Original Article

Neuromuscular Electrical Stimulation for Early Recovery of Motor Control of Ankle along with Spasticity in Stroke Patients A Prospective Randomized Controlled Study

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Abstract

Background and Purpose: Effect of neuromuscular electrical stimulation in acute stroke patients while stimulating only single muscle is not known. The purpose of the study is to find the influence of early neuromuscular electrical stimulation to the motor point of tibialis anterior muscle of the affected limb in achieving early motor control of the ankle with reduction in spasticity in poststroke patients.

Methods: One hundred and thirty-two subjects were selected between 45and 65 years of age and within 2 weeks of the first attack of stroke. They were randomly divided into study and control groups comprising 66 subjects in each group. Study group received neuromuscular electrical stimulation to tibialis anterior muscle of the affected limb, 15 minutes twice daily, 5 days a week up to 3 weeks along with conventional exercise therapy whereas control group received only exercise therapy for that period. Outcome measures include Modified Ashworth Scale for spasticity of ankle plantar flexors, motor power of ankle dorsiflexors and plantar flexors, motor control of ankle joint. They were recorded before starting treatment, after 3 weeks and at 7 weeks following starting the treatment.

Results: Significant improvement of spasticity was noticed after 7 weeks follow-up ($p=0.014$). Significant improvement also noticed in ankle dorsiflexor motor power ($p<0.001$), ankle motor control ($p=0.007$).

Conclusions: Neuromuscular electrical stimulation along with traditional exercise programme is superior to exercise alone for early recovery of ankle motor control, plantar-flexor spasticity and ankle dorsiflexor motor strength.

Key words: **Stroke, spasticity, motor control, neuromuscular electrical stimulation, tibialis anterior.**

Introduction:

Stroke is one of the most debilitating non-communicable diseases. World Health Organisation (WHO) defines stroke as "rapidly developed clinical signs of focal disturbance of cerebral function; lasting more than 24 hours or leading to death, with no apparent cause other than vascular origin"[1].The outcomes of stroke include coma, hemiplegia, hemianaesthesia, hemianopia, dysphagia, aphasia, neglect syndrome, visuospatial deficit,monoplegia,nerveparesis,cognitive dysfunction, memory loss, bladder and bowel dysfunction etc. Of this hemiplegia contributes about 90% of patients[1]. Eighty per cent of poststroke patients have some locomotor function but many have significant gait deficit[4]. Early stage training is more effective for motor recovery and functional recovery is inefficient if interventions start after 5 months of poststroke [3,4].

Neuromuscular electrical stimulation (NMES) is one of the frequently tested modalities in motor recovery of stroke patients. Lieberson and associates described the first single-channel surface peroneal nerve stimulator to provide ankle dorsiflexion during the swing phase of gait for stroke survivors. In the upper limb, its usefulness is well documented. However, we have come across only a few studies where functional electrical stimulation

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was used to influence early motor recovery of the lower limb [2,5-7]. Some studies reported that it has no advantage over conventional therapy[8,9]. Therefore, the role of neuromuscular electrical stimulation for early motor recovery and ambulation in poststroke patient is still a controversy.

After stroke extensor synergy dominates in the lower limb. This results in plantar flexion attitude of ankle, which in turn leads to compensatory circumduction gait, disturbance in balance during standing and walking. Therefore, improvement of ankle dorsiflexor motor control can influence this condition by reducing plantar flexor spasticity, increasing dorsiflexor strength and reducing plantar flexor attitude in both stance and swing phase of gait[10].

NMES can improve neuroplasticity by the following mechanisns;

1. Increase of synaptic efficacy in existing neural circuits or formation of new synapses. This can be explained by as follows;
    a) Electrical stimulation to muscles causes contraction of that particular muscle and leads to movement of joins and the limb. This sends proprioceptive inputs to brain and reinforce network connection patterns through formation of new synapses which ultimately induces cortical reorganisation (studied in monkey).
    b) Electrical stimulation to skin expands cortical representation[2].
2. Another mechanism that helps in early motor recovery is reduction of spasticity. The possible mechanisms are;
    a) Presynaptic inhibition of hyperactive stretch reflexes in spastic muscle.
    b) Direct inhibition of an abnormally excited nerve.
    c) Disinhibition of descending voluntary command to the motor neurons of the paretic muscles ultimately results in decrease in co-contraction of spastic antagonist[6].

