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Effect of compressive therapy on sensorimotor function of the more affected upper extremity in chronic stroke patients

A randomized clinical trial

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Abstract

Background: Common upper extremity (UE) physical impairments after stroke include paresis, abnormal muscle tone, and somatosensory affection. This study evaluated the effect of passive somatosensory stimulation using compressive therapy on sensorimotor function of the more affected UE in chronic stroke patients.

Methods: Forty chronic stroke patients were enrolled in this study. They were randomized into 2 groups: Gr1 and Gr2. Three patients dropped out leaving us with a total of 37 patients completing the study. Gr1 received UE motor program for the more affected UE along with sham electrical stimulation while Gr2 had the same UE motor program along with passive somatosensory stimulation. The session duration in both groups was 85 min. Gr1 and Gr2 received a total of 36 sessions for 6 successive weeks. UE function in Gr1 and Gr2 was examined, before and after treatment using Box and Block test (BBT) and Perdue Pegboard test (PPBT) as measures of motor of both the more affected and less affected UE while the Nottingham sensory assessment (NSA) scale was used as a measure of sensory function of the more affected UE.

Results: There were significant improvements in motor and sensory function of the more affected UE compared to the less affected UE in both groups, measured by the BBT, PPBT, and NSA scales post-treatment ($P < .05$). However, the comparison between both groups regarding improvement revealed no significant change ($P > .05$).

Conclusion: Upper extremity motor and passive somatosensory stimulation techniques are effective in improving sensorimotor function of the more affected UE, but none of them had the advantage over the other, in terms of improving motor and sensory function in chronic stroke patients.

Abbreviations: ADL = activities of daily living, BBT = Box and Block test, FMA-UE = Fugl Meyer scale-upper extremity, Gr = group, MAS = Modified Ashworth scale, Min = minute/s, MMSE = Mini-mental state examination, MRI = magnetic resonance imaging, NSA = Nottingham Sensory Assessment, PPBT = Perdue Pegboard test, ROM = range of motion, Sec/s = seconds, Statistical Package for Social Science (SPSS), TENS = transcutaneous electrical nerve stimulation, TS = thermal stimulation, UE = upper extremity.

Keywords: compressive therapy, passive somatosensory stimulation, stroke, stroke rehabilitation, upper extremity.

1. Introduction

Stroke results in massive impairment and functional disability in millions of people worldwide.[1,2] The Global Burden of Disease, Injuries, and Risk Factors Study reported that stroke is currently the second cause of death around the world.[3,4] A systematic review on stroke incidence worldwide showed a decreased incidence of stroke by 42% in high-income countries

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Informed consent was obtained from all subjects involved in the study.

The authors have no conflicts of interest to disclose.

The data presented in this study are available on request from the corresponding author.

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the College of Physical Therapy at Cairo University, Egypt (P.T.REC/012/002153).

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and an increased incidence by more than 100% in low to middle-income countries.[5] In Egypt, stroke incidence is high with no definitive statistics with an urgent need for more epidemiological studies.[6]

Motor impairments are common after stroke. It is estimated that nearly 80% of the patients have some motor impairment with 20% regaining part of their motor functions in the months following injury and 50%–60% are left with a chronic motor disorder.[7,8] Somatosensory deficits are reported in approximately 50% of stroke patients.[9] Commonly reported upper extremity (UE) impairments after stroke include muscle weakness, changes in muscle tone, affection of the somatosensory system, and incoordination[10–12] all resulting in motor control deficits.[10]

Rehabilitation after stroke helps patients regain function, and to return to independent performance of activities of daily living (ADL). Various rehabilitative approaches improve recovery of motor function after stroke[13–15] such as repetitive somatosensory stimulation and motor or task-specific training. Both approaches help promote cortical plasticity and brain reorganization and result in enhanced motor and functional recovery after stroke.[13,16–18]

Physical therapy approaches that emphasize on sensory stimulation have gained increased recognition among modern rehabilitation strategies.[13,16,17] Providing sensory information during active fine motor tasks improves functional movement of the hand, even though the sensory pathways after stroke remain affected.[19–21] Active training is considered more efficient than passive training, but it can't be applied to extremely impaired patients. Passive somatosensory stimulation techniques can be applied daily to stroke patients with complete paralysis.[22]

Passive somatosensory stimulation includes modalities that passively stimulate sensory receptors such as neuromuscular electrical stimulation,[19] transcutaneous electrical nerve stimulation (TENS),[19,23] intermittent pneumatic compression,[24] and thermal stimulation (TS).[25–27]

Intermittent compression technique, a neurophysiological treatment involves stimulation of cutaneous and proprioceptive receptors by repeated movements. Previous randomized control trials showed its beneficial effects on sensory and motor functions in stroke patients in both acute[13,28] and chronic[13,24] phases. A significant improvement was observed in patients after 5-year follow-up.[13,29] However, no further investigations have been conducted.

