Effectiveness of combined electrical stimulation therapy and range of motion exercise on physical health status of patients with cerebrovascular accidents

Eficacia de la terapia combinada de estimulación eléctrica y ejercicios de rango de movimiento en el estado de salud física de pacientes con accidentes cerebrovasculares

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Abstract

Introduction: Stroke is a leading cause of long-term disability worldwide, and rehabilitation strategies remain essential to optimize recovery. Electrical stimulation has been increasingly used alongside with exercise to enhance motor function and functional independence.
Objective: This study aimed to evaluate the impact of combining electrical stimulation with range of motion (ROM) exercises on health-related outcomes among stroke patients compared with ROM exercises alone.
Methods: A total of 100 stroke patients were recruited and randomly assigned into two equal groups: one received electrical stimulation combined with ROM exercises, while the other performed ROM exercises only. Functional outcomes were assessed across upper and lower limb joint movements, balance, swallowing, facial control, and cognitive orientation at three time points.
Results: The combined therapy group demonstrated significantly greater improvements in motor recovery, joint mobility, postural balance, and functional independence compared to the ROM-only group. Additionally, faster recovery was observed in swallowing function, facial symmetry, and memory orientation among patients receiving combined therapy.
Conclusion: Electrical stimulation combined with ROM exercises provides superior benefits over ROM exercises alone in stroke rehabilitation. These findings support its integration into physiotherapy practice to enhance neuroplasticity, accelerate functional recovery, and promote independence in daily life. Further large-scale and long-term studies are recommended to confirm these outcomes.

Keywords

Stroke rehabilitation; electrical stimulation; range of motion exercise; physiotherapy; functional recovery; neuroplasticity; motor function; cerebrovascular accident.

Resumen

Introducción: El ictus es una de las principales causas de discapacidad a largo plazo en todo el mundo, y las estrategias de rehabilitación siguen siendo esenciales para optimizar la recuperación. La electroestimulación se ha utilizado cada vez más junto con la fisioterapia convencional para mejorar la función motora y la independencia funcional.
Objetivo: Este estudio tuvo como objetivo evaluar el impacto de la combinación de electroestimulación con ejercicios de rango de movimiento (ROM) en los resultados relacionados con la salud de pacientes con ictus, en comparación con la realización de ejercicios de ROM únicamente.
Métodos: Se reclutó a un total de 100 pacientes con ictus y se asignaron aleatoriamente a dos grupos iguales: uno recibió electroestimulación combinada con ejercicios de ROM, mientras que el otro realizó únicamente ejercicios de ROM. Se evaluaron los resultados funcionales en los movimientos articulares de las extremidades superiores e inferiores, el equilibrio, la deglución, el control facial y la orientación cognitiva en tres momentos de evaluación.
Resultados: El grupo de terapia combinada demostró mejoras significativamente mayores en la recuperación motora, la movilidad articular, el equilibrio postural y la independencia funcional, en comparación con el grupo que solo recibió ROM. Además, se observó una recuperación más rápida de la deglución, la simetría facial y la orientación de la memoria en los pacientes que recibieron terapia combinada.
Conclusión: La electroestimulación combinada con ejercicios de ROM ofrece beneficios superiores a los ejercicios de ROM solos en la rehabilitación del ictus. Estos hallazgos respaldan su integración en la práctica fisioterapéutica para mejorar la neuroplasticidad, acelerar la recuperación funcional y promover la independencia en la vida diaria. Se recomiendan estudios adicionales a gran escala y a largo plazo para confirmar estos resultados.

Palabras clave

Rehabilitación del ictus; estimulación eléctrica; ejercicios de rango de movimiento; fisioterapia; recuperación funcional; neuroplasticidad; función motora; accidente cerebrovascular.

Introduction

Stroke, also known as cerebrovascular accident (CVA) or brain attack, is a leading global health challenge and remains one of the main causes of death worldwide (Hadi et al., 2025; Reddy et al., 2024; Mamikov et al.,2025, Meshal et al.,2025). It is defined as a sudden disruption of blood supply to the brain, resulting in acute focal neurological deficits caused by vascular injury (Hinkle et al., 2021; Werring et al., 2024).

