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Original Research Article

EFFECTS OF EARLY PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION EXERCISES ON SENSORY- MOTOR RECOVERY OF UPPER EXTREMITY AND NEUROPLASTICITY IN THE PATIENTS WITH ACUTE STROKE

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Abstract

Background: After a stroke, 80% of patients experience acute paresis of the upper extremity. Proprioceptive neuromuscular facilitation (PNF) is a widely used rehabilitation concept, but many studies do not discuss its utility as a rehabilitative tool in acute stroke. The main objective of this study was to investigate the effects of early PNF exercises on the sensory-motor recovery of upper extremity and neuroplasticity in the patients with acute stroke.

Methods: Total 90 patients were enrolled and divided randomly into two groups, Group A (n= 41), - received PNF exercises and group B (n= 49), - received traditional exercises. Patients in group A were given PNF exercises for trunk, scapula and upper extremity 30 minutes twice daily, five days a week for four weeks and patients in group B were given traditional exercises for the same duration. Fugl- Meyer Scale was assessed for sensory-motor recovery and Arm Motor Ability test scores were assessed for functional activities of the upper extremity. To look for its effects on neuroplasticity, serum BDNF levels were assessed before and after the intervention.

Results: Group A showed more improvement than group B in motor scores (Upper Extremity portion of the Fugl- Meyer assessment, p =0.017) and functional activities of the upper extremity (AMAT, p=0.038). The sensory improvement was more in group A. There was no significant difference in pain and range of motion scores. No deformity and any adverse event noted in both groups after intervention. Serum BDNF levels showed better scores in Group A.

Conclusions: PNF exercises are efficient to improve the upper extremity function in acute stroke. Early implementation of PNF exercises promotes neuroplasticity in a better way.

Keywords: Stroke, Proprioceptive Neuromuscular Facilitation Exercises, upper extremity. Brain-derived neurotrophic factor.

Abbreviations: Proprioceptive Neuromuscular Facilitation (PNF), Fugl- Meyer Scale (FMS), Arm Motor Ability Test Scores (AMAT), Brain-derived neurotrophic factor (BDNF)

Introduction

Stroke causes partial destruction of cortical tissue, which leads to disturbed regeneration and integration of the neural commands. Due to this disturbance in neural command, the motor task performance is affected [1]. The restoration of arm and hand motor function is essential for permitting the activities of daily living independently [2]. After a stroke, only 5% to 20% patients demonstrate full functional recovery from hemiparesis while there is only a minimal improvement from the initial weakness in about 55-75% cases after 3-6 months of stroke and these deficits persist thereafter causing significant disability and impaired quality of life. [3, 4, 5]. Thus, maneuvers to aid in functional recovery can have a huge impact in reducing the patient's and the caregivers' burden. Functional recovery of the arm includes gross movements, grasping, holding and manipulating objects, which require integration of complex muscular activity from the trunk, shoulder to fingers.

Recovery of motor function after a stroke involves relearning motor skills and is mediated by neuroplasticity. Although many molecular signaling pathways are involved, brain-derived neurotrophic factor (BDNF) has emerged as a key facilitator of neuroplasticity involved in motor learning and rehabilitation after stroke [11].

Recent research has focused on developing rehabilitation strategies that facilitate such neuroplasticity to maximize upper extremity function post stroke. A variety of techniques are used by physiatrists in the treatment of hemiplegic patients. Although these techniques are used widely, very few studies have been reported in the literature validating these diverse approaches for specific conditions or problems.

Previous Studies have reported positive effects of PNF in subacute and chronic stroke [7, 8]. Studies, to the best of our knowledge, regarding PNF implementation in acute stroke and its effects on sensory-motor recovery of upper extremity function and neuroplasticity are still lacking.

