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Original Article

Effects of Neuromuscular Electrical Stimulation on Motor Function of Hand in Patients with Chronic Ischemic Stroke: A Randomized Controlled Trial

Anam Raza[1], Momna Asghar[2], Wajeeha Bakhat[3*], Arooj Munawar[2]

[1]Sheikh Zayed Medical College, Lahore, Pakistan. [2]University Institute of Physical Therapy, University of Lahore, Lahore, Pakistan. [3]Gulab Devi Hospital, Lahore, Pakistan.*

ABSTRACT

Background: Stroke is the leading cause of death and disability in many areas of the world. Underdeveloped, developing and developed countries all are showing marked increases in the ratio of stroke patients. Neuromuscular electrical stimulation is used widely for motor rehabilitation of hemiplegic stroke patients worldwide. Application of neuromuscular electrical stimulation on the affected musculature improves action potential and resulting muscle contraction. **Objective:** The objectives of the study were to find out the effects of neuromuscular electrical stimulation on motor function and strength of the hand in hemiplegic ischemic chronic stroke patients. **Methods:** A randomized controlled trial was conducted on chronic stroke patients gathered from Sheikh Zayed Hospital, Rahim Yar Khan. The participants were selected and allocated using the coin toss method. A total of 144 participants were selected and equally distributed into two groups. The sampling technique used was non-probability purposive sampling. Participants included in the study were male and female patients between 40 to 60 years, hemiplegic patients having a single episode of ischemic chronic stroke diagnosed by the neurologist. The Fugl Meyer assessment scale is used for the upper limb while handheld dynamometer is used both for assessment of strength. The normality of data was assessed using the Kolmogorov-Smirnov test. The between-group comparison was done by Mann-Whitney U test. The Wilcoxon rank test was used to see the difference between outcome measures at baseline and after the treatment. **Results:** The results showed that there was a significant difference of ≤ 0.05 between the control group and the interventional group. The mean score of the Fugl Meyer assessment scale at baseline was 7.46 and after four weeks of treatment was 9.90. On the other hand, the handheld dynamometer showed a score of 14. 41 at baseline and 17.74 after four weeks of treatment. These marked differences in results between the two groups showed the significant effects of stimulation on the motor function of the hand in hemiplegic ischemic chronic stroke patients. **Conclusion:** It is concluded from the study that neuromuscular electrical stimulation is very effective in improving the motor function of the hand in chronic stroke patients.

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***Correspondence:** Wajeeha Bakhat Gulab Devi Hospital, Lahore, Pakistan.
Email: wajeehabakhat@gmail.com

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INTRODUCTION

Cerebrovascular accident or CVA, also called stroke is outlined as the sudden and abrupt loss of neurological functioning of the brain caused by a hindrance or cessation of the blood flow to the brain. Stroke can be divided into two types or categories. First and the most prevalent type is ischemic stroke, which affects about 80% of total stroke patients. When a clot hinders or ceases blood flow, causing the brain to lose essential oxygen and nutrients, it leads to ischemic stroke. Hemorrhagic stroke, the second type, occurs when circulatory structures breach, causing dribbling or leakage of blood around the brain or within it. There are many deficits focal in nature that are possible, which include changes in the level of alertness and impairment of motor, sensory, cognitive, language and perceptual functions. Stroke is the dominant cause of impairment and disability in the adult population, affecting an average of more than four million people in the US. Stroke can greatly affect survival, mental level, emotional status, or a combination of these three, and the disability caused by the stroke results in reduced employability and socialization in its survivors. Stroke can be caused by modifiable or unmodifiable risk factors. High blood pressure, obesity, a sedentary lifestyle, smoking, increased blood cholesterol levels, an increased body mass index and alcoholism are risk factors that can be modified.

Age, male gender, ethnicity, family history and habituation are unmodifiable risk factors. Male gender, high blood pressure, age, diabetes mellitus, smoking, high cholesterol especially LDL, high body mass index, physical inactivity, use of alcohol and ethnicity are the major risk factors. Among all these the modifiable risk factor can be and should be avoided. Approximately 90% of stroke patients who have survived have impaired functions. Stroke-suffering patients mostly have dysfunction linked with a reduction in functional capability. Motor impairments are the most prevalent. The most common impairments in stroke include spastic paralysis, loss of equilibrium, weakness and balance on the side that is affected resulting in an inability to maintain postural alignment. To reduce disability and promote independence, rehabilitation has a prominent role. A comprehensive plan of care (POC) is formulated according to the patient's disabilities. For that, a full squad of rehabilitation specialists is needed including the neurologist, physical therapist, physician, nurses, occupational therapist, language and speech therapist, pathologist, nutritionist and social worker. Interventions used in the plan of care are renewing (intended to improve dysfunctions, activity hindrances, and limitation in participation), preventive(to minimize complexities and squint impairments) and compensatory (by altering the task and environment according to individual capacity).