Most of the studies for lower limbs were on chronic stroke patients, some stimulated acupuncture points and most of the studies used cunctional electrical stimulation (FES) not neuromuscular single muscle stimulation. Therefore the question arises, can an isolated neuromuscular electrical stimulation of the tibialis anterior muscle influences early recovery motor control of ankle in poststroke patients in terms of decrease in ankle plantar flexor spasticity and increased in dorsiflexors strength with a decreased in antagonistic co-contraction [2,6].

This study was contemplated to find the role of neuromuscular electrical stimulation of the lower limb muscles in early motor recovery in poststroke patients. In many rehabilitation centres, only exercises are advised to stroke patients till now. Electrical stimulation is a simple, affordable and easily available therapeutic modality for stroke recovery with minimum or no adverse effects. Use of neuromuscular electrical stimulation along with exercise therapy can speed up motor recovery in stroke patients. Thus, it improves quality of life of the patients, reduces burden of impairment and disability, increases productivity.

Materials and Methods:

The study was a prospective, randomised controlled study, conducted in the Department of Physical Medicine and Rehabilitation, Regional Institute of Medical Sciences, Imphal, for a period of two years. Ethical committee approval and informed consent from the patients were taken prior to the study. Poststroke patients within 2 weeks of the first acute stroke attack admitted in the Physical Medicine and Rehabilitation Ward for rehabilitation management were taken for the study. Inclusion criteria for the study were confirmed cases of stroke by computerised tomography, independent in daily activities before stroke, having at least some visible voluntary movement in hip, knee and ankle (Medical Research Council Grade-1 and 2), age between 45 and 65years. Exclusion criteria were medically unstable patient, repeated attacks of stroke (>1 attack), patient with flaccid lower limb, unable to walk before stroke due to some other causes, any neuromuscular disease present before stroke,brain stem or cerebellar lesion, patients with cardiac pacemaker,cognitive dysfunction(using mini mental state examination), all types of aphasias. All patients were taken from the medicine ward and because of that only CT scan was taken as the investigation to homogenise all the patients.

Sample size: A sample size of 59 in each group was calculated based on effect size of 20% with 10% early recovery in conventional exercise group at 5% significance level and 80% power. Adding 10% drop out; a final sample of 66 in each group had been considered.

Method of Recruitment:

After getting informed consent, patients were allocated into two groups by using a block randomisation technique. Only the patients were blinded in the study. To minimise uneven distribution of the known variables, stratification of the variables were done.

Study variables - age, sex, aetiology of stroke - ischaemic versus haemorrhagic, paretic side - right versus left, site of lesion in the brain.

Outcome variables:

1. Ankle plantar flexor spasticity (measured by Modified Ashworth Scale).
2. Muscle strength of the muscle around the ankle specially dorsiflexors (measured manually by using Medical Research Council Scale).
3. Motor control of the lower limb specially ability to dorsiflex the ankle while lying and standing independently.

In this study, ankle motor control was classified into three groups. These are as follows:

- Poor-No voluntary ankle dorsiflexion, passive ankle dorsiflexion is full.
- Fair-Voluntary ankle dorsiflexion up to 50% of normal range, passive ankle dorsiflexion is full
- Good-Full range of voluntary ankle dorsiflexion.

A conventional exercise includes neurodevelopmental training, stretching of spastic or tight muscles and maintaining range of motion of joints of the affected part.

Procedure:

The study population was selected after taking informed consent. The study population was divided into study and control groups. The study group received both conventional hemiplegic exercise programme and electrical stimulation to the affected lower limb and the control received only the conventional exercise programme. To the study group, surged Faradic current was delivered to the motor point of tibialis anterior muscle twice a day, 15 minutes each time for 5 days a week up to 3 weeks in resting position.

