significant difference before and after treatment in each group, in addition, there was no significant difference among groups after treatment.

In our opinion, the significant difference before and after treatment in each group was related to the combined effect of neural mobilization and conventional treatment represented by TENS, U.S and I.R on the first two groups and conventional treatment's effect on the third group.

Neural mobilization exercises have a role in decreasing intraneural edema and circulatory stasis as it decreases the intraneural pressure [7] which, in turn, leads to decreasing the pain and other symptoms associated with CTS. Moreover, neural

mobilization exercises improve blood flow velocity inside the radial artery <sup>[6]</sup>.

Transcutaneous electrical nerve stimulation (TENS) was reported to decrease pain in CTS patients through releasing endogenous opiates to circulation and by inhibition of pain transmission via gate control theory <sup>[19]</sup>.

<sup>[21]</sup> reported that the most uses of ultrasound therapy (U.S) by physiotherapists were to alleviate pain, decrease edema, and improve soft tissue healing and extensibility.

Some studies observed a valuable effect of ultrasound therapy in decreasing CTS patients' symptoms <sup>[18]</sup>.

Thermotherapy like infrared radiation is a modality proved to increase blood flow and decrease muscle tension, and relax the muscles with myofascial trigger points <sup>[21]</sup>. So, also we used it in CTS patients to increase blood flow and induce muscle relaxation.

Also, we denoted that there were no significant differences between the ipsilateral group, contralateral group and conventional treatment group in decreasing pain, and improving function. In our observation, these results may be explained that although both ipsilateral and contralateral neural mobilization proved to have a positive effect on decreasing CTS symptoms, their effect is minimally related to the effect of conventional treatment which takes the upper hand. <sup>[23]</sup> agree with the current results, they made a systemic review evaluating the efficacy of neural mobilization exercises in the treatment of (CTS), and they observed lack of evidence-based studies and found a lot of controversies on the results of using nerve gliding exercises. They reported that standard conservative treatments had the upper hand in improving symptoms in CTS patients while neural mobilizing exercises are considered as an additional option to increase the chance of restoring function.

The present study is supported by <sup>[24]</sup> who found that there were no significant differences in the outcomes between the conventional treatments alone or adding ipsilateral neural mobilization to conventional treatment. Also, <sup>[25]</sup> agree with the current results, they randomly allocated 111 patients into three groups. The first group received only conventional treatment, the second group was treated with conventional treatment in addition to tendon and nerve gliding exercises, and the last group was treated only with tendon and nerve gliding exercises. They concluded that in the intermediate stage of CTS; in the group which was treated with tendon and nerve gliding exercises alone, they were less effective in decreasing pain and improving hand function than in those with conservative interventions or conservative interventions plus neural mobilizing exercises.

Another study done by <sup>[26]</sup> reported that neural mobilizing exercises are one of the manual therapy approaches that are used in the treatment of CTS as a complementary intervention to standard conventional treatment to increase the effectiveness of treatment, <sup>[26]</sup> explained that neural mobilizing exercises should not be considered as a solution for all neuromusculoskeletal cases but those exercises are a part of various evidence-based manual therapy techniques which are used in treatments.

Other studies demonstrated that neural mobilization has no significant values in decreasing pain in patients with CTS as <sup>[27]</sup> who reported an insignificant decrease in pain after tendon and nerve gliding exercises.

Other researchers used neural mobilization as a clinical approach to CTS treatment and recorded pain relief which decrease the possibility of surgical intervention in most of the patients; as <sup>[10]</sup> who found good results in patients treated with neural mobilization.

<sup>[11]</sup> reported pain relief only for patients treated by neural mobilization, and also decreased surgical interventions in all the patients who were treated by any mobilization either neural or carpal. In addition, <sup>[12]</sup> stated that neural mobilizing exercises are more effective in decreasing pain than no treatment.

<sup>[28]</sup> found no significant differences in pain level and functional state when compared two groups of patients, one wearing a wrist splint with nerve gliding exercises and the other wearing the splint without gliding exercises.