The aim of the present study was to evaluate the 1) effects of PNF exercise on the sensory-motor recovery of the upper extremity (Fugl- Meyer score) 2) functional activities of the upper extremity (by Arm Motor Ability Test) and 3) neuroplasticity (by the estimation of brain-derived neurotrophic factor levels in the serum).

Subjects and Methods

Patients with the stroke of < 6 weeks (diagnosed on the basis of clinical and CT, MRI findings) were recruited from October 2015 to July 2017 from the department of neurology, Dr. Ram Manohar Lohia Institute of Medical Sciences, a tertiary referral institute in Lucknow, Uttar Pradesh, India. Approval from the ethical committee of our institution was taken. Written consent was obtained from each patient prior to inclusion into the study. Patients with first time stroke, aged between 18- 70 years were included. Those with- recurrent stroke, severe cardiac illness, pregnancy, fracture, amputation, aphasia, severe cognitive impairment (MMSE<19), very severe stroke (NIHSS>20), subarachnoid hemorrhage were excluded from the study.

Patients were assessed for the level of consciousness (Glasgow Coma Scale) and stroke severity (National Institute of Health stroke scale- NIHSS score) within 48 hours from the admission to the hospital. Patients were divided into two groups A (Experimental) and B (control). PNF exercises were given to group A starting from trunk, scapula, upper extremity, and lower extremity. Subjects received PNF

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exercises with each session lasting 30 minutes twice daily [7], 5 days a week for 4 weeks [8]. Group B received traditional exercises. All patients were given the required medical management in addition to rehabilitation. We assessed upper extremity part of Fugl- Meyer scores in our study.

PNF Intervention

Patients were given PNF exercises from the first day of their admission to our hospital starting from trunk, scapula, and pelvis. **(Fig.1)**. 10 repetitions of each pattern were given initially for 30 minutes twice daily. The pattern and techniques followed are as follows

PNF for neck: Flexion with rotation to the left and extension with rotation to the right and vice-versa, 10 repetitions of each pattern.

PNF for trunk: Rhythmic stabilization and alternating isometrics, 10 repetitions.

PNF for scapula and pelvis: Anterior elevation and posterior depression; posterior elevation and anterior depression by rhythmic initiation and repeated contraction.

For upper extremity: D1 and D2 flexion and extension patterns.

Patients were discharged with instructions to continue the exercises at home along with medication and it was ensured over the phone that the relatives were indeed carrying on the PNF exercises as advised. PNF was given for 4 weeks and the functional activities were re-assessed in each patient.

Patients in group B were given passive, active assisted and resisted flexion-extension exercises of upper extremity for same time duration as group A. All subjects were followed up on monthly basis for 6 months.

Estimation of brain-derived neurotrophic factor

Assessment of serum BDNF levels was done by Enzyme-Linked Immunosorbent Assay (ELISA). 2ml of blood sample was collected from each subject. Blood was centrifuged and serum was separated and stored at -80°C. We used commercial ELISA KIT (Ray Biomed Human BDNF ELISA kit). ELISA was run as per kit protocol at 37°C. BDNF levels were assessed by reading the O.D. absorbance at 450 nm within 10 minutes after adding the stop solution.

The data were analyzed with statistical application SPSS 20.0. We checked the normality of scores by Kolmogorov- Smirnov test ($p > 0.05$). Scores were normally distributed in our data so we applied independent t-test to assess differences in FMS and AMAT scores (**Table 2**) before and after intervention between groups. A p-value < 0.05 was taken as a significant difference.