Stroke is classified into two major types: ischemic, caused by reduced or blocked cerebral blood flow leading to neuronal death within minutes, and hemorrhagic, caused by rupture of a cerebral vessel leading to intracranial bleeding (Zhao et al., 2021).

Pathophysiology of Ischemic Stroke: Thrombosis obstructs cerebral blood flow to the affected brain region (Markus et al., 2022).

Pathophysiology of Hemorrhagic Stroke: The hematoma disrupts neurons and glia. This results in oligemia, neurotransmitter release, mitochondrial dysfunction, and cellular swelling; thrombin activates microglia and causes inflammation and edema (Magid-Bernstein et al., 2022). The primary injury results from the compression of brain tissue by the hematoma and an increase in intracranial pressure (ICP) (Zhang et al., 2023). Secondary injury results from inflammation (Unnithan et al., 2023).

Clinical Manifestations

Clinical manifestations of cerebrovascular accident present with sudden neurological deficits such as weakness or numbness of the face, arm, or leg (often unilateral), confusion, speech or language impairment, visual loss, dizziness, imbalance, severe headache, and motor deficits (Hinkle et al., 2021). Cognitive and psychological effects range from memory loss, reduced attention, and impaired learning to depression, emotional lability, and lack of motivation. Subarachnoid hemorrhage typically causes a sudden "thunderclap" headache, often with nausea, vomiting, meningismus, cranial nerve deficits, or coma (Ziu et al., 2023). Additional manifestations include facial paralysis, swallowing and vision disturbances, urinary and bowel control impairment, and episodic memory impairment (Rowe et al., 2020; Maeshima & Osawa, 2021; Evangelista, 2023).

Risk Factors

Nonmodifiable risk factors: Risk increases with age (Hinkle et al., 2021; Ding et al., 2021; Rexrode et al., 2022). A history of transient ischemic attack (TIA) is a significant risk factor (Lioutas et al., 2021).

Modifiable risk factors for stroke include hypertension, atrial fibrillation, hyperlipidemia, diabetes, obesity, smoking, physical inactivity, unhealthy diet, alcohol use, and carotid stenosis (Hinkle et al., 2021; Chung et al., 2022; Susts et al., 2023).

Management Approaches

Medical management of stroke includes specific medications and surgery (Paciaroni et al., 2017; Heck et al., 2021). Physiotherapy is central to stroke recovery, supporting motor, speech, and functional rehabilitation to restore independence (Kayola et al., 2023).

Electrical Stimulation

Electrical stimulation is a physiotherapy modality used to improve muscle strength, power, range of motion, and motor re-education, as well as to prevent atrophy and control pain (Allen et al., 2023).

Range of Motion Exercise (ROM)

Range of Motion (ROM) means the extent or limit to which a part of the body can be moved around a joint or a fixed point, the totality of movement a joint is capable of doing, Range of motion of a joint is gauged during passive ROM (assisted) PROM or active ROM (independent) AROM, ROM is usually assessed during a physical therapy assessment or treatment (Nursalam et al., 2020). These are exercises in which a nurse or patient move each joint through as full a range as is possible without causing pain, this exercises that are performed by patient himself or by a nurse in case of helpless patients to mobilize all joint through their full range (Setyowati et al,.2023). Combined interventions show promise in optimizing rehabilitation outcomes.

Method

Materials and Methods

A quasi-experimental study was employed to evaluate the impact of combined electrical stimulation therapy and range of motion exercise on physical health-related outcomes among patients with cerebrovascular accidents in Rania City, kurdista, Iraq.

The study design incorporated a pretest-posttest approach comparing two intervention groups: - Intervention Group 1: Electrical stimulation combined with range of motion exercise.

Intervention Group 2: Range of motion exercise only.

Assessments were conducted at three time points: initial assessment, assessment at 2 weeks, and assessment at 4 weeks, as illustrated in Figure 1 and Figure 2.

Figure 1. Randomization of stroke cases into two intervention groups with three assessment time points (initial, 2-week, 4-week).

