Impact of Intermittent Pneumatic Compression on Cortical Reorganization and Functional Outcome in Patients with Stroke

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Abstract

Background: The main feature of the cerebrovascular condition known as stroke is blood vessel obstruction. The third most common cause of disability worldwide is stroke. Lowering one's quality of life and adding to the burden that stroke survivors bear is upper limb motor dysfunction. Recovery of arm and hand function is a primary objective of rehabilitation programs since it is crucial to achieving independence in daily life. The goal of neurological treatment plans adopting inflatable pressure sleeves is to decrease spasticity and to enable normal movement and sensory input on the hemiplegic part. By attaching these inflatable splints to an intermittent pressure pump, the goal was to further increase sensory input.**Aim:** The current study aims to determine and trace how intermittent pneumatic compression (IPC) affects the functional outcome of the upper extremity after a stroke and the occurring cerebral reorganization.**Methods and participants:** In this study, 40 instances of left strokes and limb disability from both sexes were randomly split into two major domains. Interventions: For 60 minutes, the study group received an upper extremity physical therapy plan along with intermittent pneumatic compression, whereas the control group received 60 minutes for the same selected physical therapy exercise only. There were 18 treatment sessions for each domain over the course of six weeks.**The outcome measures:** Using the wolf motor function scale (WMFT) and quantitative EEG (QEEG), which assesses brain activity, the upper limb motor function was assessed before and after therapy. **Results:** There was no statistically significant difference between the two groups for any of the pre-treatment examined factors. IPC showed a significantly shorter performance time in the study group as well as a significantly improved motor outcome and functional outcome of the damaged upper extremity. The excitability of the brain's motor and sensory regions increased noticeably.**Conclusion:** IPC has a positive impact on stroke cases' cortical reconfiguration as well as the functional result and motor performance of the damaged upper extremity. 2165

KeyWords: Stroke, IPC, Quantitative EEG, WMF.

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Introduction

The clinical signs of localized brain function impairment that first appear and last for 24 hours or longer are the hallmarks of the medical condition known as cerebral stroke, which results in morbidity and mortality. Ischemic strokes account for more than 80% of all strokes. The typical outcome of a large artery blockage is tissue infarction, which, unless it is swiftly reversed, results in a non-selective loss of all cells in the affected brain area. Long-term functional effects of stroke are largely dependent on the size and location of these infarcts (16).

Upper limb recovery is essential for improving quality of life and ensuring independence with activities of daily living (ADLs), such as eating, bathing, and dressing. Simple tasks like brushing one's teeth, getting a toilet paper roll from a dispenser, or shaving becomes difficult. Approximately 65% of them have ongoing limitations in UL function (11). Because a person with a stroke has a residual impairment, there is a higher chance of recurrence and mortality. To counteract the detrimental consequences of stroke damage, it is important to choose suitable therapy modalities (12).

Decreased stiffness, normalized mobility, and increased sensory input in the affected extremities on the hemiplegic side were the objectives of a neurological treatment program using inflatable pressure sleeves for the extremities. Then, by linking these inflatable splints to an intermittent pressure pump, it was attempted to further augment sensory input. The proprioceptive and exteroceptive sensory systems are stimulated by this modified application, which causes the applied sleeve to cycle between periods of inflation and deflation (5).

Subjects and Methods

Study design:

A clinical trial that is single-blind and randomized. Before each case was enrolled in the trial, the study procedure was thoroughly explained to them, and their signed written consent was obtained.

Ethical considerations:

Consent number: P.T.REC/012/003048 was reviewed for ethical consideration and authorized for the current investigation. To randomly assign subjects to the study and control groups, a blinded and impartial research assistant opened sealed, opaque envelopes containing computer-generated randomization cards. Each group contained a total of 20 cases. The privacy and anonymity of every patient were ensured.

A neurologist made referrals for each patient. The MRI or CT scan provided proof of the diagnosis. The patients were chosen from the South Valley University teaching hospital's outpatient clinic and the faculty of physical therapy's outpatient clinic at South Valley University, Qena Governorate. The research was done from December 2020 to July 2022.