A study by Robichaud et al[30] reported the effectiveness of applying air-splint pressure on the soleus muscle in temporarily decreasing spasticity of the more affected lower extremity in stroke patients.

A systematic review and meta-analysis by Serrada et al[31] reported a moderate positive effect of passive somatosensory stimulation on somatosensory function in stroke patients. Additionally, there was no evidence for the role of active somatosensory stimulation on somatosensory function due to the heterogeneity of the outcome measures used in these studies. Yet authors, still concluded that active somatosensory stimulation had a positive effect since there were positive changes in the outcome measures used.[31,32]

Due to the complex process of stroke recovery[13,33] and the methodological heterogeneity in various studies,[13,14,33,34] it is difficult to determine which physical therapy program will result in better functional outcomes. There are no specific guidelines or recommendations concerning the timing, type, and intensity of different approaches used in stroke rehabilitation.[35,36]

That is why this study aimed to study the effect of passive somatosensory stimulation using compressive therapy on sensorimotor function of the more affected UE in chronic stroke patients.

2.Subjects and Methods

2.1.Study design

This randomized clinical trial was approved by the College of Physical Therapy Ethical Committee, Cairo University, Egypt and issued the number (P.T. REC/012/002153).

Forty-nine male and female patients (n = 49) were recruited from the outpatient clinic of the College of Physical Therapy, Cairo University along with several other facilities specializing in neurorehabilitation. Patients were examined for eligibility and 9 patients (n = 9) were excluded for not meeting the inclusion criteria while the remaining 40 patients (n = 40) were enrolled in this study. Three patients dropped out of the study and the remaining 37 completed the study. Inclusion criteria were: age ranged from 40–75 years, diagnosed with first-ever ischemic stroke resulting in hemiparesis confirmed by magnetic resonance imaging (MRI), stroke duration ranged between 6 to 18 months, reported medically stable by the treating neurologist, scored ≥24 on the mini-mental state examination (MMSE); he more affected UE scored 1, 1+, or 2 on Modified Ashworth scale (MAS), and moderate to mild impairment measured on the Fugl Meyer scale-upper extremity (FMA-UE). Patients were excluded from the study if they had any cardiac arrhythmias, uncontrolled hypertension, obstructive pulmonary disease, and UE sensory deficit attributable to nonstroke pathology such as peripheral neuropathy. A proper explanation of the examination and treatment protocol was given. If agreed to participate in the study each patient was asked to sign a consent form. Each patient was instructed that if felt uncomfortable for any reason, at any moment they can withdraw from the study.

2.2.Randomization

A random number software (http://www.randomization.com) (accessed on 30th May 2020) was used to equally randomize patients into 2 equal groups (Gr1 and Gr2). Gr1 received UE motor program and sham electrical stimulation, while Gr2 received UE motor program and passive somatosensory stimulation.

2.3.Sample size

The sample size for the current study was calculated using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany), which indicated a required sample of 40 patients for the whole study (α was set at 0.05, β at 0.2, size effect 0.91 and allocation ratio N2/N1 = 1). The appropriate minimum sample size for this study was 40 patients (n = 20 patients in each group).

2.4.Clinical evaluation

The Box and Block test (BBT), Perdue PegBoard test (PPBT), and Nottingham sensory assessment (NSA) were applied twice, week 0 (pretreatment) and week 7 (posttreatment) by a well-trained and experienced physical therapist.

2.4.1.Box and Block test. The BBT is a test of unilateral gross manual dexterity, where the pick-up and release actions are performed by fingers.[37] BBT has a test-retest reliability > 0.9.[38,39]

In the current study, each patient was seated in a quiet room, in front of a table of adjustable height. A wooden box containing 150 wooden cubes of similar shapes was placed on the table. Patients were instructed to pick up 1 cube at a time with the tip of the index and middle finger of the more affected UE, move it over the separating partition of the box, and drop it into the opposite compartment, for 1 min.[40] The same task was

performed for the less affected UE. Before the test began, each patient was allowed to rehearse the pick-up and release movement of the cubes for approximately 15 s. A stopwatch was used for monitoring time. The higher the score, the better the gross manual dexterity.