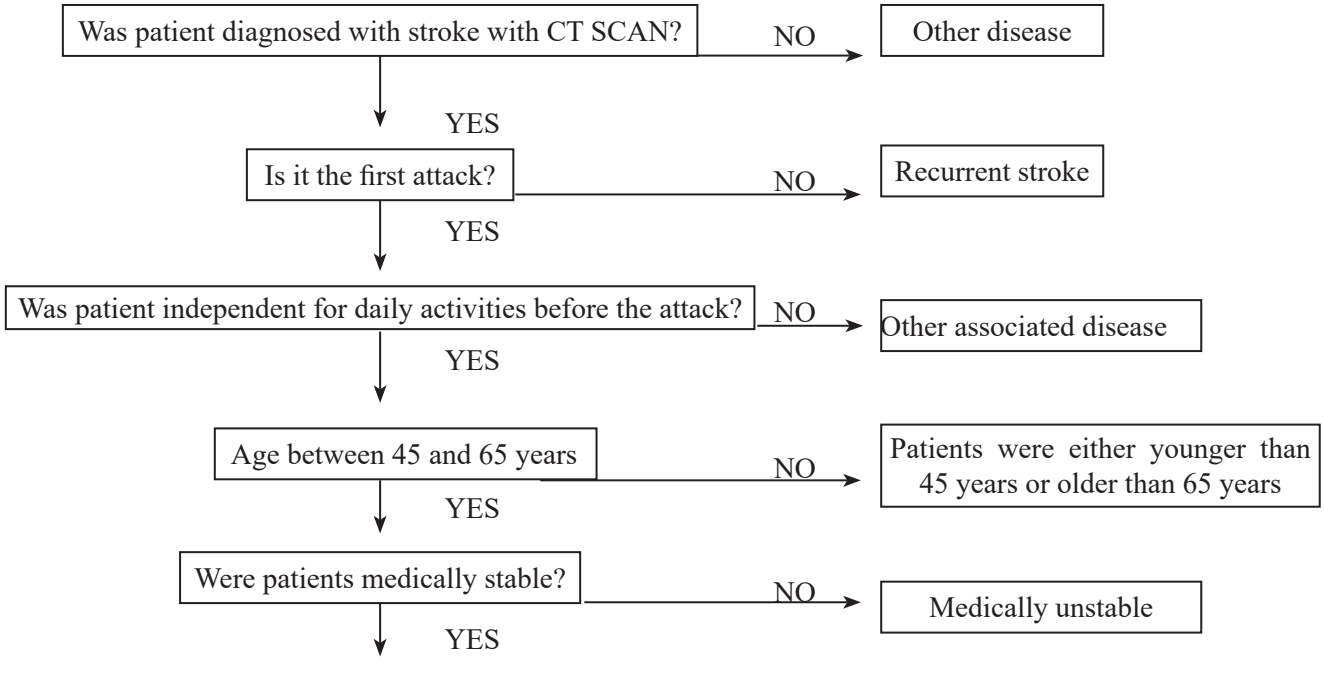
The outcome variables were measured before starting the interventions and at 3 weeks and at 7 weeks of the initiation of the intervention for both the groups.