Results

A total of 108 participants were included in the study. 52 patients were in group A and 56 in group B. While on follow up, 18 patients dropped out. 2 patients expired due to a chest infection, 12 patients were lost to follow up and 4 patients had stopped the PNF intervention and were undergoing indigenous therapies. Thus, we analyzed the details of 90 patients (41 experimental, 49 control). There were 20% males in group A and 63% in group B. 51% had left and 47% had right hemiplegia (1:1), 53% patients were diagnosed with ischemic and 47% with hemorrhagic stroke (1:1). The demographic details of the patients are listed in Table 1. Patients recruited in our study were conscious and oriented to time, place and person. Patients in both groups had mild to moderate stroke (NIHSS<20) and none of them was aphasic. The MMSE score was > 19 in all recruited patients. On comparing Fugl- Meyer Scores in both groups, group A showed significant improvement than group B [$t(88)= 2.53$ $p= 0.017$] **(Fig.4)**. Group A exhibited more improvement in upper extremity function and sensory functions

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(**Fig. 5**). However, there was no significant difference in pain and range of motion scores in both groups (**Table 2**). There was a significant improvement in AMAT scores in group A. t(88)= 2.28, p= 0.038 **(Fig. 2)**. Serum BDNF levels significantly increased in group A (**Table 2, Fig. 3**). Group A exhibited more improvement in BDNF levels as compared to group B.

Discussion

In our study patients who received PNF exercises immediately after a stroke, manifested a better functional outcome as compared to the group receiving traditional exercises. We assessed the sensory score, pain and range of motion from Fugl- Meyer score for upper extremity only, however, PNF exercises for upper extremity and trunk improves trunk stability and balance too [6]. Our findings are supported in a study conducted by Hwangbo PN (2015) on chronic stroke patients. He concluded that PNF neck exercises improve the ability to control trunk and maintain balance [7] and improved motor control of trunk is known to assist the independent performance of daily tasks [10]. Improvement in the trunk muscles may cause the irradiation effect in proximal muscles in upper and lower extremities, producing improved tone in muscles.

PNF exercises stimulate proprioceptors in muscles and even a single session can improve tone in the muscles. Proprioceptive Neuromuscular Facilitation (PNF) is a philosophy of treatment based on principles of neurophysiology. Kabat suggested that patterns of movements performed in combination with other facilitatory procedures result in enhanced voluntary responses. The PNF approach to treatment uses the principle based on early phylogenetic and embryologic observations that control of motion proceeds from proximal to distal body regions. Facilitation of trunk control, therefore, is used to influence the extremities [12-17].

PNF exercises emphasize the sensory-motor stimulation (proprioceptors), stretch reflexes, traction and approximation of joints, visual and auditory cue. PNF works on the principle that resistance to the strong muscles causes irradiation effect in surrounding weak muscles which help in the build-up of tone in muscle and strengthens it. PNF emphasizes the symmetry of both affected and unaffected sides by D1 and D2 diagonal and spiral motor patterns. PNF utilizes a typical helical and diagonal pattern which stimulates the proprioceptors and nerve roots, enhancing functional movement [6]. By giving a stretch, resistance, traction and joint approximation to the strong muscles, the tone is improved in surrounding weak muscles by overflow or irradiation effect. It decreases tone in spastic muscles and improves tone in weak muscles. Wang *et al* carried out a study on 15 chronic stroke patients. In their study PNF intervention was given for lower extremity to hypertonic muscles and on measuring muscle tone, a decrease in the tone of hypertonic muscles after the intervention was noted [8]. If there is an improvement in muscle tone in upper and lower extremities and trunk balance, it will improve activities and quality of life.

Brain-derived neurotrophic factor (BDNF), the most abundant neurotrophin within the brain, is important for post-stroke recovery since it promotes neurogenesis and angiogenesis in animals [18, 19]. It is stored and released from glutamatergic neurons in a use-dependent fashion and has been implicated in long-term potentiation, learning, memory formation, depression and recovery from brain injury [20]. Circulating BDNF protein levels are lowered in the acute phase of stroke, and low levels are associated with poor long-term functional outcome [21]. The rise in levels of BDNF

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confirms the process of neurogenesis, angiogenesis, and synaptogenesis or collectively neuroplasticity. As the release of BDNF occurs in use-dependent manner, early rehabilitation in such condition leads to early neurogenesis and hence results in early recovery. One beneficial point of the early rehabilitation is that it also reduces the length of hospital stay and overall expenditure. However, we did not include the expenditure and caregiver burden in our study but it is also a matter of interest. Stroke outcome also depends upon caregiver burden and expenditure on rehabilitation services.