2.4.2.Perdue PegBoard test. The PPBT measures fine motor dexterity of the fingers and hand. PPBT has excellent test-retest reliability.[41,42]

The PPBT consists of a board that has 2 rows with 25 holes in each row. Pins (pegs) are found at the extreme top right and left cups of the board. Collars and washers are in the middle 2 cups. Four subtests are present but in the current study only the first 2 subtests were administered, which measure unilateral hand prehension

In the current study, each patient was seated in a quiet room, in front of a table of adjustable height, with the PPBT placed in front of them. Patients were instructed to pick 1 pin at a time, starting with the more affected hand (not necessarily the right hand), and try and place it in the top hole. This was followed by the less affected hand (e.g., while testing the right hand, patients must insert as many pins as possible in the right row and vice versa for the left hand). The duration of each sub-test was 30 s. Before the test began, each patient was allowed to rehearse picking up the pins and placing them in the designated hole for approximately 15 s. A stopwatch was used for monitoring time. The higher the score, the better the fine motor dexterity.

2.4.3.The Nottingham Sensory Assessment scale. The NSA measures tactile sensations, kinesthetic sense, and stereognosis. Tactile sensations and stereognosis are measured on a numerical scale from (0–2 where 0=absent, 1=impaired, and 2=normal). For kinesthetic sensations, a scale of (0–3 is used, 0=absent, 1=appreciates the movement taking place, 2=appreciates the movement and able to mirror the direction, 3=mirrors the test movement to 10° of the new position). For sensations not examined, a score of 9 is given. Total tactile sensations score for each part of the body is calculated by adding the sum of all scores obtained, while eliminating those with score 9. Total kinesthetic sensations score is obtained by adding the sum scores for each joint examined, also excluding those with score 9.[43,44]

The examination was performed in a sitting position and both UE uncovered. The procedure was explained and demonstrated before the patient was blindfolded. During the examination, the blindfold was removed 3 times (after finishing each section of the scale) to prevent the patient from being disoriented. The examination was performed from distal to proximal for both UE. The examination started with the more affected UE followed by the less affected UE. Patients were asked to indicate if he/she feel the sensation being tested.[43–45] Sensations tested were tactile sensation, kinesthetic sense, and stereognosis. The test took an average of 15 min to administer.

Tactile sensation tested included (1) light touch using a cotton ball applied on the tested UE, (2) gentle pressure applied by the index finger of the examiner, (3) pain using a neurotip, (4) temperature using 2 test tubes, one containing hot water and the other containing cold water, (5) tactile localization using the index finger of the examiner coated with talcum powder to mark the area being touched, after which the patient was asked to point the spot being touched. Areas tested were the ones that scored 2 in the pressure sense, and (6) bilateral simultaneous touch where 2 corresponding places on the tested UE were touched by the fingertip of the examiner, and the patient was asked to indicate if he/she felt one or both areas touched. The areas tested were the ones that scored 2 in the pressure sense.[43,44]

Kinesthetic sensations tested were appreciation of movement, the direction of movement, and joint position sense. Testing started with the patient sitting and blindfolded. The more affected UE was supported and moved by the examiner in various directions but one joint at a time. The patient was asked to do the same movement with the less affected UE. Before blindfolding, 3 trials were allowed. The same was done for less affected UE. For stereognosis testing, an object was placed in the patient's hand for a maximum of 30 s. Identification was by naming, description, or pair-matching with an identical set.[43,44]

2.5.Treatment procedures

Patients in (Gr1) and (Gr2) received 6 sessions per week, for 6 consecutive weeks by a well-trained and experienced physical therapist. Session duration was 90 min. Patients in (Gr1) received UE motor program for 60 min. and sham electrical stimulation for 25 min. Patients in (Gr2) received the same UE motor program for 60 min. and passive somatosensory stimulation in the form of compressive therapy applied to the more affected UE for 25 min.

