ORIGINAL ARTICLE

Effectiveness of Functional Electrical Stimulation (FES) versus Conventional Electrical Stimulation in Gait Rehabilitation of Patients with Stroke

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ABSTRACT

Objective: To compare the effectiveness of functional electrical stimulation (FES) versus conventional electrical stimulation in gait rehabilitation of patients with stroke for finding the most appropriate problem-oriented treatment for foot drop patients in a shorter time period.

Study Design: Randomized controlled trial.

Place and Duration of Study: Armed Forces Institute of Rehabilitation Medicine, Rawalpindi, from July to December 2016.

Methodology: Subjects with foot drop due to stroke were allotted randomly into 1 of 2 groups receiving standard rehabilitation with Functional Electrical Stimulation (FES) or Electrical Muscle Stimulation (EMS). FES was applied on tibialis anterior 30 minutes/day, five days/week for six weeks. EMS was also applied on the tibialis anterior five days/week for six weeks. Outcome measures included Fugl-Meyer Assessment Scale, Modified Ashworth Scale, Berg Balance Scale (BBS), Time Up and Go Test (TUG) and Gait Dynamic Index (GDI). They were recorded at baseline, after 3 and 6 weeks. Pre- and post-treatment scores were analyzed between two groups on SPSS-20.

Results: After six weeks of intervention, significant improvement was recorded in Fugl-Meyer Assessment score ($p<0.001$), modified Ashworth Scale score ($p=0.027$), Berg Balance Scale score ($p<0.001$), Time Up and Go Test ($p<0.001$) and Gait Dynamic Index ($p=0.012$) of the group subjected to FES.

Conclusion: Gait training with FES is more effective than EMS in improving mobility, balance, gait performance and reducing spasticity in stroke patients. The research will help clinicians to select appropriate treatment of foot drop in stroke patients.

Key Words: *Functional electrical stimulation. Stroke. Foot drop. Rehabilitation.*

INTRODUCTION

Stroke is considered as the main source of disability in adults.[1] It is the second major cause of mortality worldwide.[2] In Pakistan, the stroke incidence is nearly 250 out of 100,000, that is rising to 350,000 new cases annually.[3] Almost 80% of the patients of stroke primarily lost the ability to walk independently.[4] Patients with stroke are at increased risk of fall and loss of mobility due to loss of balance.[5] After stroke, gait plays an important role in functional impairment and its correction is the main goal of rehabilitation.[6]

Functional electrical stimulation (FES) is a device which generates movement in body of people who are paralyzed due to central nervous system injury. Its main objective is to regain voluntary motor functions by developing neuroprostheses. It helps central nervous system to re-learn the execution of impaired functions.[7] Initially, it was applied in the recovery of foot drop after stroke. But now, it is also used to stimulate dorsiflexor and other affected muscles.[8] It provides asynchronous contraction which reduces muscle fatigue.[9] It provides better results when used in the early phase of rehabilitation of gait.

Electrical muscle stimulation (EMS) is a device that produces contraction of muscles through electrical impulses.[10] It is applied through electrodes attached to the skin, and generates electrical impulses similar to action potential generated by the central nervous system.[11] It provides synchronous contraction showing that all motor units are stimulated at the same time.[12] It is used for strength training as it produces muscular as well as neural adaptations.[13] It is used after musculo-skeletal injuries to prevent muscle disuse atrophy.[14]

Some studies have been done in developed countries but no work has been done in developing countries, particularly in our region, to evaluate the effect of FES on mobility, balance and gait performance of stroke patients.

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The aim of this study was to compare the effects of FES with EMS in stroke patients at AFIRM. The study will help to determine which treatment is better in improving dynamic balance and motor recovery in stroke patients and also to determine better treatment for reducing the spasticity of ankle dorsiflexors.

METHODOLOGY

This randomized controlled trial was conducted from July to December 2016 at Armed Forces Institute of Rehabilitation Medicine (AFIRM), Rawalpindi. After approval by the Ethical Committee, informed written consent was taken from all the patients. Patients were assessed for eligibility. Inclusion criteria comprised of sub-acute stroke with foot drop, anterior cerebral artery lesion, either gender, manual muscle test (MMT) of less than 3, age between 20-70 years and well-oriented patients. Patients who were medically unstable and who had fixed plantar-flexor contractures, knee deformity and cognitive impairment were excluded from the study.

Patients were randomly assigned through coining toss to conventional electrical stimulation (EMS) group and functional electrical stimulation (FES) group of 19 each. Treatment was given 5 days/week for 4 to 6 weeks. Conventional group received neuro developmental techniques, physiotherapy and occupational therapy, one hour per day, whereas in interventional group patients received the same exercise therapy and functional electrical stimulation (FES). The measurements were taken at baseline 0 week, after 3 weeks and after 6 weeks.

Trancutaneous FES with frequency 40 Hz in alternating mode, pulse width 7 to 365us, 6 sec ramping, output time 0.2 to 6s, extension time 0 to 1.2s, rising edge ramp time 0 to 2s, falling edge ramp time 0 to 2s was applied for 20-30 minutes on the tibialis muscle of the affected limb. The electrodes were placed over the common peroneal nerve as it passes over the head of fibula and the motor point of tibialis anterior to elicit dorsiflexion and eversion of the foot during the swing phase of walking. Output amplitude was 20 to 10 mA asymmetrical biphasic output and 20 to 80 mA symmetrical biphasic output.

The control group received conventional electrical on the tibialis anterior muscle for 10 min/day, 5 days/ week for 6 weeks. to produce visible contraction. The stimulation frequency applied was 50 Hz with 1 ms pulse duration. The electrodes were placed over the common peroneal nerve as it passes over the head of fibula and the motor point of tibialis anterior to elicit dorsiflexion and eversion of foot.

