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Effect Of The Sensory Re-Education Paradigm On Hand Grip Strength In Patients With Post-Covid-19 Polyneuropathy

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Abstract
Background: Recovery among patients who have contracted SARS-CoV-2 appears to display an exponential trend, even though some individuals still exhibit persistent symptoms associated with COVID-19. These enduring symptoms encompass dysautonomia, sensory and motor impairments, inexplicable exhaustion, and reduced tolerance for physical exertion. The development of late-onset neurological disease can be explained by genetic factors and host antiviral response. Genetic diversity and rapid evolution are identifiable features of COVID-19.**Aim of study:** To examine the effect of the sensory re-education paradigm on hand grip strength in patients with post-COVID-19 polyneuropathy. **Subjects and Methods:** Forty individuals who had been diagnosed with post-COVID-19 polyneuropathy were recruited and assigned randomly to two groups of equal size: the study group (A) and the control group (B). The study group (A) underwent a comprehensive treatment approach that involved sensory re-education as well as a conventional physical therapy program focusing on exercises such as proprioceptive neuromuscular facilitation (PNF), strengthening wrist extensors, hand grip muscles, and thumb opposition muscles. On the other hand, the control group (B) only received the conventional physiotherapy program without the sensory re-education component. The treatment lasted for six consecutive weeks, with one-hour sessions held three times per week. Hand grip strength was measured using a hand-held dynamometer at baseline and after treatment for all participants.**Results**: Both groups A&B exhibited a significant difference in pre- and post-treatment comparisons for the right and left hands (P = 0.001* and 0.001*, respectively). While, there were no statistically significant differences among the two groups after treatment (P = 0.473 and P = 0.665, respectively, for the right and left hands).**Conclusion**: sensory re-education has no significant effect on improving hand grip strength in patients with post-COVID-19 polyneuropathy and following the conventional program for such cases will offer the required improvement.
Keywords: Hand grip strength, Sensory re-education model, Polyneuropathy, Post-COVID-19.

INTRODUCTION

COVID-19, which originates from the Latin word "corona," meaning "crown," refers to a type of coronavirus. It leads to various respiratory tract infections in humans, with symptoms ranging from mild, cold-like symptoms to severe respiratory distress syndrome. **(1).**

Existing research has identified that individuals who have recovered from COVID-19 often experience a range of persistent symptoms, with variations in terms of their duration and frequency. These differences in symptoms may be linked to variances in the characteristics of the sample populations as well as the data collection methods employed in each study. Additionally, the highly diverse nature of post-COVID-19 syndrome could also contribute to the observed discrepancies. **(2).**

The scientific and clinical understanding of the subacute and long-term consequences of COVID-19, commonly known as post-COVID-19 syndrome, is continuously evolving. This condition has the potential to impact various organ systems within the body. (3). Preliminary findings indicate that individuals who had COVID-19 infection may experience lingering symptoms such as fatigue, shortness of breath, chest pain, cognitive issues, joint pain, and a decrease in overall quality of life (4).

The development of polyneuropathy is frequently observed in individuals with a history of COVID-19 infection, and this occurrence is especially common among patients with underlying health conditions. (5). The post-COVID-19 syndrome predominantly impacts the sensory and autonomic nerve fibers that are unmyelinated or thinly myelinated, with a specific emphasis on small-diameter nerves. However, individuals with more severe or advanced polyneuropathy may encounter damage to both large and small nerve fibers (6).

According to Mirian et al. (7), polyneuropathy refers to the dysfunction of peripheral nerves that regulate motor function, specifically affecting the muscles involved in hand grip. One prevalent indicator of polyneuropathy is a decrease in superficial sensation experienced in the hands and feet. (8).

Sensory re-education is a therapeutic approach that incorporates cognitive-behavioral therapy techniques. It involves utilizing sensory stimulation to aid in the rehabilitation of sensory loss and facilitate adaptive functioning in patients. (9).

The improvement of motor function can be significantly influenced by enhancing the sensory system. However, in the realm of physical therapy research, there has been a greater emphasis on enhancing sensory skills rather than motor abilities using sensory re-education techniques. It is important to recognize that enhancing overall sensory function may rely on enhancing motor performance as well. (10).

This study aims to examine the effects of a sensory re-education paradigm on hand grip muscle in individuals diagnosed with post-COVID-19 polyneuropathy. There are adequate evidence supporting the effectiveness of this treatment specifically for this condition, the objective is to explore its impact and efficacy.