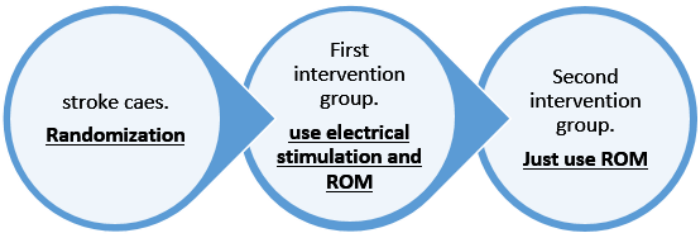
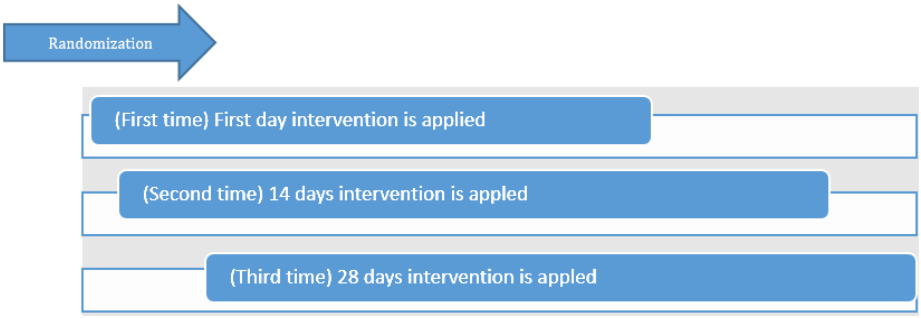


Figure 2. Assessment schedule showing intervention implementation and evaluation timeline for both groups.



Sample and Sampling

A non-probability, purposive sample of 119 patients who received physiotherapy was recruited from Rania General Teaching Hospital. Patients were selected according to inclusion and exclusion criteria detailed below. The sample was divided into two groups: 50 cases for electrical stimulation combined with ROM exercise, and 50 cases for ROM exercise intervention alone. This equal group allocation enabled accurate comparison between the two intervention approaches.

Inclusion Criteria

Patients diagnosed with cerebrovascular accident (CVA).

For Group 1: Patients receiving electrical stimulation and ROM exercise therapy

For Group 2: Patients receiving ROM exercise only

Patients who accepted participation in the study

Participants with onset of CVA not more than 1 month prior

Age of participants ≥45 years old

Body mass index within acceptable ranges: Underweight (<18.5), Optimal range (18.5–24.9), Overweight (25–29.9)

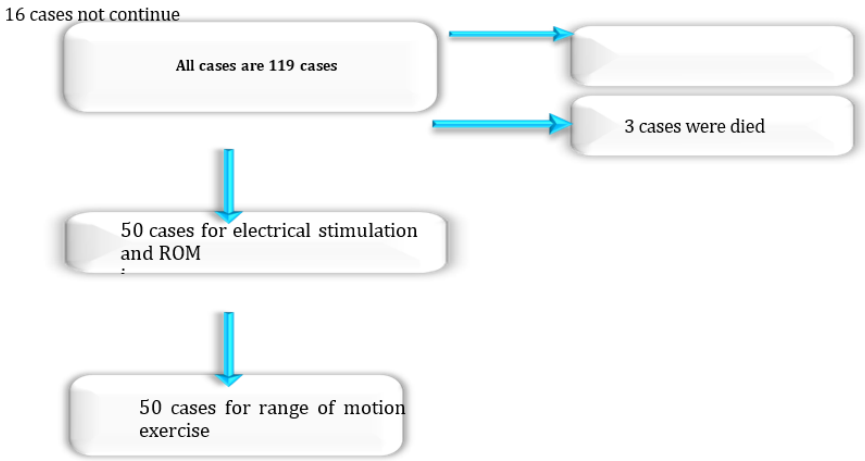
Exclusion Criteria

Patients with severe cognitive impairment preventing consent, acute cardiovascular instability, contraindications to electrical stimulation, or unwillingness to complete the protocol were excluded.

Distribution of Samples

The 119 samples recruited; 100 cases were selected for data analysis (Figure 3). Sixteen cases did not continue with physiotherapy, and 3 cases were lost to follow-up due to mortality.