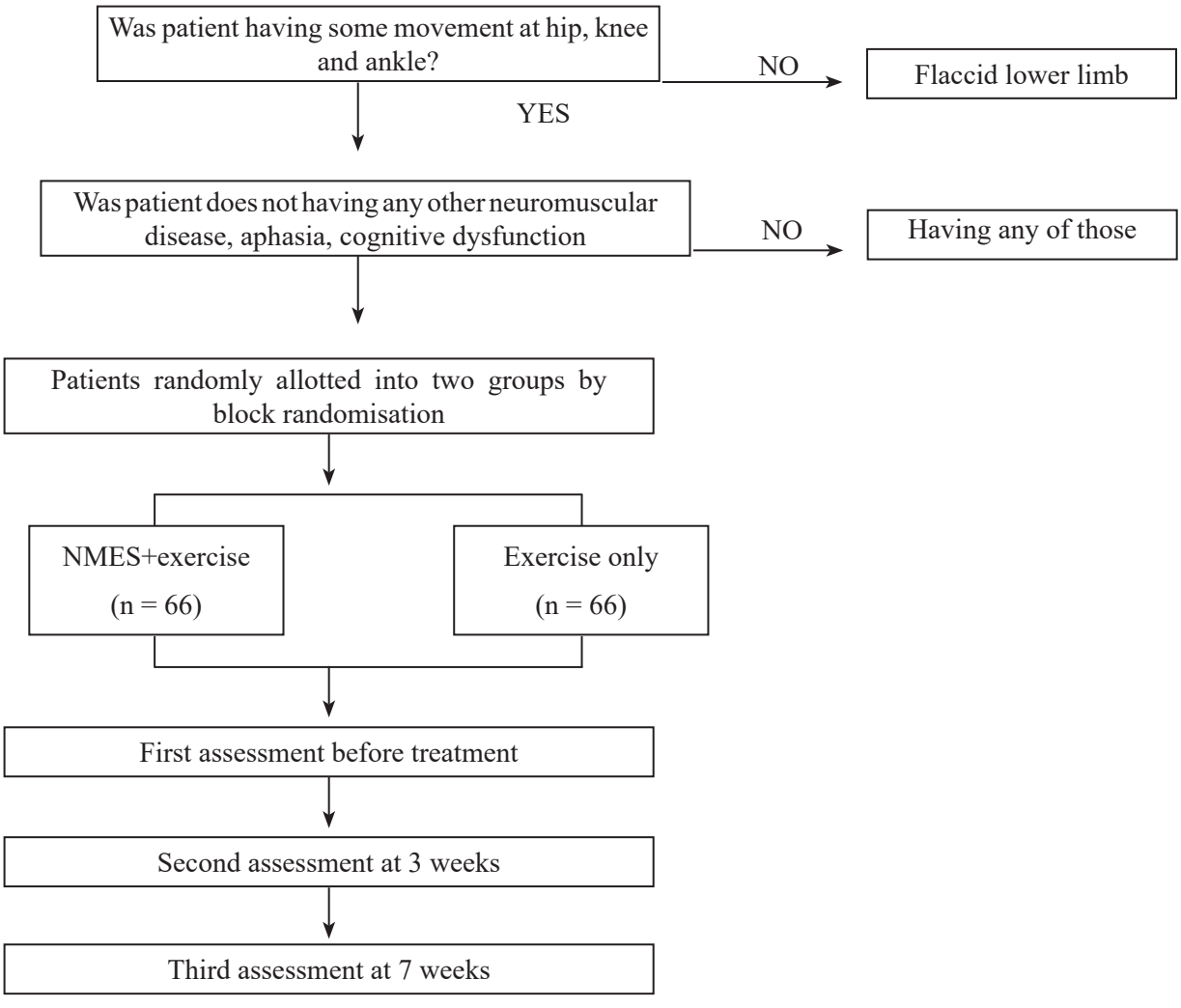
Spasticity of the ankle plantiflexors was measured by using Modified Ashworth Scale.

Strength of ankle dorsiflexors was measured by using manual muscle power grading of the Medical Research Council Scale.

Motor control of the lower limb was measured by ability to voluntarily dorsiflex the ankle while lying and standing.

Results





*Flow chart showing recruitment of cases

There was no difference in baseline characteristics between the study and control group (Table 1). Types of stroke included in the study were ischaemic, haemorrhagic and a combination of both in case of multiple site leision.

Spasticity was compared between the groups before and after therapy using pairedt-test. There was no significant difference at baseline values and no significant difference was found at 3 weeks following therapy (Table 2). But significant improvement was noticed in the study population at 7 weeks (p=0.014).

Ankle dorsiflexor motor power was improved in both the groups but more improvement was noticed in the study group compared to control group (Fig 1). At baseline, there was no significant difference in between the groups (p=0.117). But after 3 weeks and 7 weeks follow-ups, there was significant improvement in ankle dorsiflexion motor power in the study group (p<0.001).

Plantar flexor motor power was improved significantly in both the groups following treatment (Fig 2) but there were no significant difference in improvement between the groups at 3 and 7 weeks (p=0.551 and 0.206 respectively).

Significant improvement of ankle motor control was noticed in both the groups separately (Fig 3). When comparison was done between the groups, significant improvement was noticed in the study group after 3 weeks (p=0.007) and 7 weeks (p=0.007).

Table 1: *Comparison of Baseline Characteristics between Study and Control Groups:*

Variables	No of cases			P- value
	Study (N= 66)	Control (n= 66)		
Age (years)	55.64±6.70	56.89±7.25		0.303
Sex: Male	42	Male	40	0.772
Female	24	Female	26	
Type of stroke: Infarction	44	Infarction	50	0.100
Haemorrhage	18	Haemorrhage	16	
Both	4	Both	0	
Site of affection in brain: MCA	56	MCA	60	0.290
Outside MCA	10	Outside MCA	6	
Baseline spasticity: Gr 0	14	Gr 0	12	0.346
Gr 1	8	Gr 1	20	
Gr 2	30	Gr 2	23	
Gr 3	14	Gr 3	11	
Baseline ankle D/F motor power : Gr 1	41	Gr 1	32	0.117
Gr 2	25	Gr 2	34	
Baseline ankle P/F motor power: Gr 1	6	Gr 1	7	0.240
Gr 2	46	Gr 2	36	
Gr 3	14	Gr 3	23	
Baseline ankle motor control: Poor	52	Poor	45	0.170
Fair	14	Fair	21	