Subjects and Methods:

Study Design

The study design was a randomized controlled trial (RCT). The subjects were recruited from the outpatient clinic at Faculty of Physical Therapy between December 2022 and August 2023. Before participation, the patients signed written informed consent forms following a thorough explanation of the study's purpose and methods to declare their approval for taking part.

Sample Size Calculation:

G power software was used to calculate a proper sample size of (40), 20 in each group, based on the effect size (0.910), power (0.80), two-tailed and significance level (α= 0.05).

Ethical considerations

The Research Ethical Committee within the Faculty of Physical Therapy at Cairo University approved to this study (No: P.T.REC/012/004416). Furthermore, the study was registered in (ClinicalTrials.gov with ID: NCT05911113).

Participants

Forty patients from both gender with post-COVID-19 polyneuropathy were included in this study. This RCT was carried-out to examine the impact of the sensory re-education paradigm on hand grip strength in patients with post-COVID-19 polyneuropathy. The diagnosis and referral were done by fourth author and recruitment was done from outpatient clinic, Faculty of Physical Therapy and the Neurology department, Faculty of Medicine, Cairo University . A prior COVID-19 infection PCR test and nerve conduction study (NCS) were used to confirm the diagnosis of post-COVID-19 polyneuropathy by detection of prolonged distal latency,reduced conduction velocity,decrease amplitude of motor and sensory action potentials, and also, rule out the possibility of any other neurological disorder affecting upper limb function. Two groups were randomly selected from among the patients. There were 20 patients in each group. Study group (A) were given a sensory re-education paradigm and traditional physiotherapy program while, control group (B) were given the same traditional physiotherapy program only