Paralysis of half of the body is seen as one of the most prevalent impairments after stroke and has a direct opposite effect on the ability of a person to walk. Two out of three people go through continuing ambulatory difficulties following a stroke. In people suffering from stroke difficulties in walking are observed mainly because of weakness (paresis) or tone of the limbs and trunk that is not normal, altered sensorimotor systems and mechanism of central control. The 3 gait patterns of patients after stroke are marked as hemiparetic with the more marked sensorimotor dysfunctions being experienced in the opposite upper and lower limbs. Of 11 patients that have survived the stroke, about 80 percent of them, go through hemiparesis which leads to dysfunction of an upper limb soon after the episode of stroke, and about 55% and 75% of stroke survivors go on suffering and experiencing upper extremity functional motor deficits, which are adherent with a reduced quality of life that is related to health issues, even the time has lapsed for 3 to 6 months. Neuromuscular electrical stimulation (NMES) is a rehabilitative approach that is being used to strengthen muscles, strength, maintenance of muscle mass and power during ongoing late duration of immobilization,

individual muscle retraining along with selective, and control of inflammation and edema. Relatively large classes of stimulators, including the burst-modulated A.C ('Russian stimulator'), monophasic twin n spiked pulsed current and pulsed current with biphasic stimulators, have been proven to be used to produce this kind of effect. There are some prior randomized controlled trials with successful results of NMES on motor function when applied to the entire upper limb (arm and hand). This study is focused on the application of NMES only to the hand musculature and not on the rest of the arm to look for its effects. This was less time-consuming and commercially more convenient to address a single part of the limb. Hence, fine and gross motor function and strength of the hand are restored greatly. In this study not only the motor function but also the strength of the hemiplegic hand has been assessed when NMES applied to it. As per my knowledge, there is no prior study dealing with both the Fugl Meyer motor assessment scale and a hand-held dynamometer to assess hand function and strength in stroke patients.

METHOD

About 172 students for this single-blinded randomized controlled trial were recruited with a 95% confidence interval, statistical power of 80% having mean motor function scores of 35.5 and 32, and standard deviation of 7.9 and 6.5 in groups A and B respectively.[2] Participants were randomly allocated into two groups (72 patients per group), having experimental Group A (Neuromuscular electrical stimulation and routine physical therapy) and control group B (routine physical therapy). The sample size was calculated using open EPI software. The calculated sample size using the FMA score as an outcome measure was 72 in each group after adding 20% dropout. Z1-α/2: Level of significance = 95%

$$n = \frac{2\sigma^2(z_{1-\alpha/2} + z_{1-\beta})^2}{(\mu_1 - \mu_2)^2}$$

μ1: Expected mean change in Motor function in Experimental Group = 35.5
μ2: Expected mean change in Motor function in the Control Group = 32.1
δ1: Expected standard deviation in Control group = 7.9
δ2: Expected standard deviation in Experimental group = 6.5
Z1-β: power of the study = 80%
n: Expected sample size in a group = 72

After adding 20% drop out 72+14=86 in each group. This double-blinded randomized control trial was conducted in the University Physical Therapy and Rehabilitation Clinic (UPTRC) UOL, Lahore, Pakistan. The study was completed within 9 months after approval of the synopsis. The trial protocol of this study was approved by the institutional review board of the University of Lahore (IRB-UOL-FAHS/824/2021 and registered prospectively in the clinical trial registry of Iran IRCT20210702051758N1. Participants included in the study were male and female patients between 40 to 60 years, hemiplegic patients having a single episode of ischemic chronic stroke diagnosed by the neurologist. Having stroke for more than 6 months duration with spastic paralysis. Participants with no prior physical therapy session for the issue under study, and Participants should be able to understand and follow simple verbal instructions (Mini-Mental Status Examination [MMSE]≥2.[2] Participants with unstable conditions i.e. recurrent stroke, history of congenital deformities and co-morbidities, presence of contractures in the limb and implanted electrical devices (pacemaker, defibrillator, etc) were excluded from the study.[10] Measuring equipment used was a Couch Stool, Table, NMES apparatus, and Hand-held dynamometer. After giving informed signed consent, participants of the study went through a thorough examination and evaluation for eligibility as explained in the exclusion criteria and inclusion criteria. Both male and female patients were allowed in this study. The age of participants zoned from 40 to