MCA: Middle cerebral artery, D/F: dorsiflexor, P/F: plantarflexor, p< 0.05: significant

Table 2: *Comparison of Spasticity within and between Groups*

Spasticity	Sum of squares	Mean square	Significance
Spasticity at baseline:			0.346
Between Groups	.917		
Within Groups	133.167	0.917	
Total	134.083	1.024	
Spasticity after 3 weeks:			0.515
Between Groups	.371		
Within Groups	113.348	.371	
Total	113.720	872	
Spasticity after 3 weeks:			0.014
Between Groups	3.030		
Within Groups	63.485	3.030	
Total	66.515	.488	

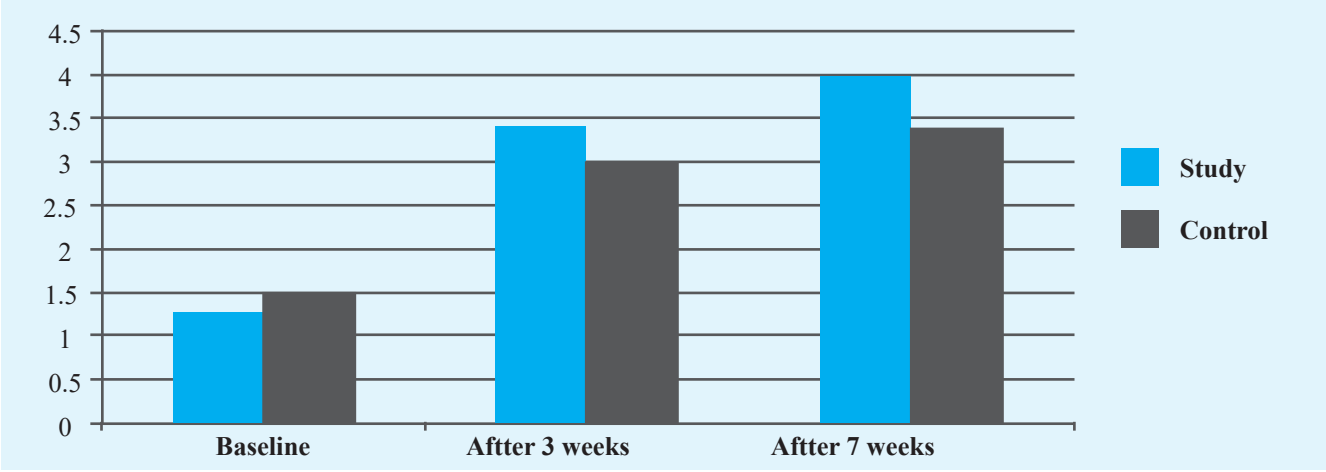


Fig 1- *Comparson of Ankle Dorsiflexor Motor Power at Baseline and afto Intervention*