Other studies reported better outcomes for patients without neural mobilization. <sup>[29]</sup> reported no significant value of neural mobilizing exercises in CTS patients. Also, <sup>[30]</sup> reported that the addition of nerve gliding exercises with conventional treatments is less effective than the collection of tendon gliding exercises with conventional treatments.

Moreover, <sup>[31]</sup> in their systematic review found insufficient evidence supporting the application of neural mobilization exercises. <sup>[32]</sup> concluded that there is no strong evidence to favor neural gliding exercises to be the most valuable nonsurgical treatment to CTS.

The Limitation of this study involves follow up assessments of patients after the end of the treatment to know the long-lasting effect of neural mobilization, which was not performed.

### Conclusion

The effect of both ipsilateral and contralateral neural mobilization exercises is only additional or complementary to the effect of conventional treatment which was found to have the main role in treating mild and moderate CTS symptoms.

**Funding source:** Nil

### References

1. Katz JN, Simmons BP. Clinical practice. Carpal tunnel syndrome. *N Engl J Med.* 2002; 346(23):1807-12.
2. Cullen KA, Hall MJ, Golosinskiy A. Ambulatory surgery in the United States. 2006. *Natl Health Stat Report.* 2009; (11): 1-25.
3. Ekstrom RA, Holden K. Examination of and intervention for a patient with chronic lateral elbow pain with signs of nerve entrapment. *Phys Ther.* 2002; 82 (11):1077-86.
4. Cleland JA, Childs JD, Palmer JA, Eberhart S. Slump stretching in the management of non-radicular low back pain: a pilot clinical trial. *Man Ther.* 2006; 11(4):279-86.
5. Quick NE, Kelly PJ. Changes in blood flow velocity in the radial artery during the upper limb tension test [abstract]. *J Orthop Sports Phys Ther.* 2007;37:A29
6. Quick NE. Measurement of changes in hand temperature during the upper limb tension test using thermal imaging [abstract]. *J Orthop Sports Phys Ther.* 2007; 37: A29.
7. Coppieters MW, Butler DS. Do 'sliders' slide and 'tensioners' tension? An analysis of neurodynamic techniques and considerations regarding their application. *Man Ther.* 2008; 13(3):213-221.
8. Butler DS. *Mobilisation of the Nervous System.* 1st ed. Melbourne, Australia: Churchill Livingstone; 1991.
9. Baysal O, Altay Z, Ozcan C, Ertem K, Yologlu S, Kayhan A. Comparison of three conservative treatment protocols in carpal tunnel syndrome. *Int J Clin Pract.* 2006; 60(7):820-82.

