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Effect of Sensory Relearning on Sensory and Motor Functions of the Hand in Patients with Carpal Tunnel Syndrome: A Randomized Controlled Clinical Trial

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Abstract--- Background: *Carpal tunnel syndrome (CTS) is the commonest type of entrapment neuropathies caused by compression of the median nerve compression as it passes through the carpal tunnel.* ***Aim:*** *To investigate the effect of somatosensory relearning on sensory and motor functions of the hand in patients with carpal tunnel syndrome.* ***Subjects and Methods:*** *Thirty-two female patients, with CTS, aged 20-50 years participated in the study. They were randomly assigned to two equal groups: Group I (experimental group) received sensory relearning in addition to a standard physical therapy program and Group II (control group) received standard physical therapy program consisting of traditional therapeutic exercises only. Assessment was done pre- and post-treatment using Semmes-Weinstein monofilament (SWM) test to measure the sensory threshold and handheld dynamometer to measure grip strength of the affected hand.* ***Results:*** *There was a statistically significant increase in sensory threshold of the affected hand in group (I) post-treatment. In addition, there was a statistically significant increase in grip strength of the affected hand in both groups post-treatment. Comparison between groups revealed a significant difference in the measured parameters post treatment in favor of group I.* ***Conclusion:*** *Sensory relearning is effective in improving sensory threshold and grip strength of the affected hand when added to the standard physical therapy program in patients with CTS.*

Keywords--- *Carpal Tunnel Syndrome, Strength, Sensation, Sensory Relearning, Physical Therapy.*

I. INTRODUCTION

Carpal tunnel syndrome (CTS) is the most common type of entrapment neuropathies that affect the upper extremity (UE) in middle aged people. It is common in females compared to males, with a female to male ratio of 3:1 [1, 2]. It is caused by compression of the median nerve as it passes through the carpel tunnel. Compression of the median nerve results in sensory abnormalities such as numbness and tingling sensation along the course of the nerve in the hand, in addition to loss of strength of muscles supplied by the median nerve [3, 4]. It has been found that even

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if motor function is normal in CTS, hand function can be greatly affected by loss of hand sensation. Sensation of the hand provides feedback to the brain for various activities such as object recognition and exerting the proper amount of force to hold an object [(5)].

Nerve conduction studies (NCS) are performed to diagnosis accurately the presence of CTS. According to electrophysiologic testing, in the early stage of CTS, sensory latencies compared to motor ones commonly become prolonged, while in the intermediate stage of CTS there is constant sensory deficits accompanied sometimes with motor impairment. In advanced cases of CTS, there is severe loss of sensory and motor function, along with atrophy in the thenar muscles [(4)].

Conservative treatment includes neural mobilization of the median nerve and carpal bone mobilizations [(6),] wearing braces/splints, steroid injections along with other interventions. However, surgical release of the carpel tunnel (decompression) is often the preferred approach [(7)] when conservative treatment fails.

Somatosensory rehabilitation aims to increase and improve the quality of touch sensation or even normalize sensation in cases of neuropathic pain. Somatosensory rehabilitation includes various techniques such as rehabilitation of hyposensitivity, desensitization of the site of axonal lesions and distant vibrotactile counter stimulation [(8, 9)].

Sensory relearning (SR), is technique used in somatosensory rehabilitation, also known as sensory retraining or reeducation, is an "approach that uses 'learning-dependent' cortical plasticity". Different somatosensory stimuli are used combined with attention and sometimes the use of visual feedback to facilitate somatosensation in the hand or UE [(10)]. There is particularly good evidence that SR is efficient in the treatment of sensory deficits caused by neurological disorders including peripheral nerve injuries [(11)].

This study was designed to investigate the effect of sensory relearning on sensory and motor functions of the hand in patients with carpal tunnel syndrome.

II. SUBJECTS AND METHODS

This was a single blind randomized controlled clinical trial conducted on thirty-two female patients diagnosed with CTS recruited from the outpatient clinic of the Faculty of Physical Therapy, Cairo University and the Clinical neurophysiology unit of Cairo University hospitals, between the period of January 2019 to June 2019. The study was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University, Egypt. The study protocol was explained in detail to every patient and a signed written consent was obtained before participation.

Patients were randomized by sealed, opaque, identical envelopes into two groups: group (I) and group (II). Each patient drew an envelope containing the group she was in, whether it was group (I) or (II). The number of patients in each group was 16. The anonymity and confidentiality of each patient was assured.

Inclusion criteria were: **(1)** female patients diagnosed with CTS based on the American Academy of Neurology clinical diagnostic criteria of Carpel Tunnel Syndrome [(12)]; **(2)** age range from 20-50 years; **(3)** fractionated sensory nerve conduction velocity of the median nerve across the wrist of 40 milliseconds or less [(13)] and **(4)** sensory distal latency more than 3.6 milliseconds and less than 4 milliseconds [(14)].