By the intervention of early PNF, we received positive results. There was an early improvement in functional activities that are performed with upper extremity. There was also an improvement in lower extremity tone and trunk balance, but in this study, we have mentioned only upper extremity function.

Previous studies have stated that BDNF levels decrease after stroke [26] and a low BDNF level correlates with poor recovery after stroke [27]. Hence it is very important to implement such rehabilitation strategy that raises BDNF levels.

In our study, group A that underwent PNF intervention showed more improvement in serum BDNF levels than traditional exercises group. Thus it can be postulated that PNF is also effective in promoting neural and synaptic regeneration, though this statement is in its infancy and a study with a large number of patients needs to be done to come to a definite conclusion.

It is believed that high-intensity exercise will increase resting BDNF concentrations. Griffin et al. (2011) investigated the effect of acute and long-term cycling exercise in young adults [22]. They found that cognitive function and BDNF were enhanced through acute exercise, and a transient increase in the motor response BDNF expression level was reported in the long-term aerobic exercise group [23-25].

In our results, there was no significant difference in pain and range of motion scores. As both groups were on rehabilitation of equal time, we did not notice any adverse event like pain, fall or fracture in our study.

PNF exercises use typical patterns and are difficult to implement without practice. Patient's caregivers were not able to implement the exercise in the manner exactly as demonstrated by the practitioner.

Patients from rural areas were difficult to follow-up. Patients with pain in the shoulder joint and restricted range of motion exhibited improvement in range of motion but not in pain.

Conclusion

PNF exercises can improve tone in muscles and hence functional activities if given as early as possible. Delay in the treatment leads to slow improvement. PNF can be recommended in acute stroke if the patient is conscious and oriented. PNF helps inducing voluntary control. The PNF exercises should be given as early as possible after stroke and it shows improvement irrespective of brain area involved, gender and type of stroke.

Acknowledgments

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Conflict of interest: None

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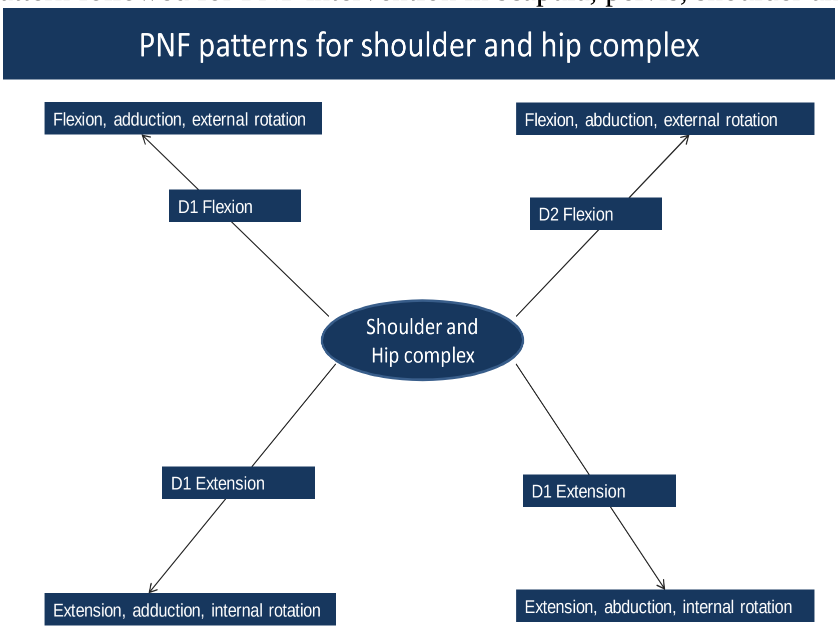
Figure 1 Pattern followed for PNF intervention in scapula, pelvis, shoulder and Hip joint



