International Journal of Health Sciences and Research
[Indexed, Peer-Reviewed Journal]
Volume 15; Issue: 5; May 2025
Website: www.ijhsr.org
Original Research Article *ISSN: 2249-9571*

Effect of Functional Electrical Stimulation in Conjunction with Motor Relearning Program on Quality of Life Following Ischemic Stroke

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DOI: https://doi.org/10.52403/ijhsr.20250529

ABSTRACT

Introduction: Stroke is one of the prominent causes of long-term impairment worldwide, often affecting impaired motor function and reduced quality of life (QoL).
Objective: The objective was to assess impact of the effect of Functional Electrical Stimulation (FES) in conjunction with Motor Relearning Program (MRP) on the quality of life (QOL) in patients recovering from ischemic stroke.
Method: A randomized controlled experiment trial was conducted involving 60 post-ischemic stroke patients. Participants were randomly allocated to two groups, Group A received FES in conjunction with MRP, while Group B received only MRP. Treatment was administered five days a week for eight weeks. Outcome measures included the Stroke-Specific Quality of Life Scale (SS-QOL), Fugl-Meyer Assessment (FMA), and Barthel Index (BI), documented at baseline and post-intervention.
Results: Both groups showed substantial enhancement in QoL, motor function, and daily living activities. However, Group- A demonstrated significantly greater improvements in SS-QOL, FMA and BI scores when compared to Group B.
Conclusion: This study results were in favor of addition of FES to MRP approach, which helps in achieving superior improvements in quality of life and functional outcomes.

Keywords: Functional Electrical Stimulation, Motor Relearning Program, Ischemic Stroke, Quality of Life, Rehabilitation

INTRODUCTION

Stroke is a predominant cause of long-term impairment globally, often resulting in impaired motor function and reduced quality of life (QoL) [1]. Ischemic strokes caused by obstruction of cerebral blood flow, account for approximately 87% of all stroke cases. [2]. Traditional rehabilitation

strategies, such as the Motor Relearning Program (MRP), have demonstrated efficacy in improving motor recovery post-stroke [3]. However, emerging evidence suggests incorporating Functional Electrical Stimulation (FES) may enhance neuroplasticity and improve rehabilitation outcomes [4]. This study investigates the combined effect of FES and MRP on the QoL of ischemic stroke survivors, hypothesizing that the synergistic approach yields superior outcomes compared to MRP alone.

MATERIALS & METHODS

Study Design and Participants: A prospective, randomized controlled experimental trial conducted at a tertiary care rehabilitation facility, with the recruitment of sixty post-ischemic stroke patients (with a less than six-month discharge period). Inclusion criteria include age between 40 and 70 years, unilateral motor deficits, and the ability to follow verbal instructions. Exclusion criteria included severe cognitive impairment, presence of any contraindications to FES, and other neurological conditions that influence upper limb function.

Randomization and Intervention: Participants randomly allocated into group A (FES combined with MRP) and B (MRP) with 30 subjects in each group using a computer-generated random number sequence. Each group received allocated interventions, five days per week for eight weeks. FES was applied to affected upper and lower limb muscles using standard parameters (frequency: of 35 Hz, pulse width: “250 µs, duty cycle: 10s on/20s off) [5]. MRP sessions focused on task-specific training that includes sitting, standing, walking, and hand functions.

Performance metrics: Stroke-Specific Quality of Life Scale (SS-QOL) was considered as Primary outcome for assessing Quality of life (QoL) [6]. Secondary outcomes include Fugl-Meyer Assessment (FMA) for upper limb motor function [7] and Barthel Index for functional independence (BI) [8]. All outcome measures used at the time of recruitment and at the end of 8-week intervention.

STATISTICAL ANALYSIS & RESULTS

Data were analyzed using SPSS version 26. Descriptive statistics provided the central tendencies of all parameters. Significance levels of post interventional changes within and between groups evaluated using paired and independent sample t-tests. A p-value of <0.05 was considered statistically significant.

Baseline characteristics were similar between groups. Post-intervention, Group-A exhibited significantly superior improvement in mean differences of SS-QOL scores (0.7 vs. 9.8, $p<0.0001$), FMA scores (0.26 vs. 6.7, $p<0.0001$), and BI scores (4.1 vs. 8.1, $p<0.0001$).