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Exclusion criteria were: **(1)** systemic disease causing CTS (i.e., rheumatoid arthritis, thyroid disease, Diabetes Mellitus); **(2)** cervical radiculopathy; (3) history of wrist surgery or fracture, **(4)** history of carpal tunnel injection two weeks prior to the study; **(5)** any concomitant neurological diseases; **(6)** complete median nerve conduction block; **(7)** previous regular exposure to hand-held vibrating tools; **(8)** previous CTS operation, or pregnancy.

Evaluation Procedures

The affected hand of each patient was evaluated twice, pre- and post-treatment by the same evaluator using:

1- Semmes Weinstein Monofilament (SWM): is a clinical test that measures sensory threshold (touch) using a numerical value. This test was made to identify patients at risk of neuropathic ulceration and is used, currently, in the evaluation of peripheral nerve lesions [15]. In the current study, the short version (pocket filaments) with five filaments from 0.07 to 300 g was used **(Touch Test® Sensory Evaluators, North Coast Medical Inc.)**.

Testing was done in a quiet room to help patients concentrate during the testing procedure. The patient's upper extremity (UE) was placed on a stable, padded surface. Vision was occluded using a shield, or by asking to simply close the eyes or look away. Patients were instructed to respond when they felt the stimulus by saying "touch" or "yes". Examination proceeded from distal to proximal and from small to large monofilaments. The palmar surface of the index finger and thumb was tested to evaluate median nerve function. The filament was placed at a 90° angle and pushed against the skin until it bent and was held in place for 1.5 seconds and then removed. For monofilaments from 1.65 to 4.08, the stimulus was applied in the same location up to three times to elicit a response and a single response indicated a positive response. For filaments 4.17 through 6.65, the stimulus was applied one time only. Testing results were recorded using a colored pencil that corresponds to the color on the handle of the monofilament used. The size of each monofilament was noted and recorded in order to evaluate the touch detection thresholds of the hand and fingers.

Touch detection threshold was scored on a 0 to 5-point scale, where 5 represents the thinnest filament and 0 represents the largest filament. Three different positions of the hand were tested: the fingertip on the index and thumb fingers and the proximal phalanx of the index finger, yielding a total sum score of 15 points as follows [16]:

- 0 = not testable
- 1 = filament 6.65 (magenta 300g)
- 2 = filament 4.56 (red 4g)
- 3 = filament 4.31 (violet 2.0g)
- 4 = filament 3.61 (blue 0.4g)
- 5 = filament 2.83 (green 0.07g)

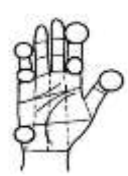

Figure 1: Positions of Monofilaments Testing (Paula et al., 2016)

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2- Handheld dynamometer. Hand grip strength was measured using a commercially available handheld strength-testing device (CAMRY Digital Hand Dynamometer, Camry Scale – USA). In sitting position, the elbow joint was placed in flexion and the forearm in mid position. The third handle position was used, and each patient was instructed to slowly squeeze the dynamometer and stop at the first feeling of discomfort. Three trials were recorded, separated by a 20 seconds time interval. Patient's grip strength was then calculated by averaging all measurements [17, 18].

Treatment Procedures

Both groups received three sessions per week for four weeks. The duration of each session was approximately one hour. Treatment program was as follows:

1- Group I (experimental group) received somatosensory relearning program for the affected UE for 45 minutes in addition to 15 minutes of standard physical therapy program as follows:

a- Splinting as a source of maintained pressure for 15 minutes. The patient wore a hand and wrist splint which kept the wrist joint in neutral position [19].

b- Topical anesthesia using 8% lidocaine spray as a source of sensory desensitization mainly and secondary for pain relief, for ten minutes. The patient's affected UE extremity was placed on a stable surface and then sprayed. Patient was asked to relax for 15 minutes [20, 21].

c- Massage using different textures of material (sensory relearning) starting from soft textures and progressing to rougher ones for 15 minutes, to reduce hyperesthesia of the affected UE (as another source of desensitization). The patient's affected UE was placed on a stable surface and then massage was applied over sensitive areas for five minutes with the same speed, pressure and direction, followed by massage using different textures (e.g., cotton, velvet, terry cloth, polyester, wool) over the same areas. Each material was used for two minutes [22].

d- Proprioceptive neuromuscular facilitation (PNF) technique for the affected UE using the pattern extension, adduction, internal rotation with elbow straight) for five minutes from sitting position on a chair with back support [23].