2.5.1.Motor upper extremity program. Exercises for each patient progressed in parallel with improvement in motor performance. Rest periods between exercises were given when necessary. Progression included increasing the number of repetitions, increasing range of motion (ROM), altering movement speed, and decreasing rest time between each exercise and resistance. Some of the exercises used were based on motor learning concepts. Repetitive practice of meaningful tasks with increasing difficulty, practicing tasks that motivated patients and provide enhanced feedback, was stressed. Eccentric, isometric, or concentric muscle contractions of different movements for the more affected UE (e.g., reaching, grasp, and release in addition to manipulation)[46] were practiced.

A home program was given for each patient and consisted of exercises performed during the sessions. The patient was instructed to practice these exercises as much as possible at home. Exercise selection, varied from one patient to another, depending on the status of the more affected UE. Exercises performed during the session were as follows[46]:

(1) Passive stretching at the beginning of the session to decrease soft tissue contractures and muscle tone.
(2) Mobilization of the scapula to facilitate movement in the glenohumeral joint.
(3) Different varieties of strengthening exercises with a maximum repetition of up to 10 times practiced in 3 sets.
(4) Enhancing functional performance of both UE using different weight-bearing positions such as prone on elbows, and quadruped. Once the patient could weight bear (support the body) on the more affected UE, the less affected UE was used for the performance of activities of daily living (ADL).
(5) Simple active exercises during the session and as part of the home program including wrist extension, forearm supination, shoulder joint muscles, shoulder shrugging, and reaching.
(6) Reaching and balance training with the following progressions:

Each patient sat on a stool or plinth and tried to reach forward, sideways, or backwards to pick up an object, transport it to another place (e.g., the floor), pick it up again, and reach as far in one direction as possible then put it down.

Bimanual reaching (both UE) to pick up large objects.

Pointing to different parts of a target.

While standing, each patient reached down to pick up and place objects on stool or floor. The distance of object placement varied depending on the patient's ability.

While sitting or standing, each patient reached up to pick an object or place an object on the wall. Height of reaching varied depending on the patient's ability.

(7) Manipulation and dexterity training to increase speed and movement precision. During the application of the following movements, each patient was instructed to use the pads of the thumbs and fingers for grasping and not the lateral surfaces. In addition, the wrist joint was kept in extension and all opposition movements were performed by the carpometacarpal joint of the thumb:

- Tapping tasks.
- Picking different objects between thumb and finger(s), and placing them on various targets.
- Picking up larger objects from one side of the table and place to the other side; vary weight, and distance to be moved.

(8) Bimanual practice is when the patient gained the ability to control simple movements. Exercises included push-ups against the wall, picking up and placing objects of different shapes, sizes, and weights, walking, walking up and down steps, and standing up.

2.5.2.Passive somatosensory stimulation. Passive somatosensory stimulation was applied after completing the motor UE program. Compressible therapy (POWER-Q1000 PLUS, Wonjin Mulsan Co., Ltd, Namchon-dong, Namdong-gu, Incheon, Korea; Model: WHF-324) (Fig. 1) was applied for 25 min[24] as follows:

Each patient sat comfortably on a chair with back support with both UE positioned on the treatment table.

The more affected UE was positioned as follows: shoulder protraction and external rotation, the angle between the trunk and the UE was approximately 45°, radioulnar supination, and elbow, wrist, and fingers in extension.

A long inflatable pressure splint was applied to the more affected UE along with a pressure pad placed inside the pressure splint, under the dorsal aspect of the hand.

The splint was then, connected to the compressible therapy system. The machine timer was set for 25 min. and then turned on. The inflation peak was set to 70 mmHg.

Each patient was asked to look to the more affected UE during the stimulation period.

2.6.Statistical analysis

Statistical Package for Social Science (SPSS) Software (version 19) (IBM, Armonk, NY) for Windows was used for analysis. Descriptive statistics (e.g., mean, median, standard deviation) were calculated for all variables in the study. The independent sample *t*-test and chi-squared test were used to test the presence of significant differences between scores of demographic variables in (Gr1) and (Gr2). The Mann–Whitney test and the Wilcoxon test were used for comparison between scores of the BBT, PPBT, and NSA within and between both groups. All tests were set significant if the *P* value is <.05.

Figure 1. Body of the compressible therapy device.

3.Results

Forty-nine stroke patients were screened for eligibility, 9 did not match the specified inclusion criteria of the study, and the remaining 40 patients were enrolled in the study, where 37 completed the study (Fig. 2).