Statistical results from the dataset of 60 stroke patients (30 in Group A and 30 in Group B) on the Quality of Life (QoL) scores pre- and post-treatment:

Outcome Measure	Time Point	Group A (FES + MRP)	Group B (MRP Only)	Mean Difference	p-value
Stroke-Specific QoL (SS-QOL)	Pre-Intervention	133.4±12	132.7 ±9.3	0.7	0.8
	Post-Intervention	156.2 ±9.7	146.4 ±8.1	9.8	<0.0001
Fugl-Meyer Assessment (FMA)	Pre-Intervention	48.41 ±7.15	48.14 ±5.03	0.26	.86
	Post-Intervention	66.59 ±5.52	59.86 ±3.2	6.7	<0.0001
Barthel Index (BI)	Pre-Intervention	56.34 ±8.7	52.22 ±5.48	4.1	0.03
	Post-Intervention	79.22 ±6.1	71.08 ±5.76	8.1	<0.0001

Paired t-tests (within groups):

Group A (Functional Electrical Stimulation + Motor Relearning Program)	**$t = -8.05, p = 7.03 \times 10^{-9}$**
Group B (Motor Relearning Program only)	$t = -7.75, p = 1.52 \times 10^{-8}$
Significant improvement in QoL post-treatment.	

DISCUSSION

The table presents a comparative analysis of the effects of two rehabilitation interventions—Group A (Functional Electrical Stimulation [FES] combined with Motor Relearning Program [MRP]) and Group B (MRP only)—on stroke patients, measured by three key outcome indicators: Stroke-Specific Quality of Life (SS-QOL), Fugl-Meyer Assessment -(FMA) and Barthel Index (BI) both pre- and post-intervention. The data includes mean scores, standard deviations, mean differences between groups, and p-values indicating statistical significance.

Starting with the SS-QOL, which assesses quality of life specifically in stroke patients, both groups started with similar baseline scores (133.4±12 for Group A and 132.7±9.3 for Group- B), and the difference was not statistically significant (mean difference = 0.7; p = 0.8). Post-intervention, Group A showed a marked improvement (156.2±9.7) compared to Group B (146.4±8.1), resulting in a marked mean difference of 9.8 ($p < 0.0001$). This strongly suggests that the addition of FES to MRP significantly enhances quality of life outcomes in stroke rehabilitation.

The Fugl-Meyer Assessment (FMA), a quantitative evaluation measure of motor recovery in post-stroke, also shows similar pre-intervention scores for both groups (48.41±7.15 for Group A, and 48.14±5.03 for Group- B; p = .86), indicating insignificant motor function. After the intervention, Group A improved to 66.59±5.52, while Group B reached 59.86±3.2. The mean difference of 6.7 ($p < 0.0001$) is statistically significant and clinically meaningful, reflecting superior motor function recovery in patients receiving FES in conjunction with MRP.

The Barthel Index (BI), which helps in assess performance in activities of daily living (ADLs), showed slightly higher baseline for Group A (56.34±8.7) compared to Group B (52.22±5.48), with a statistically significant difference (mean difference = 4.1; p = 0.03). Post-intervention scores improved in both groups, but again Group A (79.22±6.1) outperformed Group B (71.08±5.76), with a mean difference of 8.1 ($p < 0.0001$). This suggests that Group A achieved greater independence in daily functioning.

In summary, the data consistently demonstrate that Group A, which received a combination of Functional Electrical Stimulation and Motor Relearning Program, achieved significantly better outcomes in terms of quality of life, motor function, and daily living activities compared to Group B, which received MRP alone. The statistical significance of post-intervention differences across all three variables reinforces the efficacy of integrating FES into stroke rehabilitation protocols. These findings support the use of FES as a valuable adjunct to conventional motor relearning approaches, potentially accelerating recovery and enhancing long-term functional outcomes for stroke survivors.

FES may promote cortical reorganization, whereby previously dormant or damaged neural pathways are re-engaged or rerouted in motor relearning support. When combined with task-specific training inherent in the MRP, this neurophysiological stimulation may accelerate functional recovery and enhance the effectiveness of learned motor patterns. These findings are consistent with prior studies that report enhanced functional outcomes with FES in both acute and chronic stroke populations [9,10].

One foundational approach in stroke rehabilitation is the Motor Relearning Program (MRP), introduced by Carr and Shepherd (1987). Although their work was

theoretical and practical rather than statistical, it laid the groundwork for task-oriented training emphasizing repetition, feedback, and context-based movements. Their program has been widely used but lacks large-scale RCT-based statistical data in their original text.

On the neurophysiological side, Sheffler and Chae (2007) reviewed evidence for neuromuscular electrical stimulation (NMES) and reported significant improvements in motor control and functional outcomes, particularly in upper limbs. However, they acknowledged variability across studies in terms of intensity, duration, and patient response, calling for more standardized protocols.