60 years. Patients were selected with ischemic, chronic stroke (>6 months), with hemiparesis and weakness of the hand. Participants were allocated randomly into two study groups i.e., a control group, which received only routine therapy and an experimental group with both NMES and routine therapy. Simple randomization with the coin toss method was used for assignment and randomization was done by one of the research team members.

For both groups, the intervention progresses during the regularly scheduled therapy session. In both groups, training was provided at the physical therapy department during the 1-hour therapy session on 5 consecutive working days of the week, for 4 weeks (20 sessions). In the conventional group, participants went for conventional physical therapy. In the interventional group, after conventional physical therapy, neuromuscular electrical stimulation was applied to the affected limb musculature. To assess the qualification, participants underwent detailed masking and scrutiny. Pretests (t0) were applied after this masking and scrutiny of eligible participants. To evaluate the presenting state of the patient, the Fugal Meyer Assessment scale and handheld dynamometer were used as outcome measures. Participants were assessed at two intervals, namely, baseline and after 4 weeks of treatment. After baseline assessment, eligible participants were at random assigned into groups (control group) and groups (experimental group). The dependent variables in this study were motor function and strength of the hand in ischemic chronic stroke patients. The conventional group received conventional physical therapy for 1 hour. First, a hot pack was applied for 10 minutes on the affected limb. Then ROM exercises were performed. Stretching and isometric exercises followed by ROM exercises. Mobilizations and functional activities were performed later. Finally, the home plan was taught(physio handball, finger wall climbing, door knob rotation, etc.)[11] Interventional groups received conventional physical therapy for 30min.s after the application of NMES for 30min. NMES was applied using a pair of surface electrodes. The indifferent electrode was placed on the upper arm while the active electrode was placed on the muscle bellies of muscles of the dorsum of the hand; i.e. extensors and abductors (hand opening) then the active electrode was moved to the volar aspect of the hand on flexors and adductors (hand closing). Pulsating, biphasic current from a portable electrical stimulator was used with a frequency of 30Hz. After the application of NMES, conventional physical therapy was given to in control group. Data was analyzed using SPSS version 22. The numerical data was presented in the form of mean and standard deviation. While qualitative data like gender in the form frequency. The normality of

RESULTS

Table 1: Demographics of Patients in Both Groups

	Group A (Experimental Group)	Group B (Conventional Group)
Age Groups (Years)		
40-45	17 (23.6%)	22 (30.3%)
46-50	24 (33.3%)	18 (25.0%)
51-55	14 (19.4%)	19 (26.4%)
56-60	17 (23.6%)	13 (18.1%)
Gender		
Male	50 (69.4%)	50 (69.4%)
Female	22 (30.6%)	22 (30.6%)
Hemiplegic Side of Body		
Left	41 (56.9%)	47 (65.27%)
Right	31 (43.1%)	25 (34.72%)
Post-Stroke Duration		
>6months	27 (32.5%)	29 (40.3%)
>8months	18 (25.0%)	20 (27.8%)
>1year	17 (23.6%)	12 (16.7%)
>2years	10 (13.9%)	11 (15.3%)