3.1.Demographic data and clinical characteristics

No statistically significant pre-treatment difference ($P > .05$) was present between Gr1 and Gr2 in age, duration of stroke (months), and side of affection (Table 1).

3.2.Clinical scales

3.2.1.Box and Block test There were significant changes between the more affected and less affected UE pre- and posttreatment in Gr1 and Gr2 ($P < .05$) Additionally, there were significant changes between the more affected UE pre-and posttreatment and the less affected UE pre- and posttreatment in both groups ($P < .05$) (Table 2). On the other hand, no significant change between **Gr1** and **Gr2**, in the more affected UE, pre-and posttreatment was reported while in the less affected UE there was a significant change, posttreatment between Gr1 and Gr2 (Table 3).

3.2.2.Perdue Pegboard test There was a significant change between the more affected and less affected UE pretreatment in Gr1 and Gr2 ($P < .05$) while there was no significant change posttreatment. Additionally, there were significant changes between the more affected UE pre-and posttreatment and the less affected UE pre- and posttreatment in both groups ($P < .05$) (Table 4). On the other hand, no significant change between Gr1 and Gr2 was reported in the more affected UE, pre-and posttreatment while in the less affected UE there was a significant change between pre- and posttreatment (Table 5).

3.2.3.Nottingham Sensory Assessment scale. There were no significant changes between the more affected and less affected UE pretreatment in Gr1 and Gr2 ($P < .05$) except in pretreatment scores of tactile sensations of both groups with no significant changes reported post-treatment. Additionally, there was a significant change between pre- and posttreatment scores of the tactile sensation only in both groups ($P < .05$) (Table 6). On the other hand, significant changes between **Gr1** and **Gr2**, in stereognosis, tactile sensations, and kinesthetic sense, pretreatment were reported in the more affected UE, ($P < .05$), while no significant changes were reported post-treatment and in the less affected UE (Table 7).

4.Discussion

The current study was designed to study the effect of passive somatosensory stimulation using compressive therapy on sensorimotor function of the more affected UE in chronic stroke patients. This was achieved using outcome measures that examined the motor and sensory function of the more affected and less affected UE. These included BBT as a measure of gross manual dexterity, PPBT as a measure of fine manual dexterity, and NSA scale as a measure of somatosensory function.

In this study, improvements were observed in gross manual dexterity, fine motor dexterity, and tactile sensation of the more affected UE compared to the less affected UE in both groups. This was consistent with expectations that applying UE motor