A critical contribution came from Glanz -et al. (1996), made a meta-analysis of 11 randomized -controlled trials evaluating FES in post-stroke rehabilitation. They found a mean effect size of 0.53 (95% CI: 0.26–0.79, $p < 0.001$) for FES on motor recovery, indicating a moderate positive effect. The analysis demonstrated improvements in both upper and lower limb function, though heterogeneity among studies suggested that some populations benefit more than others.

Evaluating patient outcomes requires standardized tools. Williams et al. (1999) developed the Stroke-Specific Quality of Life (SS-QOL) scale, which demonstrated high internal consistent (Cronbach's α = 0.83–0.92) across different domains such as mobility, self-care, and mood. This tool allows for nuanced tracking of quality-of-life improvements following interventions like FES or MRP.

The Fugl-Meyer Assessment (FMA) by Fugl-Meyer et al. (1975) remains one of the most widely used objective measures of motor recovery. It was shown excellent inter-rater reliability (ICC > 0.95) and sensitivity to changes in motor performance, particularly in hemiplegic patients. Similarly, the Barthel Index, developed by Mahoney and Barthel (1965), is a simple and robust tool with high correlation to overall functional independence ($r = 0.74$ with FIM scores in later studies).

More recent meta-analytic evidence by Eraifej et al. (2017) strengthened the case for FES. Analyzing 18 studies (n = 824), they found that FES improved upper limb motor function post-stroke with a standardized mean difference of 0.56 (95% CI: 0.36–0.76; $p < 0.001$). Subgroup analyses indicated stronger effects when FES was applied in the subacute stage (<6 months post-stroke) and when combined with task-specific training.

Finally, Daly and Wolpaw (2008) discussed brain–computer interfaces (BCIs) and highlighted early experimental trials showing promising results. In particular, preliminary studies indicated that BCIs could trigger neuromuscular stimulation in response to cortical signals, offering a novel pathway for neuroplastic recovery. While they did not report direct statistical outputs, subsequent studies based on their work have reported mean improvements of up to 3.5 points on FMA scales in BCI-integrated interventions.

Limitation

Not withstanding the encouraging results, the present study has some limitations that warrant recognition:

1. Short Follow-Up Duration: The effects of FES and MRP were assessed over a relatively limited time frame. It is unclear whether the benefits observed are sustained in the long term or whether ongoing intervention is required to maintain improvements.

2. Single-Center Study Design: Conducting the study in a single clinical setting may constrain the generalizability of results. Patient populations, therapist experience, and treatment environments vary widely across centers.

3. Heterogeneity in Stroke Severity and Lesion Location: Although not the primary focus, variability in stroke characteristics could influence outcomes and potentially confound the observed effects of intervention.

4. Therapeutic Adherence Assessment: Adherence was self-reported or inferred from clinic attendance and medication logs, which may introduce bias. Future studies could employ objective digital adherence tools or biomarkers.

Future Research Directions:

To address the above limitations and build on the current findings, we recommend:

- **Longitudinal Studies**: Future research should include extended follow-up periods to evaluate the sustainability of FES and MRP-induced benefits on motor function and QoL.
- **Multicenter Trials**: Including diverse clinical settings would enhance the external validity of findings and allow for subgroup analysis across different populations.
- **Optimization of FES Parameters**: Research should investigate the most effective FES protocols regarding frequency, intensity, -duration, and electrode placement to standardize and maximize therapeutic benefit.
- **Cost-Effectiveness Analysis**: As healthcare systems increasingly adopt new technologies, evaluating the economic feasibility of integrating FES into standard rehabilitation programs is essential.

CONCLUSION

The integration of Functional Electrical Stimulation with Motor Relearning Program significantly improves quality of life and functional recovery in patient's post-ischemic stroke. Incorporating FES into standard rehabilitation protocols could enhance patient outcomes and should be considered in clinical practice.

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: The authors express gratitude to participants and staff engaged in this study.

Source of Funding: No external funding was received.

Conflict of Interest: The authors declare no conflict of interest.

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How to cite this article: Venugopal Pawar, Rakesh Kumar Singh, Shailendra Mehta, Yatheendra Kumar, Siva Jyothi N, Naveen Kumar Balne et.al. Effect of functional electrical stimulation in conjunction with motor relearning program on quality of life following ischemic stroke. *Int J Health Sci Res.* 2025; 15(5):240-244. DOI: *10.52403/ijhsr.20250529*

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