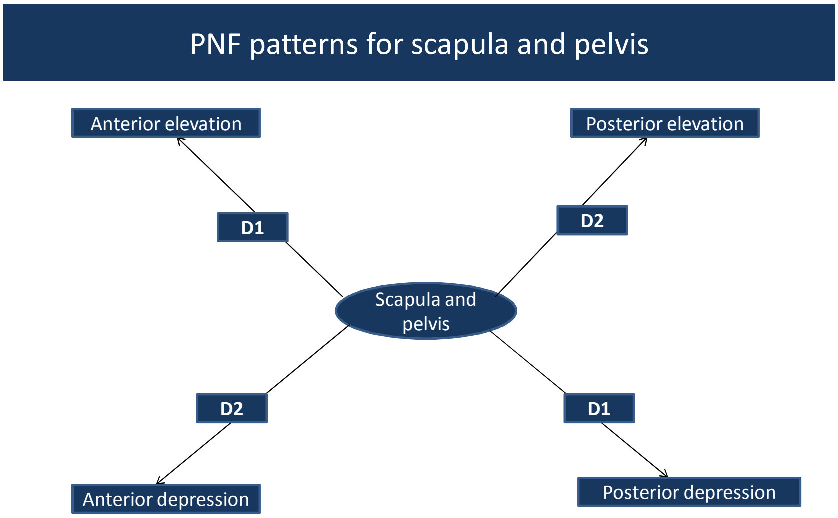


Figure 2 Showing more improvement in Arm Motor Ability Scores in (Experimental) group A and control group (Group B)