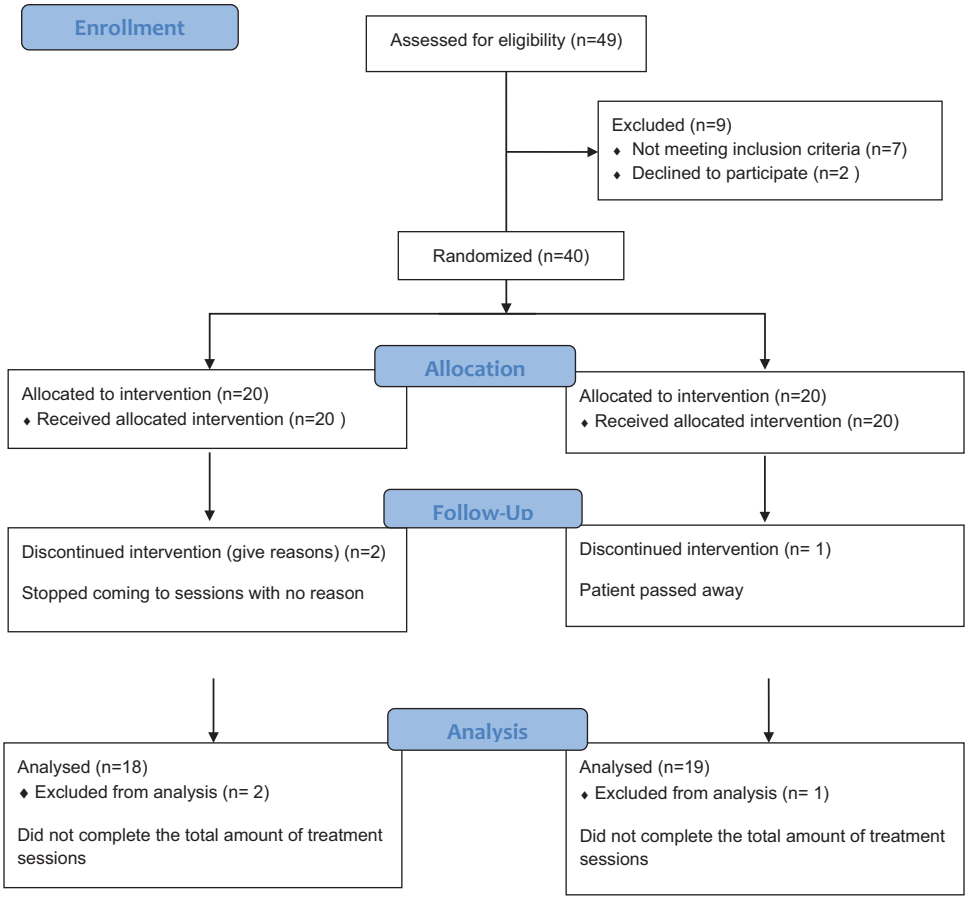

Figure 2. Study design.

Table 1

Demographic and baseline clinical characteristics in both groups, pretreatment.

	Gr1 (*n*=18)	Gr2 (*n*=19)	*P* value
Age (y)	58.8 ± 5.1	56.7 ± 2.6	.222[a]
Type of stroke (Ischemic)	18	19	1
Duration of stroke (months)	10 ± 0.2	10 ± 0	.114[a]
Gender (male/female)	14/4	13/6	.495[b]
Side of affection (right side/left side)	10/8	13/6	1[b]
Edinburgh handedness inventory for dominance (right-handed)	18	19	1[b]
Mini-mental state examination (MMSE)	28.2 ± 2.5	28.7 ± 1	.562[a]
Modified Ashworth scale (MAS)	1.1 ± 0.2	1.1 ± 0.3	1[c]
Fugl–Meyer assessment of the upper extremity (FMA-UE)	36 ± 21.5	38 ± 14.3	.418[c]

aUnpaired *t* test,
bchi-squared test,
cMann–Whitney test,
*$P < .05$= significant.

Table 2

BBT scores of the more affected and less affected UE in (Gr1) and (Gr2), pre- and posttreatment.

			More affected side	Less affected side	*P* value
BBT	Gr1	Pretreatment	23 ± 21.9	40 ± 14.2	.005*[a]
		Posttreatment	38 ± 22.1	45 ± 13.4	.005*[a]
		P value	**.005***[b]	**.011***[b]	
	Gr2	Pretreatment	14 ± 15.5	28 ± 8.1	.002*[a]
		Posttreatment	20 ± 12.3	32 ± 9.8	.010*[a]
		P value	**.002** *[b]	**.005***[b]	

aMann–Whitney test,
bWilcoxon test,
*$P < .05$= significant.

program in (Gr1) and adding passive somatosensory stimulation in the form of compressive therapy to the motor program in (Gr2) can improve the function of the more affected UE. Both treatment programs seemed to improve scores of BBT, PPBT, and NSA, indicating some sort of improved function of the more affected UE. Although the sample size was small, the effects of treatment were significant in both groups.

Results of the current study agree with that of Cambier et al[24] who evaluated the effectiveness of using intermittent pneumatic compression on treating sensory affection of the more affected UE in stroke patients. 23 stroke patients were enrolled in the clinical trial and randomized to 2 groups. The experimental group (n = 11) received standard physical therapy along with intermittent pneumatic compression (10 cycles of 3 mins with a peak of 40 mmHg) for the more affected UE. The control group (n = 12) received the same standard physical therapy program along with a placebo treatment, which was short-wave therapy applied on the more affected UE. Clinical evaluation of sensation was performed 3 times over 4 weeks using the NSA scale. Results showed improvement in somatosensation in both groups, but the experimental group improved more than the control group ($P = .036$) or 81.1% improvement versus 30.9 %. The authors concluded that the use of intermittent pneumatic compression in stroke rehabilitation may be

Table 3

BBT scores of the more and less affected UE in (Gr1) and (Gr2), pre- and posttreatment.

			Gr1	Gr2	*P* value
BBT	Pretreatment	More affected UE	23 ± 21.9	14 ± 15.5	.517[a]
		Less affected UE	40 ± 14.2	28 ± 8.1	.017*[a]
	Posttreatment	More affected UE	38 ± 22.1	20 ± 12.3	.790[a]
		Less affected UE	45 ± 13.4	32 ± 9.8	.017*[a]

aMann–Whitney test,
*$P < .05$= significant.