Inclusion criteria

40 cases with a left chronic stroke from both sexes participated in the study. The cases are between the ages of 45 and 60. The patients were divided into two major domains, each with 20 patients: G1 (control group) and G II (study group). Patients having a single ischemic cerebrovascular accident (CVA) in the right hemisphere were included in the study. The sickness lasted between six months and two years. Patients had normal sensations (deep & superficial), patients had normal cognitive levels according to the mini-mental scale (MMS), all the patients were clinically and physically stable, and the muscle tone of the affected upper limb muscles ranged from 1 to 1+ grade according to modified Ashworth scale and the muscle power of the affected upper limb muscles ranged from 'three to 'four' according to manual muscle testing. The physical therapy treatment plan given to GI (the control group) includes stretching exercises for tight upper limb muscles, proprioceptive neuromuscular facilitation as the last stage, and active resistance exercises for weak upper limb muscles (PNF) While a physical therapy exercises and IPC were selected for GII (study group).

Exclusion criteria

Aphasia, dementia, active neoplastic illness, significant orthopedic or chronic pain in the upper limbs, symptomatic heart failure or unstable angina, uncontrolled hypertension (>190/110 mm Hg), or unstable angina were all factors that disqualified cases.

Evaluation procedures:

Cases in both groups obtained the wolf motor function test (WMFT), which was adopted in the current study to time the movement of the upper limb and to gauge the functional performance of the upper limb as a whole. The use of this scale **was** established by the research by (17), which suggested that the WMFT was a useful tool for assessing upper extremity motor function in hemiplegic patients. Performance time and functional ability were divided into two groups on a time-based scale comprised of 15 functional assessments (17). Studies showed that in patients with chronic stroke, the test had good responsiveness, validity, and reliability (18).

Using the spectral analysis of Q-EEG, the neuroplasticity in the motor and sensory regions of the affected and unaffected hemispheres was assessed before and after therapy. Spectral analysis of Q-EEG was carried out on a computerized EEG-EP multifunction system with 10–20 channels (wide band). Italy — Florence — Mizar-PC Peripheral System, Ebneuro Version b9800037800. The Galileo Mizar system "digital electroencephalograph" is used to realize the new Ebneuro digital EEG/ep line. EEGs were recorded using a unipolar montage and the international 10-20 standard derivations f4, f8, c4, p4, f3, f7, c3, and p3. The following waves were recorded: theta, delta, theta 1, beta 2, and others. To perform spectrum analysis, the average ranges of each wave were then determined at the f4+f8, c4, and p4 motor areas and sensory areas of the damaged hemisphere as well as the f3+f7, c3, and p3 motor areas and sensory areas of the unaffected hemisphere.

To identify neuronal plasticity and fluctuating excitability in motor areas, an equation based on the fast wave/slow wave ratio or the ratio of the mean frequency of (beta 2+ beta 1+alpha/theta + delta) was used. The ratio varies as the quick waves grow or the slow waves shrink, which shows the neuroplasticity or learning ability of the motor areas (13).

Treatment procedures:

Physical therapy activities for the afflicted upper limb's tight muscles, active resistive exercises for its weak muscles, and proprioceptive neuromuscular facilitation (PNF) for 60 minutes were given to the control group (GI) (14). The study group (GII) received IPC in addition to the selected physical therapy program. The IPC device consists of an inflatable arm or leg wrap with multiple pressure compartments and an electrical pneumatic pump that fills the garment with compressed air. The garment is intermittently inflated and deflated with cycle times and pressures that vary between devices (15).

Patients in (GII) got a 30-minute IPC session in addition to a 30-minute physical therapy program of their choice, such as (GI). IPC will be administered with the patient laying supine, the trunk and arm at a 45-degree angle, and the elbow, wrist, and fingers extended. It has a 30-minute automatic intermitting pattern with a 90-second duty cycle for inflation and a 90-second duty cycle for deflation. The 40-mmHg inflation peak was chosen. This intermittent pressure technique, which consisted of 10 cycles of 3 minutes, lasted 30 minutes (5). For six weeks, the treatment was given three days a week. Both groups get traditional lower limb physical therapy treatments.

Statistical analysis

The normality assumption test and the homogeneity of variance test were performed on the data. The data were put through a normality test using the Shapiro-Wilk and Levene's tests to determine the homogeneity of variance after outliers were removed using box and whiskers plots to identify them. These findings allowed for the execution of both parametric and non-parametric analysis. A parametric analysis is done on the normally distributed data on the excitability of the right and left brains in the affected and unaffected hemispheres. However, non-parametric analysis is utilized because the WMFT data are not regularly distributed.