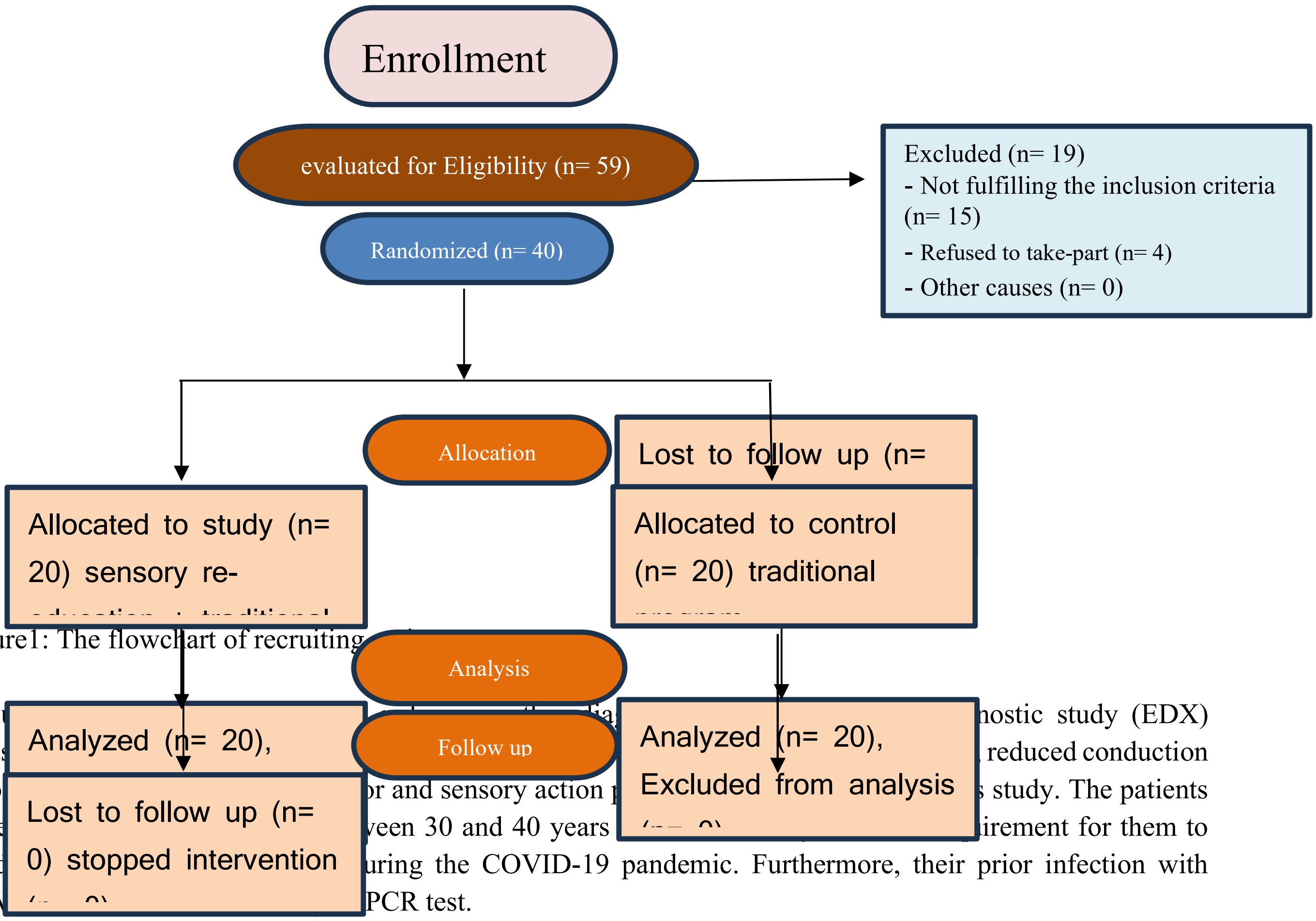

Figure1: The flowchart of recruiting

Incl... ia... nostic study (EDX) meas... reduced conduction velo... or and sensory action p... study. The patients were... veen 30 and 40 years ... irement for them to resic... uring the COVID-19 pandemic. Furthermore, their prior infection with COV... PCR test.

The exclusion criteria for this study included patients with existing conditions such as Diabetes mellitus (DM), Guillain-Barré syndrome (GBS), as well as any other infections causing sensory neuropathy. Patients with pre-existing neurological diseases of the central or peripheral nervous system, and those who had undergone previous surgeries or were on medications that may contribute to neuropathy, were also excluded from the study.

Evaluation procedures:

Participants were assessed at baseline and after treatment by Hand held dynamometer (model number: 14192-709E , manufacturer : camry, country: Jaban) as a following: The patient assumed a sitting position with the elbow flexed and the forearm in a mid-position. The dynamometer was set to the third handle position, and the patient was instructed to gradually squeeze the device until the first sign of discomfort appeared. Three separate trials were conducted, with a 20-second interval between each trial. The grip strength of the patient was determined by calculating the average of all the measurements obtained during the trials, and the readings were recorded in kilograms of force (11).

Treatment procedures:

The study group (A): was given a sensory re-education model for 30 minutes as well as the conventional physiotherapy program for 30 minutes including proprioceptive neuromuscular facilitation (PNF) and strengthening exercises for wrist extensors, hand grip muscles, and the muscles of thumb opposition. The total duration of session was conducted for one hour, three sessions per week for six successive weeks.

Control group (B): was given the conventional physiotherapy program only, which included in each session (graduated active and resisted strengthening exercises for wrist extension for 10 minutes, hand grip muscles strengthening exercise for 10 minutes, and thumb opposition exercise for 10 minutes, and PNF diagonal 2 flexion 15 minutes and PNF diagonal 1 Extension 15 minutes), The total duration of management was conducted for one hour, three times a week for 6 successive weeks.

The sensory re-education model applied for group A only:

Step 1. Training on texture discrimination:

• After positioning the patient's arm on a stable surface, the palm and fingertips were massaged with a consistent pace, pressure, and direction, as long as the patient was able to endure it. In addition, materials such as cotton, velvet, terry cloth, polyester, and wool were used to gently press on delicate parts. To lessen reliance on visual signals, this technique was done for two minutes with eyes open and two minutes with eyes closed. This process was performed on each hand for a total of eight minutes. **(12).**

Step 2. Limb position sense:

A. Passive proprioceptive training: The patient's limb was stabilized on a steady surface, with the forearm in the prone position. Passive manipulation of the patient's wrist and finger joints was then carried out, including various levels of extension. The patient was instructed to focus on these movements while maintaining their awareness with their eyes open for a duration of 4 minutes. Afterward, the process was repeated to perform flexion of the wrist and fingers, starting from a supinated forearm position. During this repetition, the patient was instructed to keep their eyes open and concentrate on the movement for another 4-minute interval **(13).**

B. Joint repositioning training: The patient's limb was immobilized on a stable surface, and the wrist joint and fingers were manipulated passively to achieve a targeted range of motion (extension or flexion). Simultaneously, the patient was instructed to focus their attention on these movements while visually perceiving and memorizing the specific angle. Subsequently, the limb was returned to its initial position, and the patient was instructed to close their eyes and attempt to replicate the same movement without relying on visual cues. This task was performed for a total duration of 8 minutes, with each hand receiving 4 minutes of practice per session **(14).**