10. Fernandez-de-Las-Penas C, Cleland JA, Ortega-Santiago R, de-la-Llave-Rincon AI, Martinez-Perez A, Pareja JA. Central sensitization does not identify patients with carpal tunnel syndrome who are likely to achieve short-term success with physical therapy. *Exp Brain Res.* 2010; 207(1-2):85-94.
11. Tal-Akabi A, Rushton A. An investigation to compare the effectiveness of carpal bone mobilisation and neurodynamic mobilisation as methods of treatment for carpal tunnel syndrome. *Man Ther.* 2000; 5(4):214-222.
12. Muller M, Tsui D, Schnurr R, Biddulph-Deisroth L, Hard J, MacDermid JC. Effectiveness of hand therapy interventions in primary management of carpal tunnel syndrome: a systematic review. *J Hand Ther.* 2004; 17(2): 210-228.
13. Shacklock MO. *Clinical neurodynamics: A new system of musculoskeletal treatment.* Edinburgh: Elsevier/Butterworth Heinemann; 2005.
14. Castilho J, Ferreira LA, Pereira WM, Neto HP, Morelli JG, Brandalize D, et al. Analysis of electromyographic activity in spastic biceps brachii muscle following neural mobilization. *J Bodyw Mov Ther.* 2012; 16(3): 364-8.
15. Sharma S, Cleland J. Effect of tensioner neural mobilization on the flexibility of contralateral lower extremity. *Man Ther.* 2016; 25:118.
16. Stratford PW, Binkley JM, Stratford DM. Development and initial validation of the upper extremity functional index. *Physiother Can.* 2001; 53(4): 259-267.
17. Boonstra AM, Schiphorst Preuper HR, Reneman MF, Posthumus JB, Stewart RE. Reliability and validity of the visual analogue scale for disability in patients with chronic musculoskeletal pain. *Int J Rehabil Res.* 2008; 31(2): 165-169.
18. Bakhtiary AH, Rashidy-Pour A. Ultrasound and laser therapy in the treatment of carpal tunnel syndrome. *Aust J Physiother.* 2004; 50(3):147-151.
19. Koca I, Boyaci A, Tutoglu A, Ucar M, Kocaturk O. Assessment of the effectiveness of interferential current therapy and TENS in the management of carpal tunnel syndrome: a randomized controlled study. *Rheumatol Int.* 2014; 34(12):1639-45.
20. Evan R. Therapist's management of carpal tunnel syndrome: A practical approach. In: Osterman AL, Skirven TM, Fedorczyk JM, Amadio PC, eds. *Rehabilitation of the Hand and Upper Extremity.* Philadelphia, PA: Elsevier; 2011: p. 666-77.
21. Wong RA, Schumann B, Townsend R, Phelps CA. A survey of therapeutic ultrasound use by physical therapists who are orthopaedic certified specialists. *Phys Ther.* 2007; 87(8): 986-994.
22. Moraska AF, Hickner RC, Kohrt WM, Brewer A. Changes in blood flow and cellular metabolism at a myofascial trigger point with trigger point release (ischemic compression): a proof-of-principle pilot study. *Arch Phys Med Rehabil.* 2013; 94(1):196-200.
23. Ballesterro-Pérez R, Plaza-Manzano G, Urraca-Gesto A, Romo-Romo F, Atín-Arratibel ML, Pecos-Martín D, et al. Effectiveness of Nerve Gliding Exercises on Carpal Tunnel Syndrome: A Systematic Review. *J Manipulative Physiol Ther.* 2017; 40(1):50-59.
24. Heebner ML, Roddey TS. The effects of neural mobilization in addition to standard care in persons with carpal tunnel syndrome from a community hospital. *J Hand Ther.* 2008; 21(3):229-24.
25. Bardak AN, Alp M, Erhan B, Paker N, Kaya B, Onal AE. Evaluation of the clinical efficacy of conservative treatment in the management of carpal tunnel syndrome. *Adv Ther.* 2009; 26(1): 107-116.
26. Kostopoulos D. Treatment of carpal tunnel syndrome: a review of the non-surgical approaches with emphasis in neural mobilization. *J Bodyw Mov Ther.* 2004; 8(1): 2-8.
27. Pinar L, Enhos A, Ada S, Gungor N. Can we use nerve gliding exercises in women with carpal tunnel syndrome? *Adv Ther.* 2005; 22(5): 467-475.
28. Brininger TL, Rogers JC, Holm MB, Baker NA, Li ZM, Goitz RJ. Efficacy of fabricated customized splint and tendon and nerve gliding exercises for the treatment of carpal tunnel syndrome: a randomized controlled trial. *Arch Phys Med Rehabil.* 2007; 88(11): 1429-35.
29. O'Connor D, Marshall S, Massy-Westropp N. Non-surgical treatment (other than steroid injection) for carpal tunnel syndrome. *Cochrane Database Syst Rev.* 2003; (1): CD003219.
30. Horng YS, Hsieh SF, Tu YK, Lin MC, Wang JD. The comparative effectiveness of tendon and nerve gliding exercises in patients with carpal tunnel syndrome: a randomized trial. *Am J Phys Med Rehabil.* 2011; 90(6): 435-442.
31. Ellis RF, Hing WA. Neural Mobilization: A Systematic Review of Randomized Controlled Trials with an Analysis of Therapeutic Efficacy. *J Man Manip Ther.* 2008; 16(1):8-22.
32. McKeon JM, Yancosek KE. Neural Gliding Techniques for the Treatment of Carpal. Tunnel Syndrome: A Systematic Review. *J Sport Rehabil.* 2008; 17(3): 324-341