Statistical analysis was performed by utilizing Windows version 25 of the statistical SPSS package application (SPSS, inc., Chicago, il). The mean and standard deviation are used to express quantitative data for age, height, weight, BMI, functional performance, time of performance, brain excitability from the non-affected hemisphere (left hemisphere), and brain excitability from the affected hemisphere (right hemisphere). Data on gender are expressed as a number and a percentage for qualitative purposes.

The chi-square test for gender-related characteristics and the independent-t test for factors related to age, weight, height, and BMI to compare the two groups were adopted in the current study. The Wilcoxon signed ranks test was used to compare pre-and post-treatment values for WMFT variables within the study group and control group. The Mann-Whitney u test was used to compare the WMFT variables between the study group and the control group before and after treatment. Using multivariate analysis of variance, the tested primary variables of interest were compared across several tested groups and measurement intervals (MANOVA). A mixed design 2 x MANOVA test was used to assess the important variables of interest (right and left-brain excitability from the affected & the non-affected hemisphere). The Bonferroni adjustment test was used to compare the evaluated variables within and across groups for which the MANOVA test's f value was significant. At the 0.05 level of probability, all statistical tests were significant.

Results

Twenty patients from each of the two genders were categorized into two groups, totaling forty cases (18 men and 22 women). According to patient demographic data, there were no clear variances between the study group and control group in terms of age (p=0.401), weight (p=0.147), height (p=0.114), BMI (p=0.405), or gender (p=1.000) (p>0.05).

Table 1. Comparison of general characteristics between groups a and b.

Items	Groups		*P*-value
	Control group (n=20)	Study group (n=20)	
Age (year)	50.05 ±3.60	53.25 ±3.97	0.401
Weight (kg)	76.40 ±5.82	73.90 ±4.81	0.147
Height (cm)	166.65 ±5.86	162.60 ±3.47	0.114
BMI (kg/m²)	27.51 ±1.78	27.93 ±1.34	0.405
Gender (males: females)	9 (45.00%): 11 (55.00%)	9 (45.00%): 11 (55.00%)	1.000

P-value: probability value; **NS:** non-significant

Age, weight, height, and BMI are all quantitative variables that are expressed as mean standard deviation and compared using a t-independent test. An analysis of variance (chi-square) test is adopted to compare qualitative data (gender) expressed as percentages.

Table 2's statistical analysis of the time effect for WMFT variables within each group revealed that the WMFT for functional performance within the control group (p=0.001) and study group (p=0.0001) increased at post-treatment compared to pre-treatment. The WMFT for the time of performance at post-treatment compared to pre-treatment within the control group (p=0.001) and study group (p=0.0001) decreased significantly (p <0.05).

The study group exceeded the control group in terms of impressive WMFT for functional performance and WMFT for the time of performance. Furthermore, compared to the control group, the study group showed greater gains in WMFT for functional performance and WMFT for performance time (73.08 and 49.76%, respectively).

Statistical analysis of group effect for WMFT variables between both groups (table 2) revealed that no clear disparity (p>0.05) at pre-treatment WMFT for functional performance (p=0.155), and WMFT for the time of performance (p=0.102) between the two-study domain. However, there were clear variances (p<0.05) between the control group and the study group at post-treatment in WMFT for functional performance (p=0.0001), and WMFT for the time of performance (p=0.0001).

Table 2. within and between groups comparison WMFT

Variables	Items	Groups (Mean ±Sd)		Change	*p*-value
		Control group (n=20)	Study group (n=20)		
WMFT for functional performance	Pre-treatment	28.75 ±5.97	26.00 ±6.01	2.75	0.155
	Post-treatment	31.10 ±5.46	45.00 ±7.15	13.90	0.0001*
	Change	2.35	19.00		
	Improvement %	8.17%	73.08%		
	P-value	0.001*	0.0001*		
WMFT for the time of performance	Pre-treatment	1402.25 ±24.37	1390.30 ±23.73	11.95	0.102
	Post-treatment	750.00 ±13.30	698.50 ±23.03	51.50	0.0001*
	Change	652.25	691.80		
	Improvement %	46.51%	49.76%		
	P-value	0.001*	0.0001*		