Step 3. Tactile object recognition: This step aimed for improving their ability to perceive and differentiate various characteristics, such as shape, size, weight, and hardness, using a variety of multidimensional objects. During the training, the patient would place their limb on a stable surface and engage in the task of catching and returning objects to a designated box while their eyes were open. Subsequently, they would be challenged to identify the same objects solely by touch while their eyes were closed. Each hand underwent this task for 4 minutes, resulting in a total training time of 8 minutes. The objects used were systematically arranged in order of increasing size, weight, and complexity to progressively enhance the patient's sensory perception and discrimination abilities **(15).**

The physical therapy program applied for both groups A & B:

1- proprioceptive neuromuscular facilitation (PNF):

The PNF patterns of diagonal movement employed in study were the Diagonal 1 (D1 extension) as well as Diagonal 2 (D2 flexion) for 3 sessions per week for successive 6 weeks as a following:

- Upper Limb Diagonal 2 (ULD2 flexion):

pattern comprises shoulder Extension/Adduction/Internal Rotation. This exercise was performed for six minutes in every session as the following:

The patient was in supine position. Shoulder (extension, adduction as well as medial rotation), elbow flexion, forearm pronation, in addition to flexion of hand and fingers. The therapist stood next to the patient and applied gentle resistance by placing her distal hand over the patient's palm along with her proximal hand on the antero-lateral surface of the patient's arm. The patient was then instructed to squeeze her hand while she moves her arm in the opposite direction. A forward stride was taken by the therapist as the patient moved his/her arm. For a total of six minutes, the same pattern was performed with the arm over the forehead in flexion at the shoulder, abduction, lateral rotation, elbow extension, forearm supination along with extension of wrist and fingers **(16).**

- Upper Limb Diagonal (ULD1 extension):

This exercise was performed for six minutes in every session as a following:

The patient had been positioned supine. Shoulder (flexion, adduction, as well as lateral rotation), elbow flexion, forearm supination, in addition to flexion of hand and fingers. the therapist stood somewhat next to the patient, placing the distal hand upon the patient's dorsal surface of the hand along with the proximal hand upon the posterolateral part of the patient's arm to exert slight resistance. The patient's hand was instructed to be opened, and their arm was instructed to move against resistance in the opposite manner. A forward stride was taken by the therapist when the patient moved an arm. Shoulder extension, abduction, medial rotation, elbow flexion, forearm pronation, wrist flexion, and finger extension finished the sequence **(16).**

2- Graduated active and resisted strengthening exercises:

The subject was instructed to complete the exercises (wrist extension, hand grip muscles, and thumb opposition exercises) against resistance for 3 sessions per week for successive 6 weeks for each exercise while seated in a chair (with his/her back properly supported and shoulders in a relaxed position).

Statistical analysis:

The statistical analysis was conducted by the IBM SPSS statistical software program, version 25 for Windows (SPSS, Inc., Chicago, IL). The subsequent statistical procedures were carried-out:

Quantitative descriptive statistics data such as the mean and standard deviation for the normally distributed variables; age, weight, height, body mass index (BMI), bilateral hand grip strength (pre- and post-treatment). Chi-Square Test was utilized to compare the gender distribution (females and males) of the two groups. Paired (Dependent) t-test utilized for the pairwise comparison of the means in the same group for different times of measurement (pre-and post-treatment) for the normally distributed variables. Unpaired (Independent) t-test was utilized to compare the means of the two groups for the normally distributed variables. All statistical analyses were significant at $P \leq 0.05$.

Results:

1. Demographic characteristics of participants:

Subject characteristics for both group A and group B were displayed in Table 1. Distributions of age, weight, height, BMI, and sex were similar between the two groups. The results showed non-significant differences ($p > 0.05$).

Table 1. Comparison of subject characteristics between group A and B:

	Group A	Group B	t-value	p-value
Age, (years)	35.60±2.82	34.75 ±3.02	0.920	0.553
Weight (Kg)	73.25 ±6.74	74.40 ±5.62	-0.586	0.532
Height (cm)	171.35 ±8.45	173.00 ±6.86	-0.678	0.120
BMI,	24.84 ±1.84	24.98 ±2.09	-0.233	0.556
Sex, n (%) Female	10 (50%)	7 (35%)	(χ^2 = 0.921)	0.337
Male	10 (50%)	13 (65%)		

Data were presented as mean ± SD; SD, Standard deviation; t, unpaired t value; χ^2, Chi squared value; p value, Level of significance.