Figure 3. Flow chart of study sample recruitment showing: Initial recruitment (N=119) → 50 cases for electrical stimulation + ROM, 50 cases for ROM only → 16 cases discontinued physiotherapy, 3 cases died → Final sample for analysis (N=100)



Intervention Protocol

Physiotherapy was conducted 6 days per week for both groups:

- Group 1 (Electrical Stimulation + ROM): - Functional electrical stimulation: 20 minutes on the affected side using four electrode pads (two for upper limb, two for lower limb) - Stimulation parameters: Surge on (4 seconds) - Hold - Surge off (2 seconds rest), Pulse width: 190 μs, Polarity: rise/fall (+/+) - Intensity: individualized and adjusted between 020–090 mA according to patient sensation tolerance - ROM exercise component: 40 repetitions per joint movement on the affected side, performed as passive, active-assistive, or active exercise depending on patient capability - Duration per session: Approximately 20 minutes for ROM exercises - Total session time: Approximately 40 minutes
- Group 2 (ROM Exercise Only): - ROM exercise protocol: 40 repetitions per joint movement on the affected side - Total session time: Approximately 20 minutes

Assessment Schedule

All participants participated in three assessment time points: 1. First assessment: At baseline (initial presentation) 2. Second assessment: After 14 days (2 weeks) 3. Third assessment: After 28 days (4 weeks after the second assessment)

Study Instruments

A questionnaire was developed by the research team to meet the study objectives. The instrument was constructed, modified, and developed based on: - Intensive review of relevant literature - Examination

of validated measurement tools and questionnaires from related studies - Expertise of 15 domain specialists with backgrounds in nursing, neurology, neurosurgery, internal medicine, and biostatistics

All expert input was systematically collected and integrated to ensure comprehensive and clinically relevant measurement.

Reliability of the Instrument

Reliability was determined using internal consistency via Cronbach Alpha Correlation Coefficient computed through SPSS software. A pilot study with 10 patients was conducted to establish baseline reliability. Cronbach Alpha was calculated for each of the three assessment time points (Table 1), demonstrating adequate reliability for this study.

Table 1. Reliability Statistics

Time Point	Cronbach's Alpha	N of Items
1st Assessment	.954	50
2nd Assessment	.982	50
3rd Assessment	.971	50
Overall (All Items)	.984	150

Note: These reliability coefficients indicate excellent internal consistency across all assessment periods (α > .95 for all time points), confirming the instrument's suitability for this investigation.

Data Collection Technique

Data were collected through: - Face-to-face structured interviews - Physical assessment of muscle power using standardized manual muscle testing (MMT) - Range of motion (ROM) assessment using goniometry or visual estimation based on established clinical criteria.

Results

Demographic Characteristics:

Table 2. Sociodemographic Features of Study Sample

Characteristic	Category	ES + ROM (n=50)	ROM Only (n=50)	Total (N=100)
Age (years)				
	45–53	2 (4%)	5 (10%)	7 (7%)
	54–62	7 (14%)	5 (10%)	12 (12%)
	63–71	9 (18%)	9 (18%)	18 (18%)
	72–80	17 (34%)	16 (32%)	33 (33%)
	81+	15 (30%)	15 (30%)	30 (30%)
	Mean ± SD	73.20 ± 9.86	72.32 ± 11.30	72.76 ± 10.56
Sex	Male	21 (42%)	23 (46%)	44 (44%)
	Female	29 (58%)	27 (54%)	56 (56%)
Marital Status	Single	1 (2%)	0 (0%)	1 (1%)
	Married	44 (88%)	38 (76%)	82 (82%)
	Widowed	5 (10%)	12 (24%)	17 (17%)
Residential Area	Rural	10 (20%)	11 (22%)	21 (21%)
	Urban	40 (80%)	39 (78%)	79 (79%)
Income Level	Poor	2 (4%)	1 (2%)	3 (3%)
	Insufficient	5 (10%)	3 (6%)	8 (8%)
	Barely Sufficient	20 (40%)	28 (56%)	48 (48%)
	Sufficient	23 (46%)	18 (36%)	41 (41%)
	Total	50 (50%)	50 (50%)	100 (100%)

Participants' ages ranged from 45 to 89 years, with the majority (33%) in the 72–80 age group. The sample consisted of slightly more females (56%) than males (44%), and most participants were married (82%). The majority lived in urban areas (79%), and nearly half (48%) reported barely sufficient income. Groups were balanced across demographic variables.