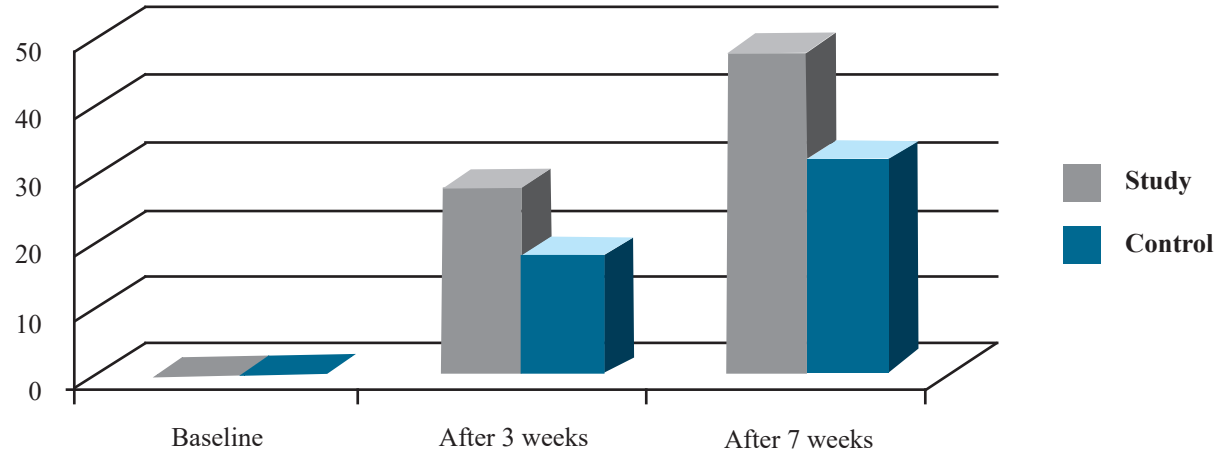


Fig 3- *Showing No of Patients with Good Ankle Motor Control*

Discussion:

This randomised controlled study was performed on 132 patients suffering from hemiplegia due to cerebrovascular accident within 2 weeks of attack. This study showed significant improvement of plantar flexor spasticity following NMES of tibialis anterior muscle of the affected limb in comparison to conventional therapy group. There was also significant improvement of ankle dorsiflexor motor power and ankle motor control in the study group. NMES was well tolerated in patients and there was not any report of any type of adverse effects.

Clinical NMES systems stimulate either the nerve directly or the motor point of the nerve proximal to the neuromuscular junction. The threshold for eliciting a nerve fibre action potential is 100 to 1,000 times less than the threshold for muscle fibre stimulation. The nerve fibre recruitment pattern mediated by NMES follows the principle of "reverse recruitment order" wherein the nerve stimulus threshold is inversely proportional to the diameter of the neuron. It preferentially recruits type II muscle fibres. NMES is delivered as a waveform of electrical current characterised by stimulus frequency, amplitude and pulse width. Frequency range for NMES systems is 10–50 Hz. Ideal stimulation frequencies range from 12–16 Hz for upperlimb applications and 18–25 Hz for lowerlimb applications[11].

Yan *etal*[6] conducted a randomised placebo controlled trial in acute stroke patients to find out the effectiveness of functional electrical stimulation for early motor recovery and walking ability. They stimulated hamstring, quadriceps, tibialis anterior and medial gastrocnemius for 3 weeks. They found positive result in terms of improvement in composite spasticity score, maximum isometric voluntary contraction of ankle dorsiflexors and plantar flexors and walking ability. Our study was also done on acute stroke patients but we applied NMES only in tibialis anterior muscle to gain early motor recovery in ankle joint. We found it quiet impressive in terms of early recovery of ankle motor

control in compared to traditional exercises alone.

Mesci *etal*[12] did a similar study on chronic stroke patients and found neuromuscular than conventional rehabilitation programme for the improvement of ankle dorsiflexor motor power and reducing plantar flexor spasticity. Our study shows similar findings in acute stroke patients.

Sabut *etal*[13] concluded from their study that therapy combining FES and conventional rehabilitation programme was superior to a conventional rehabilitation programme alone, in terms of reducing spasticity, improving dorsiflexor strength and lower extremity motor recovery in stroke patients. In the study they stimulated the tibialis anterior and peroneal nerve whereas, we stimulated the tibialis anterior muscle only to acute stroke patients to get early ankle motor control.

Yavuzer *et al*[8] did a randomised controlled, triple blinded trial with 25 poststroke patients with mean age 55 years and without volitional ankle dorsiflexion. NMES was given to the study group 5 days a week for 4 weeks to tibialis anterior muscle of paretic limb. In this study, NMES was not found superior to conventional rehabilitation therapy. Brunnstrom stages improved significantly in both groups ($p<0.05$). In total, 58% of the NMES group and 61% of the control group gained voluntary ankle dorsiflexion. Between-group difference of percentage change was not significant ($p<0.05$). Gait kinematics was improved in both groups, but the difference between groups was not significant.

In this study, there was significant improvement in both the groups. This can be explained by case selection procedure. We selected cases with ankle dorsiflexor motor power of grades 1 and 2 according to Medical Research Council scale within 2 weeks of stroke attack. Poor prognostic factors are usually not present in our study population resulting in good recovery. This study also shows that early rehabilitation has a great role in stroke recovery. Study limitations are small sample size, less duration of therapy, few assessment tools. Thus, future studies with bigger sample size, longer duration of therapy and with multiple standardised assessment tools to gain unbiased results are recommended.

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