Data are expressed as mean ± standard deviation (SD) p-value: probability value *significant (p<0.05)

No clear variations (p>0.05) between the pre-and post-treatment of f3 + f7 (p=0.292), c3 (p=0.171), and p3 (p=0.712) within the control group due to the time effect were found according to multiple pairwise comparison tests for brain excitability from the non-affected hemisphere (left hemisphere) variables within each group. However, within the study group, there were significantly (p0.05) higher levels of brain excitability in the f3 + f7 (p=0.001), c3 (p=0.007), and p3 (p=0.008) at post-treatment compared to pre-treatment. The study group outperformed the control group in terms of these significant changes in brain excitability from the unaffected hemisphere (left hemisphere) for the f3+f7, c3, and p3 variables. Furthermore, the study group fared better on the f3 + f7, c3, and p3 tests than the control group (1.18, 2.04, and 0.33%, respectively).

Table no.3 highlights the statistical multiple pairwise comparison tests (group effect) for the variables f3 + f7 (p=0.180), c3 (p=0.171), and p3 (p=0.057) at pre-treatment revealed no disparity between the control group and study group that were statistically remarkable (p>0.05). At the end of the treatment, there were, nevertheless, crystal-clear changes (p0.05) between the two study domains in the f3 + f7 (p=0.0001), c3 (p=0.007), and p3 (p=0.0001).

Table 3. within and between groups comparison for brain excitability from the non-affected hemisphere (left hemisphere).

Variables	Items	Groups (Mean ±SD)		Change	*p*-value
		Control group (n=20)	Study group (n=20)		
F3 + f7	Pre-treatment	101.70 ±3.24	99.00 ±3.45	2.70	0.180
	Post-treatment	102.90 ±1.51	95.00 ±4.99	7.90	0.0001*
	Change	1.20	5.20		
	Improvement %	1.18%	4.04%		
	P-value	0.292	0.001*		
C3	Pre-treatment	49.00 ±3.06	50.00 ±1.62	1.00	0.171
	Post-treatment	50.00 ±2.42	52.00 ±1.74	2.00	0.007*
	Change	1.00	2.00		
	Improvement %	2.04%	4.00%		
	P-value	0.171	0.007*		
P3	Pre-treatment	44.85 ±0.81	48.95 ±1.63	4.10	0.057
	Post-treatment	45.00 ±0.85	50.05 ±1.57	5.05	0.0001*
	Change	0.15	1.10		
	Improvement %	0.33%	2.25%		
	P-value	0.712	0.008*		

Data are expressed as Mean ± Standard deviation (SD), P-value: probability value; * significant (p<0.05)

In both the control group (p=0.033) and the study group (p=0.0001), statistical multiple pairwise comparison tests (time effect) for brain excitability from the affected hemisphere (right hemisphere) variables within each group demonstrated a substantially (p <0.05) increase in f4 + f8 for brain excitability from the non-affected hemisphere (right hemisphere) at post-treatment compared to pre-treatment. There were no distinct changes in c4 (p=0.228) and p4 (p=0.054) in the control group, but time effect had considerably (p<0.05) increased c4 (p=0.0001) and p4 (p=0.0001) at post-treatment compared to pre-treatment within study group. These significant variations in brain excitability from variables in the right hemisphere, which is unaffected, are more in favor of the study group than the control group. In addition, the study group fared better than the control group in terms of f4 + f8, c4, and p4 (8.73, 16.75, and 8.06%, respectively) than in terms of 1.68, 2.08, and 2.33%.

No distinct variances (p>0.05) at pre-treatment of f4 + f4 (p=0.132), c4 (p=0.064), and p4 (p=0.420) between the two-study categories, according to multiple pairwise comparison tests (group effect) for brain excitability from the non-affected hemisphere (right hemisphere) variables between both groups (table 4). However, at the post-treatment time points in f4 + f8, c4, and p4, there was a clear disparity (p<0.05) between the two study domains.

Table 4. within and between group's comparison for brain excitability from the affected hemisphere (right hemisphere).