- **Standard physical therapy program** for 15 minutes, including: tendon gliding exercises for five minutes, median nerve gliding for five minutes and graduated active exercises and circulatory exercises for five minutes [24].

2- Group II (control group) received only traditional therapeutic exercises (tendon and median nerve gliding exercises, graduated active exercises, and circulatory exercises), for the affected UE for one hour.

III. STATISTICAL ANALYSIS

Data was screened for normality assumption, homogeneity of variance, and presence of extreme scores. Kolmogorov-Smirnov test for normality showed that demographic and clinical characteristic data, in addition to data of the handheld dynamometer were normally distributed while data obtained by the Semmes Weinstein Monofilament (SWM) was not normally distributed. Paired t-test was used for statistical analysis of subject

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characteristics in both groups (group I and group II) pre-treatment and for statistical analysis of data of the handheld dynamometer between and within group comparison. On the other hand, data of the SWM was analyzed by Wilcoxon test for within subjects' comparison and Mann-Whitney test for between groups comparison. Statistical analysis was conducted using Statistical Package for the Social Science (SPSS, Chicago, IL, USA) for windows, version 20 (SPSS, Inc., Chicago, IL). The p-value was set at < 0.05.

IV. RESULTS

A total of 32 female patients, divided into two equal groups (I and II) participated in the study **(fig. 2)**.

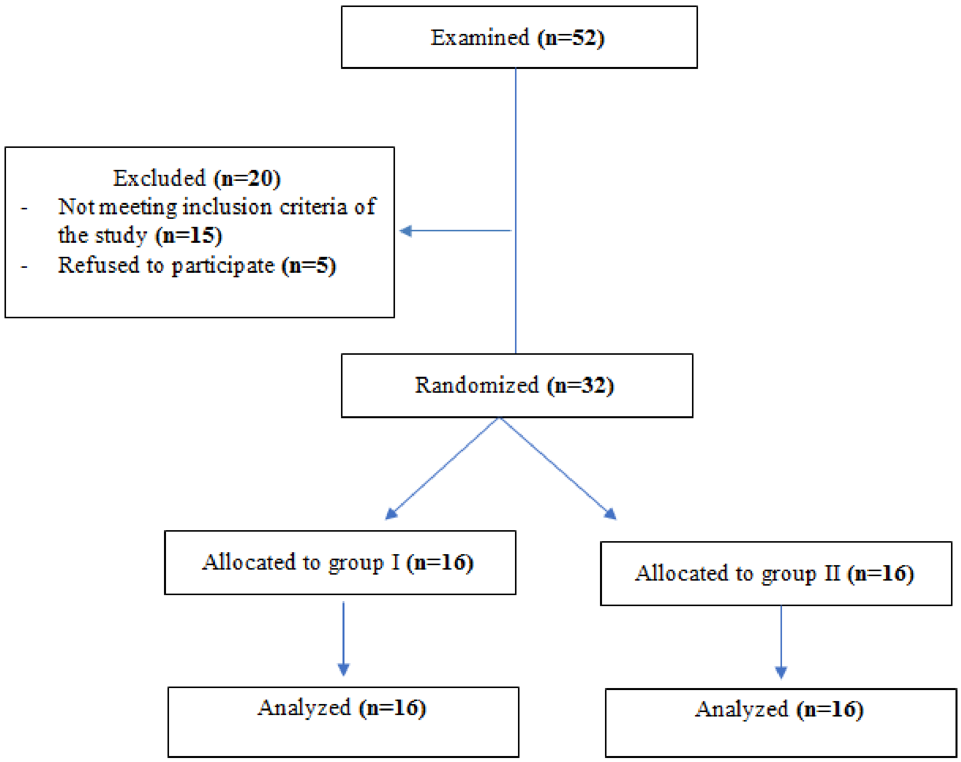

Figure 2: Flow Diagram of the study

- **Characteristics of subjects in both groups:**

There were no significant differences in clinical characteristic between both groups (I and II), pre-treatment (p> 0.05) **(table 1)**.

Table 1: Characteristics of Patients in Both Groups (I and II)

Items	Group (I)	Group (II)	t-value	P-value
Age (year)	37.06 ± 13.2	40.06± 9.8	0.727	0.473
MSDL (milliseconds)	3.75± 0.2	3.77± 0.17	0.228	0.821
MMDL (milliseconds)	3.8± 0.49	3.49± 0.83	1.301	0.203
MSV (meters/second)	37.8±3.6	38.2±2.89	0.367	0.716

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MSDL: Median nerve sensory distal latency, MMDL: Median Nerve Motor Distal Latency, MSV: Median Nerve Sensory Velocity, P: probability value, P<0.05 = significant, P>0.05 = Non-significant.