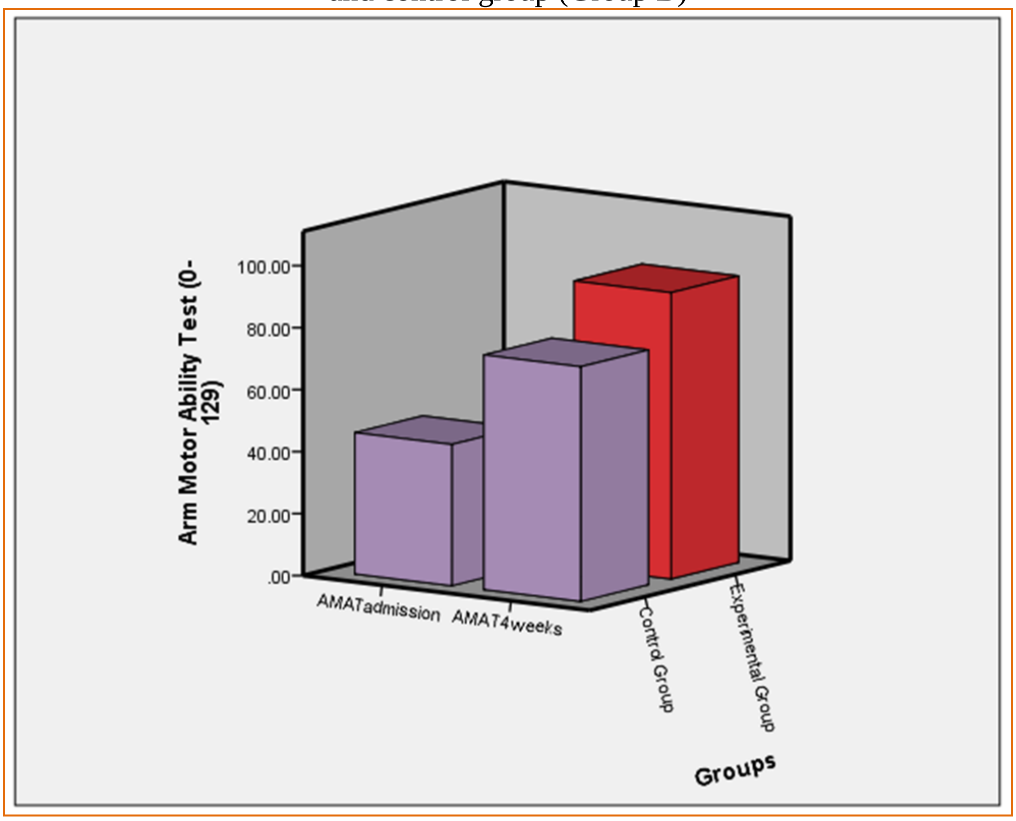


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Figure 3 Showing significant improvement in serum BDNF levels in group A (PNF group)

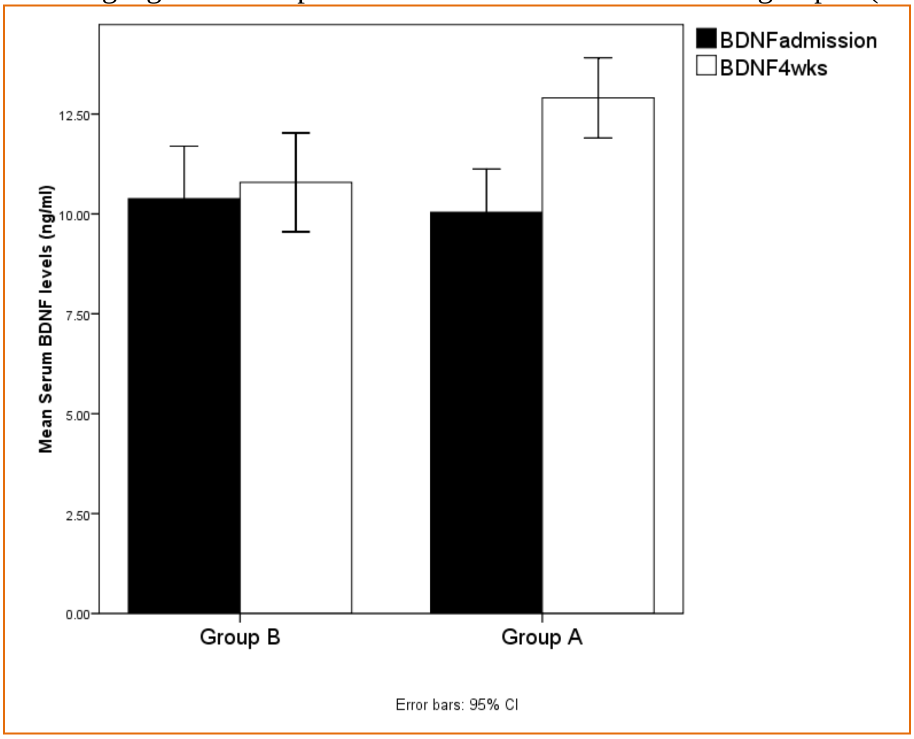

Figure 4 Showing more improvement in upper extremity function (part of Fugl- Meyer Scale) in Group A