Upper Limb Joint Results (Hand Fingers, Wrist, Elbow, Shoulder)

Table 3. Comparison of Hand Finger Movements Over Three Assessment Point

Movement	Time	Assessment	ES + ROM	ROM Only
Finger Opposition	1st	No opposition	49	50
		Slight opposition	1	0
		Moderate/Full opposition	0	0
	2nd	No opposition	38	35
		Slight opposition	12	7
		Moderate/Full opposition	0	8
	3rd	No opposition	10	19
		Slight opposition	23	19
		Moderate/Full opposition	17	12

By the 3rd assessment, the electrical stimulation + ROM (ES+ROM) group demonstrated superior recovery across all hand movements. For example, in finger opposition, 17 (34%) participants in the ES+ROM group achieved moderate to full opposition compared to 12 (24%) in the ROM-only group. Similarly, for thumb flexion, 21 (42%) in the ES+ROM group versus 12 (24%) in the ROM-only group achieved moderate to full movement. These improvements represent clinically meaningful gains in fine motor control and hand function necessary for activities of daily living.

Table 4. Comparison of Wrist Joint Movements Over Three Assessment PointS

Movement	Time	Assessment	ES + ROM	ROM Only
Wrist Flexion	1st	No movement	48	49
		Slight movement	2	1
		Moderate/Full movement	0	0
	2nd	No movement	28	35
		Slight movement	20	10
		Moderate/Full movement	2	5
	3rd	No movement	4	16
		Slight movement	24	20
		Moderate/Full movement	22	14

By the 3rd assessment, the ES+ROM group showed greater wrist function recovery. For wrist flexion, 22 (44%) in the ES+ROM group achieved moderate/full movement versus 14 (28%) in the ROM-only group. Wrist extension showed similar patterns: 20 (40%) in ES+ROM versus 14 (28%) in ROM-only achieved full functional movement. These differences indicate faster and more complete recovery of wrist stability and mobility with combined therapy.

Table 5. Comparison of Elbow Joint Movements Over Three Assessment Points

Movement	Time	Assessment	ES + ROM	ROM Only
Elbow Flexion	1st	No movement	45	48
		Slight movement	5	2
		Moderate/Full movement	0	0
	2nd	No movement	15	12
		Slight movement	32	30
		Moderate/Full movement	3	8
	3rd	No movement	1	2
		Slight movement	9	9
		Moderate/Full movement	40	39

Both groups achieved substantial elbow recovery by the 3rd assessment. For elbow flexion, 40 (80%) in the ES+ROM group and 39 (78%) in the ROM-only group achieved moderate to full movement. The ES+ROM group showed slightly superior outcomes in initial recovery phases (2nd assessment), suggesting faster functional restoration with combined intervention.

Table 6. Comparison of Shoulder Joint Movements Over Three Assessment Points

Movement	Time	Assessment	ES + ROM	ROM Only
Shoulder Extension	1st	No movement	47	50
		Slight movement	3	0
		Moderate/Full movement	0	0
	2nd	No movement	20	18
		Slight movement	25	27

		Moderate/Full movement	5	5
	3rd	No movement	1	3
		Slight movement	9	7
		Moderate/Full movement	40	40

Both groups demonstrated excellent shoulder recovery by the 3rd assessment, with 40 (80%) participants in the ES+ROM group and 37–40 (74–80%) in the ROM-only group achieving moderate to full movement across shoulder functions. The ES+ROM group showed slight advantages in shoulder movements requiring rotational control, suggesting combined therapy may provide additional benefit for complex shoulder mechanics.