2.Scores for hand grip strength in the right and left hand:

- For group A, showed improvement 25.03% after six weeks of treatment. While 22.14% was noted in group B. Within group comparison showed significant difference (P=0.001, and 0.001) in groups A and B, respectively for both right and left hands. For between groups comparisons, group A & B, showed non-significant differences in right-hand grip strength pre-treatment (P= 0.385), and post-treatment (P= 0.473). Also, it revealed non-significant differences in left-hand grip strength pre-treatment (P= 0.494), and post-treatment (P= 0.665) (Table 2).

Table 2: Comparison of the means of the right- and left-hand grip strength in Group A and B and between two groups.

scores of right-hand grip strength	Group A	Group B				
	Mean± SD	**Mean± SD**	**MD**	**95% CI**	**t-value**	**P-value**
Pre treatment	19.30±5.49	20.78±5.12	1.48	-4.87–1.92	-0.879	0.385
Post treatment	24.13±5.29	25.38±5.52	1.24	-4.70–2.22	-0.725	0.473
MD post treatment	4.84	4.60				
95% CI post-treatment	5.59 – 4.08	5.32 – 3.88				
t-value	-13.458	-13.388				
P-value	0.001*	0.001*				
scores of left-hand grip strength	Group A	Group B				
	Mean± SD	**Mean± SD**	**MD**	**95% CI**	**t-value**	**P-value**
Pre treatment	17.31±5.56	18.45±4.85	1.14	-4.87–1.92	-0.691	0.494
Post treatment	21.51±5.20	22.26±5.64	0.75	-4.70–2.22	-0.437	0.665
MD post treatment	4.20	3.81				
95% CI post-treatment	5.19 – 3.21	4.77–2.85				
t-value	-8.902	-8.325				
P-value	0.001*	0.001*				

Data are expressed as mean ±standard deviation P-value: probability value
MD: Mean difference CI: Confidence interval
t-value: Unpaired t-test t-value: Paired t-test

Discussion:

Polyneuropathies (PNP) affect the whole peripheral nerve system, with 5–8% of the population being affected. Weakness, numbness, and pain, typically in the hands and feet, are common symptoms of peripheral neuropathy, which is caused by damage to the nerves that travel outside the brain and spinal cord. It can also have an impact on the digestive, urinary, and circulatory systems. Since these diseases can have a multitude of etiologies and concomitant **(17).**

Recent researches have reported many cases of neuropathy as a possible complication of novel coronavirus and, frequently manifests following a COVID-19 infection. The immune system's attack on nerve cells is responsible for the distinctive numbness, tingling sensations and muscle weakness experienced in the extremities, often regarded as an initial symptom of polyneuropathy **(18).**

The aim current study was conducted to examine the effect of sensory re-education paradigm on hand grip muscles strength in patients with post-COVID-19 polyneuropathy.

Both groups showed homogeneity in term of age, height, weight, and BMI ,which is suggesting that the two groups were comparable. Both groups showed significant improvements in hand grip muscle strength scores in comparison of pre-treatment and post-treatment readings. However, between groups comparisons showed no significant differences among them that demonstrated limitation of sensory re-education to improve hand grip muscles strength.

Our results in the conducted study showed lack of superiority of sensory re-education over standard physical therapy program. This can be explained as sensory re-education primarily targets the nervous system, aiming to facilitate the brain's ability to interpret sensory information from the hand. which can enhance motor control and coordination and this may not be directly result in increasing the strength of the hand grip muscles. Muscular strength depends on muscular adaptations, such as hypertrophy (growth) of the muscle fibers, which are more influenced by specific strength training exercises.

Moreover, findings of our study came in agreement with **(Paula et al., 2016)** **(19)** which has conducted parallel RCT on 32 participants divided into groups to investigate effect of sensory re-education on hand after nerve repair. This study showed no statistically significant differences between two groups regarding to hand grip strength.

However, **(Yousuf et al., 2020)** **(20)** agreed with our RCT, they examined the effects of a sensory re-education paradigm on those suffering from carpal tunnel syndrome found that grip strength (motor function) within the affected hand improved significantly in both groups after treatment.

Furthermore, (Abdel-Fattah et al., 2014) **(21)** disagreed with our study as they showed superiority of hand grip strength in the study group which may imply improvement of NCV of median nerve as there is direct correlation among motor and sensory NCVs of the median nerve as well as hand grip strength in women.

Conclusion: The results of this study indicate that, when it comes to strengthening hand grip strength in patients with post-COVID-19 polyneuropathy, the sensory re-education model is not more effective than the conventional physical therapy program. Further researches are suggested for validation of the current study results.

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The Authors declare that there is no conflict of interest.

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