Outcome measures were Fugl-Meyer Assessment (FMA) Scale, modified Ashworth Scale, Berg Balance Scale (BBS), Time Up and Go Test and Gait Dynamic Index. Pre- and post-treatment scores were analyzed through SPSS-20. Normality test was applied on all the scales. The value of Shapiro-Wilk significance for Baseline Fugl-Meyer Assessment Scale was 0.113, Time Up and Go Test was 0.073 and Berg Balance Scale was 0.108. As these values were greater than 0.05, therefore, Independent t-test was applied. Whereas, the Shapiro-Wilk significance value for Baseline modified Ashworth Scale was 0.001 and for Gait Dynamic Index was 0.006. As these values were less than 0.05, therefore, Mann-Whitney Test was applied.

RESULTS

The data at baseline for Fugl-Meyer Assessment Scale, Time Up & Go Test and Berg Balance Scale was normally distributed.

Table I shows that at baseline there was no variation in these groups. But after intervention, p-value was less than 0.05 for all these tests showing significant difference between these groups.

The baseline modified Ashworth Scale was not normally distributed (Table II).

Before intervention, p-value was greater than 0.05 which means there was no difference at baseline in these groups. But after intervention, p-value was less than 0.05 demonstrating significant difference between these groups. Similar trend was found for Gait Dynamic Index (Table III).

Table I: Baseline data of the studied group for Fugl-Meyer scale, Time Up and Go and Berg Balance scale.

Variables	Intervention group Mean ± SD	Control group Mean ± SD	P-value
Fugl Meyer Scale 0	12.26 ±1.56	12.31 ±2.10	0.931
Fugl Meyer Scale 3	15.95 ±1.78	13.74 ±2.23	0.002
Fugl Meyer Scale 6	22.42 ±2.89	15.36 ±2.52	<0.001
Time up and go 0	35.42 ±12.98	36.37 ±13.76	0.828
Time up and go 3	26.63 ±9.80	35.21 ±13.27	0.030
Time up and go 6	17.00 ±5.81	33.00 ±12.74	<0.001
Berg Balance Scale 0	25.35 ±7.5	25.58 ±7.06	0.912
Berg Balance Scale 3	34.16 ±5.14	27.05 ±6.88	0.001
Berg Balance Scale 6	47.63 ±2.77	29.42 ±6.5	<0.001

Table II: Modified Ashworth Scale of the studied groups.

Variable	Intervention group Mean rank	Control group Mean rank	Z value	P value
Ashworth Scale 0	19.55	19.45	0.034	0.977
Ashworth Scale 3	18.24	20.76	0.805	0.488
Ashworth Scale 6	15.53	23.47	2.966	0.027

Table III: Changes in Gait Dynamic Index.

Variable	Intervention group Mean rank	Control group Mean rank	Z value	P value
Gait Dynamic Index 0	17.95	21.05	0.087	0.402
Gait Dynamic Index 3	20.29	18.71	0.442	0.665
Gait Dynamic Index 6	23.97	15.03	2.50	0.012

DISCUSSION

Previous RCT studies examined the effects of FES on chronic stage of stroke and used multi-channel electrodes. Whereas, the present study examine the effects of FES on sub-acute stage of stroke and used single-channel electrode. Treatment period was not standardized in previous studies. No study observed the effects of FES for a prolonged duration.

The study concludes that gait training with functional electrical stimulation positively affects motor recovery, mobility performance and balance in comparison with gait training with conventional electrical stimulation. FES works on coordination as well as spasticity.[15,16] Whereas, conventional electrical stimulation works on strength and bulk. It may increase spasticity because it produces synchronous contractions.[17,18] FMA score showed beneficial effects after 3 and 6 weeks of treatment. Improvement in static and dynamic balance and reduction in fall risk is seen after treatment measured by Berg Balance scale, Gait Dynamic Index and Time Up and Go Test. Significant reduction in spasticity was seen measured by modified Ashworth scale. So, it was concluded that gait training with FES was better as compared to gait training with conventional electrical stimulation.

The findings of present study confirm the results of an earlier study conducted by Tiebin *et al*. They studied 46 patients on whom FES was applied 30 minutes/day for 3 weeks and found reduction in spasticity measured by composite spasticity scale.[19] A previous study compared the effects of neuromuscular electrical stimulation (NMES) on tibialis anterior applied for 10 minutes, 5 days/week for 4 weeks with conventional gait rehabilitation. It showed brunnstrom stages and gait kinematics improved equally in both groups and there was no difference between these groups.[20] The current study finds significant improvement in FMA, BBS and TUG score after six weeks of treatment. The findings of this study fairly consistent with previous study in literature which reports significant improvement in FMA, BBS and 10 meter walking test after 3 weeks of FES treatment.[21] A meta-analysis also supports that FES is more effective than transcutaneous electrical nerve stimulation (TENS) in improving gait speed in post-stroke patients.[22] A meta-analysis was done by Cinara *et al*. reported NMES is effective in reducing spasticity and improving range of motion after stroke.[23] Eun Jo compared the effects of core muscle strengthening with NMES. The results showed that the group receiving core muscle strengthening along with NMES showed better results in improving trunk balance.[24] Nunes observed that NMES sessions once weekly or twice weekly up to seven weeks both are effective in improving range of motion, muscle strength and gross motor function among spastic hemiparetic children.[18]

There are certain limitations to the generalizations of this study results. Sample size was very small because of time constraint and study was done only in one rehabilitation centre. The study observed the effects of electrical stimulation only on one muscle. These results, therefore, need to be validated through studies designed to overcome these flaws.

CONCLUSION

Gait training with FES is more effective than conventional electrical stimulation in foot drop of stroke patients.

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