Table 4

PPBT scores of the more affected and less affected UE in (Gr1) and (Gr2), pre- and posttreatment.

			More affected side	Less Affected Side	*P* value
PPBT	Gr1	Pretreatment	4.75 ± 3.77	10.5 ± 4.04	.007*[a]
		Posttreatment	8.75 ± 4.99	12 ± 3.55	.079[a]
		P value	.001*[b]	.001*[b]	
	Gr2	Pretreatment	1.75 ± 2.36	7 ± 3.82	.004*[a]
		Posttreatment	4.75 ± 3.59	9.5 ± 5.57	.078[a]
		P value	.001*[b]	.001*[b]	

aMann–Whitney test,
bWilcoxon test,
*$P < .05$= significant.

Table 5

PPBT scores of the more and less affected UE in (Gr1) and (Gr2), pre- and posttreatment.

			Gr1	Gr2	*P* value
PPBT	Pretreatment	More affected UE	4.75 ± 3.77	1.75 ± 2.36	.052[a]
		Less affected UE	10.5 ± 4.04	7 ± 3.82	.052[a]
	Posttreatment	More affected UE	8.75 ± 4.99	4.75 ± 3.59	.079[a]
		Less affected UE	12 ± 3.55	9.5 ± 5.57	.215[a]

aMann–Whitney test,
*$P < .05$= significant.

important for the restoration of sensory function. Drawbacks of that study included small sample size and a short follow-up period. It is also worth mentioning that the only clinical trial evaluating the effect of using intermittent pneumatic compression on upper extremity function in stroke patients was that by.[24]

Generally, the results of the current study match work by[13–15,33,34,47] who demonstrated the benefits of physical therapy on UE function in stroke patients, and work by[13,17,18,26,48–52] who proved the benefits of somatosensory stimulation on UE function in stroke patients.

As mentioned previously, improvement was observed in gross manual dexterity of the more affected and less affected UE in both groups which indicates that both physical therapy programs were effective in improving function. On the other hand, the comparison between both groups did not show the superiority of one treatment approach over another which did not agree with our assumption that somatosensory stimulation added to the motor program will result in better improvement of motor and sensory function of the more affected UE. What led to this assumption is that adding somatosensory stimulation to the treatment program improves motor function due to the connections present between the sensory and motor pathways and the documented importance of sensation in motor learning.[32,53] Another surprising finding was the improvement in scores of BBT of the less affected UE posttreatment compared to pretreatment scores in Gr1 only. One justification can be the somatosensory stimulation modality used in the current study is considered a passive one (pneumatic pressure pump/compressive therapy), thus did not result in great effect despite that a systematic review and meta-analysis[31] reported that "passive somatosensory stimulation modalities may assist in improving activity after stroke".

Regarding the improvement of fine motor dexterity, several interesting findings were noted. First, there was a significant difference in the pretreatment scores of the PPBT in both groups, between the more affected and less affected UE. The scores changed to non-significant post-treatment which can be interpreted as an improvement in fine motor dexterity. Additionally, a comparison between pre- and posttreatment scores in the more and less affected UE in both groups revealed significant improvement posttreatment, yet as in the BBT scores, no treatment program appeared to be superior to the other.

As for somatosensation in both groups, the results were quite challenging. It was observed that there was a significant difference between the more and less affected UE in both groups which changed to nonsignificant, again indicating improvement in tactile sensation. Also, a comparison between both groups showed improvement in tactile sensation, stereognosis, and kinesthetic sense the more affected UE. This again agrees with Serrada et al and De Bruyn et al.[31,32]

It is not easy to compare the results of the current study with other studies since 2 studies only using compressive therapy were published; one by Cambier et al[24] and the outcome measures used were FMA-UE, modified Ashworth scale, and NSA scale, and the other by.Feys et al[28]

On the contrary, the results of this study disagreed partially with the review by Doyle et al[54] who reported that sensory stimulation techniques were limited to improving tactile and kinesthetic sensation and there was not sufficient evidence to support the efficacy of these intervention strategies in improving manipulation in the UE. The same applies to results by Poole et al[55] who reported no statistically significant differences in mean change in motor function measured by FMA-UE from week 0 to week 3 between subjects who received pressure splint treatment and subjects who did not wear the splints.