Figure 1: CONSORT Flow Diagram

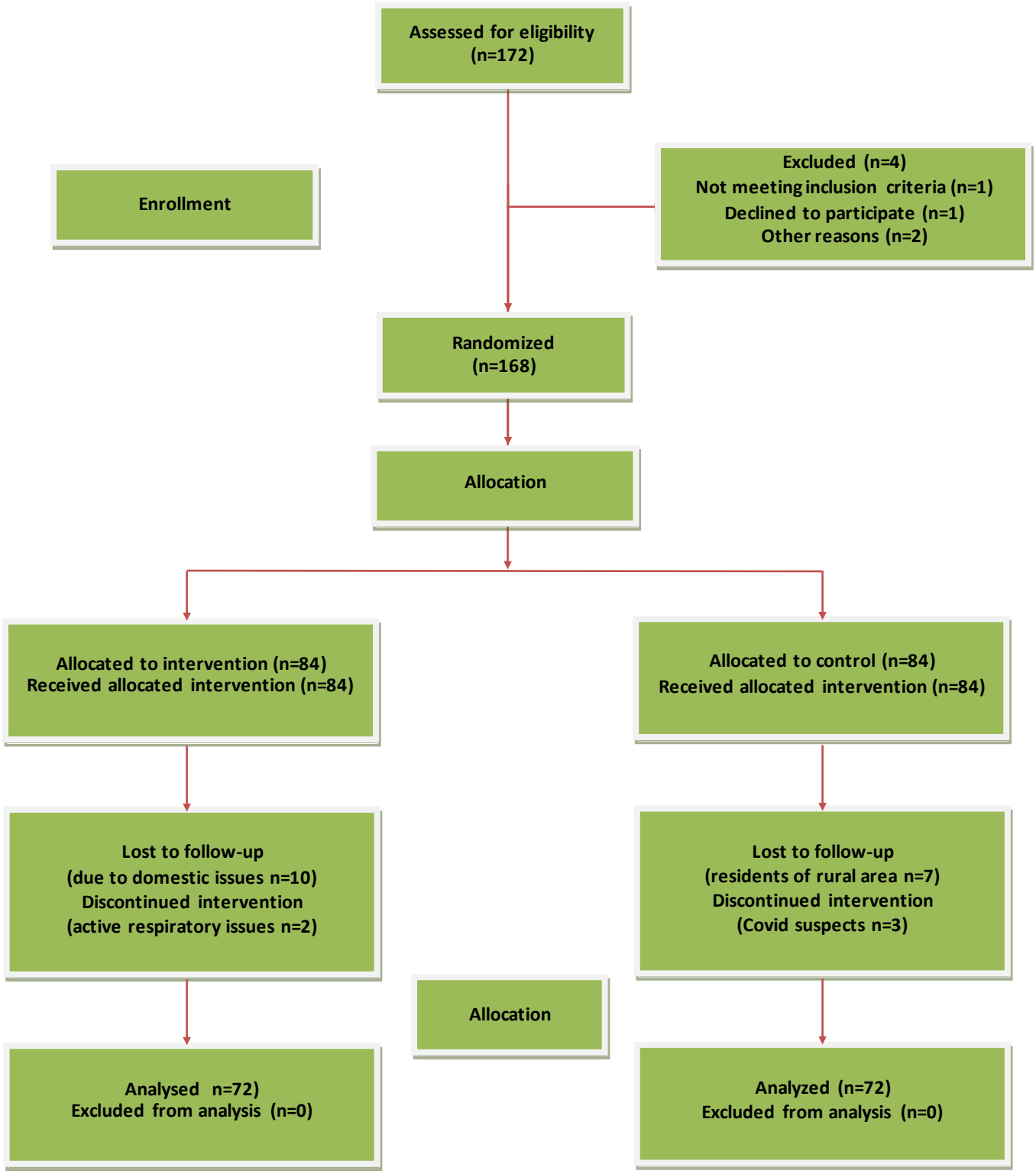

Table 2: Descriptive Statistics Between Groups

	Study Group	Mann-Whitney Test				
		N	S.D	Mean	Mean ranks	P-value
FMA scale at baseline	Group A	72	2.96	7.46	72.47	.994
	Group B	72			72.53	
FMA scale after 4 weeks	Group A	72	3.43	10.47	80.70	.000
	Group B	72			56.30	
Dynamometer at baseline	Group A	72	7.82	14.41	72.49	.997
	Group B	72			72.51	
Dynamometer after 4 weeks	Group A	72	7.76	18.09	83.89	.001
	Group B	72			61.11	

Table 3: Descriptive Statistics Within Groups (Wilcoxon Signed Ranks Tests)

	Groups	N	Mean	Mean ranks	S.D	P-value
FMA baseline	Group A Group B	144	7.46	.00	2.91	.00
FMA after 4 Weeks of treatment	Group A Group B	144	10.47	70.0	3.43	
Dynamometer at baseline	Group A Group B	144	14.41	.00	7.82	.00
Dynamo meter after 4 weeks of treatment	Group A Group B	144	18.09	72.00	7.76	

data was assessed using the Kolmogorov-Smirnov test. The between-group comparison was done by Mann-Whitney U test. The Wilcoxon rank test was used to see the difference between outcome measures at baseline and after the treatment. The p-value of less than and equal to 0.05 was considered significant.