Variables	Items	Groups (Mean ±SD)		Change	*P*-value
		Control group (n=20)	Study group (n=20)		
F4 + f8	Pre-treatment	101.45 ±3.23	100.25 ±1.48	1.20	0.132
	Post-treatment	103.15 ±1.53	109.00 ±3.14	5.85	0.0001*
	Change	1.70	8.75		
	Improvement %	1.68%	8.73%		
	P-value	0.033*	0.0001*		
C4	Pre-treatment	48.00 ±1.58	49.55 ±3.10	1.55	0.064
	Post-treatment	49.00 ±1.45	57.85 ±3.58	8.85	0.0001*
	Change	1.00	8.30		
	Improvement %	2.08%	16.75%		
	P-value	0.228	0.0001*		
P4	Pre-treatment	43.00 ±1.52	44.05 ±1.46	1.05	0.420
	Post-treatment	44.00 ±0.85	47.60 ±2.28	4.70	0.0001*
	Change	1.00	3.55		
	Improvement %	2.33%	8.06%		
	P-value	0.054	0.0001*		

Data are expressed as Mean ± Standard deviation (SD), P-value: probability value; * significant (p<0.05)

Discussion

Intermittent pneumatic compression uses a device that enables the injection of progressive pressure gradients on lymph arteries and improves lymph flow (IPC). Although 30 to 60 mmHg pressures were frequently preferred, this equipment could apply pressures up to 300 mmHg (1). To improve the microcirculation of the foot and reduce the risk of diabetic foot ulcers in those with type II diabetes, the suggested inflation pressures for IPC were 90 and 120 mmHg. These IPC dosages work well to improve blood flow in healthy people, with 120 mmHg IPC perhaps being better suited for people with vascular problems (2).

The inflation pressure, which decreases venous pressure and increases the arteriovenous pressure gradient, directly affects the therapeutic effectiveness of IPC treatment. To address the numerous underlying circulatory system deficits, the appropriate inflation pressures for patients who have circulatory issues in their lower limbs due to various pathological reasons should differ from one another (3).

The outcomes of this study are in line with those of (5), who suggested that utilizing inflatable pressure splint wraps for the extremities could reduce stiffness, enable normal mobility, and boost sensory input in the affected extremities on the hemiplegic side. They then connected these inflated splints to an intermittent pressure pump to improve sensory input even more.

The study group's findings corroborate those of (6), who found that intermittent sequential pneumatic compression (ISPC) can successfully improve microcirculation and increase blood flow. An increase in blood flow velocity and pressure gradient brought on by an ISPC has been proposed as a potential method to enhance patient microcirculation.

The current result lends credence to past studies that showed focused injury after a stroke significantly affects the network connectivity structure of the entire cortical region and contributes to differences in the cerebral hemispheres. Wavelet amplitude (WA) and laterality index are two important measurements for determining the degree of brain activation and hemisphere differences (LI). WA is the measurement of the magnitude of the fluctuation of the original signal by multichannel fNIRS (functional near-infrared spectroscopy) operating at a particular frequency. This measurement might represent the activity of the cerebral cortex (7).

The results of the current study suggest that intermittent pneumatic compression can improve upper limb somatosensation in hemiplegic stroke patients, making intermittent pressure splints an essential component of their regular stroke therapy. Our investigations, which demonstrate elevated brain activity in the motor and sensory areas, are consistent with their ability to correct sensory impairments, particularly tactile sensitivity (4).

Cortical activity has improved, which can be explained by the significant improvement in the affected arm's motor function in the study group that received IPC. This conclusion was consistent with that made by (8), who stated that alpha and delta bands were markers of the healing process, with higher alpha power indicating a better prognosis for patients. Additionally, they observed that when motor performance and daily living tasks improved, relative QEEG power in the alpha bands tended to increase (ADL).

According to available data, aerobic exercise may have benefits that transcend beyond cardiovascular health indicators and may even affect brain health by preserving tissue volume. Increases in the amount of representation, however, are inconsistent in individuals with complex regional symptoms (10), as prolonged immobility of the limb reduces the area of representation rather than inflicting pain or injury. These findings imply that adjustments to the motor cortex affect adjustments to postural strategies (9).

Conclusion

According to the study's findings, intermittent pneumatic compression helps enhance functional abilities and raise cortical activity in the motor and sensory cortex in stroke cases.

Conflict of interest

Authors declare no conflict of interest.

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