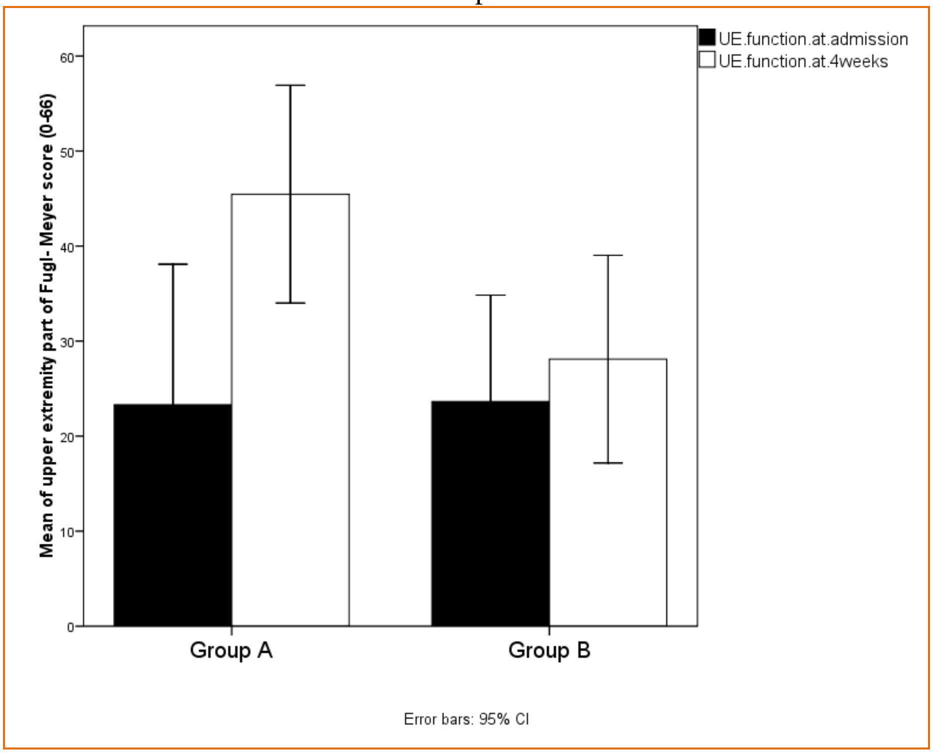

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Figure 5 Showing more improvement in sensory scores (sensory part of Fugl- Meyer scale) in group A

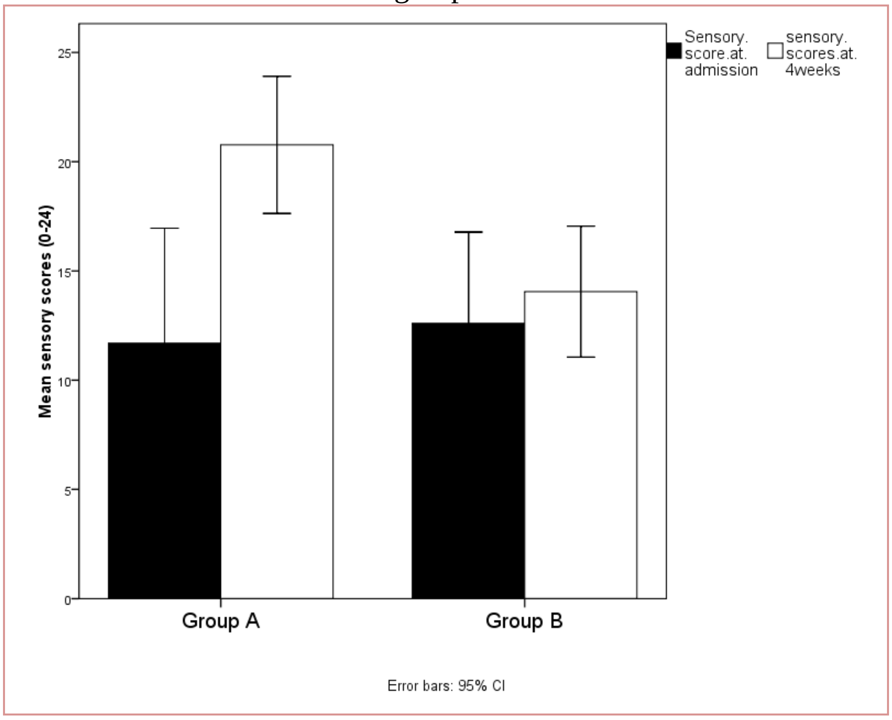

Table1. Baseline Characteristics of subjects of both groups

	Group A (n= 41)	Group B (n= 49)
Gender		
Males/ females	8(20%)	31(63%)
Females	33(80%)	18(37%)
Age (Yrs.)	61.3±13.3	55.29± 15.9
Side affected		
Right	15	20
Left	26	29
Type of stroke		
Ischemic	25	38
Haemorrhagic	16	11
GCS	14.9±.218	14.9±.285
NIHSS	6.53±3.49	6.53±3.79
MMSE	23.26±4.65	23.88±4.96
MRS	3.75±0.560	3.68±0.756