DISCUSSION

Neuromuscular electrical stimulation is a novel modality used for a long period to address motor impairments, especially in stroke patients. Much research has shown improvements in motor function of the affected part of the body when NMES is applied along with routine physical therapy. To check this improvement in motor function and strength of the hand, especially in the upper limb of chronic stroke patients, the Fugl Meyer assessment scale and hand-held dynamometer are used as the gold standard for evaluation. This section is based on the important objective assemblage of the study. The use of Neuromuscular Electrical stimulation (NMES) in stroke patients after more than six months of the event was found to be very

effective in gaining motor function of hemiplegic hand over one month. The strength of the hemiplegic hand was also found to improve largely after the treatment.

The two outcome measures used as tools for assessment were the Fugl Meyer motor assessment (FMA) scale for an upper limb to assess function and the hand-held dynamometer for strength. All the participants of the study were screened and evaluated equally at the start of the treatment session using outcome measures and also carefully measured at the end of the 4-week treatment session. All the participants fulfilled the inclusion criteria described in the study. Owing to the large sample size of 144, Mann-Whitney and Wilcoxon rank tests were used to calculate the results of variables i.e. FMA (Full Meyer motor scale) and handheld dynamometer before the treatment session began and at the end of the therapy session.[12] Results demonstrated a remarkable improvement of hand functioning on the first outcome measure which is the Fugl Meyer motor assessment scale, after 4 weeks of treatment as evident from statistical results. The FMA score of Group A receiving NMES and routine physical therapy was compared before and after the treatment. Spasticity was reduced greatly. This showed the high significance and effectiveness of NMES in improving the motor function of the hand in chronic stroke patients. Both control and experimental groups showed improved motor function but the improvement was more marked in the experimental group in addition to routine physical therapy.[13]

AP Salazar et al., conducted a study in 2019, a meta-analysis, that was later published in the Brazilian Journal of Physical Therapy on improvement in gross motor function of trunk and lower limb musculature in cerebral palsy patients. Six different (RCT) randomized controlled trials summing a sum of 174 patients were conducted. It was obtained that NMES when applied in combination with other therapies as routine physical therapy, provided improved results that showed an improvement in gross motor function. On the contrary, participants receiving only routine physical therapy did not show that much prominent results.[14] A study conducted in 2018 by SJ Park, PS Youn et al, to see the effects of NMES on the strength of back musculature with horse riding in spastic diplegic children. Two groups were divided one of which, the experimental group received both the NMES and horse riding and the placebo group received placebo NMES with horse riding. Each group consisted of 10 participants making the study sample size of 20. both groups received general physical therapy and occupational therapy for 15 minutes each. Then the intervention group underwent 15 min of NMES treatment and 15 minutes of horse riding. The results showed a great improvement in strength of back muscles along with improved gross motor function. It showed that horse riding can improve motor function but when combined with NMES can further enhance the gross and fine motor functioning in spastic diplegic patients.[12] A Boyaci; et al, conducted a study, (RCT) randomized controlled trial to see the comparative effects of passive and active neuromuscular electrical stimulation on the upper extremities of stroke patients.

Almost 31 post-stroke patients meeting the criteria were selected and randomly assigned into three groups. 1st study group received active NMES, 2nd group received passive NMES and 3 group received conventional therapy. Fugl Meyer motor scale, MAL, self-care FIM and some other means were used for assessment. The results showed an improvement in both the 1st and 2nd groups receiving active and passive NMES on outcome measures. Hence, it was concluded that both the active and passive NMES were effective in gaining motor function in hemiplegic upper extremities after stroke.[15] Hence, this historical review of literature about the effectiveness of NMES on motor function is also consistent with the study results under discussion.

CONCLUSION

It is concluded from the results that there is a significant improvement in Fugl Meyer score and also the hand-held dynamometer score in group A patients who received neuromuscular electrical stimulation in addition to routine physical therapy. On the other hand, group B has also shown improvements in both the outcome measures, but the effects are less than those of group A. Hence, neuromuscular electrical stimulation (NMES) when applied with routine physical therapy, is effective in improving motor function and strength of hand in stroke patients.

DECLARATIONS

Consent to participate: Written consent had been taken from patients. All methods were performed following the relevant guidelines and regulations.

Availability of data and materials: Data will be available on request. The corresponding author will submit all dataset files.

Competing interests: None

Funding: No funding source is involved.

Authors' contributions: All authors read and approved the final manuscript.

CONSORT Guidelines: All methods were performed following the relevant guidelines and regulations.

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