Accordingly, based on the results of the current study, it can be assumed that both motor UE programs and passive somatosensory stimulation programs are equally effective in terms of improving sensorimotor function of both the more affected and less affected UE in chronic stroke patients.

4.1. Limitations

First, the sample size is considered quite small and leads to reduced power of the study. Second, the follow-up was only 6 weeks after therapy, which may be too short to find retention effects. Third, the duration of treatment also is considered too short, maybe a longer period of treatment was required. Fourth, more objective ways can be implemented to measure the changes in motor and sensory function in both UE such as functional magnetic resonance imaging (fMRI) or quantitative electroencephalogram (QEEG).

5.Conclusion

The purpose of this study was to investigate the effect of adding passive somatosensory stimulation to the rehabilitation program of stroke patients. The results obtained are promising but further investigations are required due to the complex and changing nature of stroke rehabilitation. Passive somatosensory stimulation is considered a nonexpensive modality and can help in improving both motor and sensory function of the UE in stroke patients when added to the treatment program.

Table 6

NSA scores of the more affected and less affected UE in (Gr1) and (Gr2), pre- and posttreatment.

				More affected side	Less affected side	*P* value
NSA	Stereognosis	Gr1	Pretreatment	22 ± 2.7	22 ± 0.0	.063[a]
			Posttreatment	22 ± 0.0	22 ± 0.0	1[a]
			P value	.063[b]	1[b]	
	Tactile sensation		Pretreatment	16 ± 0.0	48 ± 0.0	.002*[a]
			Posttreatment	48 ± 8.4	48 ± 0.0	.157[a]
			P value	.003*[b]	1[b]	
	Kinesthetic sense		Pretreatment	12 ± 1.7	12 ± 0.0	.157[a]
			Posttreatment	12 ± 0.0	12 ± 0.0	1[a]
			P value	.157[b]	1[b]	
	Stereognosis	Gr2	Pretreatment	22 ± 0.0	22 ± 0.0	1[a]
			Posttreatment	22 ± 0.0	22 ± 0.0	1[a]
			P value	1[b]	1[b]	
	Tactile sensation		Pretreatment	16 ± 15.8	48 ± 0.0	.005*[a]
			Posttreatment	48 ± 0.0	48 ± 0.0	1[a]
			P value	.005*[b]	1[b]	
	Kinesthetic sense		Pretreatment	12 ± 0.0	12 ± 0.0	1[a]
			Posttreatment	12 ± 0.0	12 ± 0.0	1[a]
			P value	1[b]	1[b]	

aMann–Whitney test,
bWilcoxon test,
*$P < .05$= significant.

Table 7

NSA scores (stereognosis, tactile sensation, and kinesthetic sense) of the more affected and less -affected UE in (Gr1) and (Gr2), pre- and posttreatment.

				Gr1	Gr2	*P* value
NSA	Stereognosis	Pretreatment	More affected UE	22 ± 2.7	22 ± 0.0	.019*[a]
			Less affected UE	22 ± 0.0	22 ± 0.0	1[a]
		Posttreatment	More affected UE	22 ± 0.0	22 ± 0.0	1[a]
			Less affected UE	22 ± 0.0	22 ± 0.0	1[a]
	Tactile sensation	Pretreatment	More affected UE	16 ± 0.0	16 ± 15.8	.049*[a]
			Less affected UE	48 ± 0.0	48 ± 0.0	1[a]
		Posttreatment	More affected UE	48 ± 8.4	48 ± 0.0	.112[a]
			Less affected UE	48 ± 0.0	48 ± 0.0	1[a]
	Kinesthetic sense	Pretreatment	More affected UE	12 ± 1.7	12 ± 0.0	.112[a]
			Less affected UE	12 ± 0.0	12 ± 0.0	1[a]
		Posttreatment	More affected UE	12 ± 0.0	12 ± 0.0	1[a]
			Less affected UE	12 ± 0.0	12 ± 0.0	1[a]

aMann–Whitney test;
*$P < .05$= significant.

Author contributions

Funding acquisition, the experimental design of the study, and the work: RMA, NNA, WMR, and HMZ; validation: NFM; writing–original draft, writing–review and editing: HRE. All authors have read and agreed to the published version of the manuscript.

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