Table2. Showing overall Fugl- Meyer scores and its components for upper extremity and Arm Motor Ability test scores at admission and 4 weeks

Parameter	**Admission (Mean± SD)**		**p-value 95% CI**	**4 weeks (Mean± SD)**		**p-value 95% CI**
	Group A	Group B		Group A	Group B	
Fugl- Meyer Scale (0-226)	124.26±19.98	136.6±21.47	0.221 (-5.28-4.28)	180.73±36.90	153.53±19.25	0.017 (5.18-49.21)
UE function(0-66)	24.45±23.31	23.65± 23.35	0.968 (-17.86-17.18)	45.46±18.95	28.10±23.35	.032 (1.55-33.16)
Sensory (0-24)	11.69±8.71	12.60±8.92	0.775 (-7.33-5.51)	20.77±5.19	12.95±5.28	<.01 (5.00-12.63)
Pain (0-44)	43.0±2.38	43.89±.459	0.119 (-2.03-.242)	43.38±1.50	42.74±5.04	0.658 (-2.30-3.60)
Range of motion (0-44)	43.85± 0.55	44.00± 0.00	0.220 (-.40- .097)	44.00±0.00	43.45±0.65	0.320 (-0.34-.095)
AMAT	38.33±16.04	45.60±19.73	0.432 (-3.21-4.67)	92.40±24.60	75.73±16.40	0.038 (1.02-32.30)
Serum BDNF (ng/ml)	10.04±4.06	10.38±3.99	0.689 (-1.34-2.02)	12.73±3.72	10.85±3.73	0.017 (-3.42- -.343)

UE; Upper Extremity, ROM; Range of Motion, AMAT; Arm Motor Ability Scores, S. BDNF; Serum Brain-Derived Neurotrophic Factor

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Table3. Arm Motor Ability test scores used for assessment of upper extremity function

Task	Time (Max. limit 2 minutes	Functional ability
Pick up utensil		0 1 2 3 4 5
Cut meat		0 1 2 3 4 5
Fork to mouth		0 1 2 3 4 5
Pick up sandwich		0 1 2 3 4 5
Sandwich to mouth		0 1 2 3 4
Pick up spoon		0 1 2 3 4 5
Bean in spoon		0 1 2 3 4
Spoon to mouth		0 1 2 3 4 5
Grasp mug handle		0 1 2 3 4
Mug to mouth		0 1 2 3 4
Pick up comb		0 1 2 3 4
Comb hair		0 1 2 3 4
Grasp jar top		0 1 2 3 4
Open jar		0 1 2 3 4
Tie lace		0 1 2 3 4
Phone to ear		0 1 2 3 4
Press phone		0 1 2 3 4
Wipe up water		0 1 2 3 4 5
Throw away towel		0 1 2 3 4 5
Paretic arm in sleeves		0 1 2 3 4 5
Button to button		0 1 2 3 4 5
Arm in t-shirt		0 1 2 3 4 5
Shirt overhead		0 1 2 3 4 5
Straiten shirt		0 1 2 3 4 5
Prop on external arm		0 1 2 3 4 5
Turn on light		0 1 2 3 4 5
Open door		0 1 2 3 4 5
Close door		0 1 2 3 4 5
Sum (Range)		**129 (0- 129)**

Supplementary material: Figure showing the MRI finding of a patient with stroke. The patient was given PNF exercises and after the intervention of 20 days, he was able to hold a newspaper.

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