- **Sensory threshold of the affected hand measured by Semmes-Weinstein monofilament (SWM) test:**

There was a significant increase in the sensory threshold of the hand within group I post-treatment (p=0.000). Also, there was a significant difference between both groups in the sensory threshold post-treatment (P= 0.001) in favor of group I **(table 2).**

Table 2: Comparison of Pre- and post-treatment Mean Values of the Sensory Threshold of the Affected Hand within and between Groups (I and II).

Items	Sensory threshold of the affected hand		
	Group (I)	**Group (II)**	**P-value**
Pre-treatment	11.62±1.3	11.13±1.6	0.897
Post-treatment	14.67±1.1	11.51±1.7	0.001*
P-value	0.001*	0.18	

P: probability value, ±: standard deviation, P<0.05* = significant, P>0.05 = Non-significant.

- **Hand grip strength measured by handheld dynamometer:**

There was a significant increase in hand grip strength within groups I and II post-treatment (p=0.001, 0.012 respectively). Also, there was a significant difference between both groups in hand grip strength post-treatment (P= 0.024) in favor of group I, **(table 3).**

Table 3: Comparison of Pre- and post-treatment Mean Values of Grip Strength of the Affected Hand Within and between Groups (I and II).

Items	Grip strength of the affected hand(Kg)		
	Group (I)	**Group (II)**	**P-value**
Pre-treatment	6.35±3.51	8.8±4.6	0.307
Post-treatment	17.31±8.1	14.62±7.1	0.024*
P-value	0.001*	0.012*	

P: probability value, P<0.05* = significant, P>0.05 = Non-significant.

V. DISCUSSION

Although SR is well established in the rehabilitation of nerve repair**,** it is not addressed by most therapists in the rehabilitation program of CTS [25, 26]**.**

In this randomized controlled clinical trial, sensory threshold of the affected hand significantly improved post treatment only in group I who received SR in addition to standard physical therapy. This finding agrees with **Rosen et al., 2014** [27] who reported that early use of sensory re-education/retraining three months after nerve repair in the hand resulted in significant improvement in perception of touch sensation but poor ability to identify and discriminate touch. This was explained by the fact that perception of touch requires only the identification of a

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stimulus, whereas the ability to discriminate objects requires both detection and interpretation of the perceived stimulus which is more difficult due to the way the somatosensory re-organizes after peripheral nerve lesions [28]. Also, **Vikström et al., 2018** [29] reported that early SR improves long term somatosensory recovery after nerve repair.

On the contrary, a systematic review by **Oud et al., 2007** [5] reported limited evidence of the effectiveness of sensory relearning/ re-education in the management of peripheral nerve lesions in the UE, however, most of the studies included in the review evaluated proximal lesions of mixed nerves of the UE and not just sensory nerves. Another review by **Manoli et al., 2016**[30] **reported** limited evidence supporting the use of early and late SR modalities in the treatment of peripheral nerve lesions. Additionally, only mixed nerves were included in that analysis.

In the current study, there was significant improvement of grip strength (motor function) of the affected hand in both groups post-treatment, especially in group I. This finding can be attributed to the therapeutic effect of the standard exercise program (e.g., tendon and median nerve gliding), which agrees with **Warran, 2001** [24], who reported that standard physical therapy treatment was effective in treatment of for CTS symptoms. The additional improvement in the experimental group who received SR may be attributed to improvement of hand sensibility as there is a direct correlation between motor and sensory conduction velocities of the median nerve and hand grip strength in women as reported by [31]. Our findings also support that despite motor function of the hand is normal, hand function can be greatly affected by the sole loss of hand sensation [5]. So, improving sensory threshold can improve motor function and overall functional outcome of the hand [32].

There were several limitations in the current study which included lack of measurement of sensory and motor conduction velocities post-treatment and studying their correlation with the measured parameters. However, to the best of our knowledge, no previous studies investigated early sensory re-learning efficacy in CTS, hence our results are preliminary.

VI. CONCLUSION

In view of the findings revealed in this study, it could be concluded that adding SR to standard physical therapy programs, helps in improving sensory and motor functions of the affected hand in CTS patients. Further research is needed on the effectiveness of somatosensory rehabilitation programs of nerve dysfunctions. This may require more individually tailored exercises to address specific sensory deficits and frequent monitoring of patient progress. Objective correlative studies of functional outcome measures and nerve conduction studies of the affected nerves are also warranted.

Abbreviations

CTS: Carpel Tunnel Syndrome; NCS: Nerve Conduction Studies; PNF: Proprioceptive Neuromuscular Facilitation; SPSS: Statistical Package for the Social Sciences; SR: Sensory Relearning; UE: Upper Extremity.

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