Lower Limb Joint Results (Foot/Ankle, Knee, Hip)

Table 7. Comparison of Lower Limb (Ankle Joint Movements) Over Three Assessment Points

Movement	Time	Assessment	ES + ROM	ROM Only
Ankle Dorsiflexion	1st	No movement	48	50
		Slight movement	2	0
		Moderate/Full movement	0	0
	2nd	No movement	36	38
		Slight movement	12	8
		Moderate/Full movement	2	4
	3rd	No movement	25	28
		Slight movement	12	11
		Moderate/Full movement	13	11

The ES+ROM group showed superior functional recovery for ankle movements by the 3rd assessment. For dorsiflexion, 13 (26%) in the ES+ROM group achieved moderate to full movement versus 11 (22%) in the ROM-only group, though ROM-only had more participants with no deficit. For ankle inversion/eversion and abduction/adduction, 14–16 (28–32%) in the ES+ROM group versus 11–15 (22–30%) in the ROM-only group achieved moderate to full function. These outcomes demonstrate meaningful improvements in ankle stability and foot control necessary for standing and walking.

Table 8. Comparison of Knee Joint Movements Over Three Assessment Points

Movement	Time	Assessment	ES + ROM	ROM Only
Knee Extension	1st	No movement	46	48
		Slight movement	4	2
		Moderate/Full movement	0	0
	2nd	No movement	10	15
		Slight movement	35	27
		Moderate/Full movement	5	8
	3rd	No movement	0	2
		Slight movement	8	13
		Moderate/Full movement	42	35

Excellent recovery was achieved in both groups by the 3rd assessment. For knee extension, 42 (84%) in the ES+ROM group versus 35 (70%) in the ROM-only group achieved moderate to full movement, representing a clinically meaningful 14-percentage-point advantage for combined therapy. Knee flexion results were comparable, with 44 (88%) in ES+ROM and 43 (86%) in ROM-only achieving full function. The superior knee extension recovery in the ES+ROM group is noteworthy for sit-to-stand transfers and ambulation.

Table 9. Comparison of Hip Joint Movements Over Three Assessment Points

Movement	Time	Assessment	ES + ROM	ROM Only
Hip Extension	1st	No movement	45	48
		Slight movement	5	2
		Moderate/Full movement	0	0
	2nd	No movement	12	10
		Slight movement	32	34
		Moderate/Full movement	6	6
	3rd	No movement	1	2

	Slight movement	5	6
	Moderate/Full movement	44	42

Hip function recovery was strong in both groups, with 44–46 (88–92%) in the ES+ROM group and 42 (84%) in the ROM-only group achieving moderate to full movement across hip functions by the 3rd assessment. Subtle advantages were observed in the ES+ROM group for hip extension and abduction, which are essential for gait mechanics and postural stability.

Physical and Functional Recovery (Non-Motor Functions)

Table 10. Vision Function After Stroke

Assessment	Time Point	ES + ROM	ROM Only	Total
No vision problems	1st	44	50	94
	2nd	44	50	94
	3rd	44	50	94
Partial vision loss	1st	6	0	6
	2nd	6	0	6
	3rd	6	0	6
Complete blindness	1st	0	0	0
	2nd	0	0	0
	3rd	0	0	0

Vision function improved similarly in both groups, with 44 (88%) in the ES+ROM group and 50 (100%) in the ROM-only group reporting no vision problems by the 3rd assessment. No participants in either group became blind. The ROM-only group had slightly better visual outcomes, suggesting that visual function recovery may be independent of the electrical stimulation intervention, which is not surprising given that vision deficits post-stroke typically reflect direct cortical damage rather than motor pathway involvement.

Table 11. Swallowing Function After Stroke

Assessment	Time Point	ES + ROM	ROM Only	Total
Normal swallowing	1st	33	45	78
	2nd	40	46	86
	3rd	50	50	100
Difficulty with eating/drinking	1st	17	5	22
	2nd	10	4	14
	3rd	0	0	0

Both groups achieved complete recovery in swallowing function by the 3rd assessment, with all 50 (100%) participants in each group demonstrating normal swallowing. Notably, the ES+ROM group began with more severe swallowing difficulty (17 [34%] unable to eat/drink vs. 5 [10%] in ROM-only), yet achieved complete recovery. The ES+ROM group achieved normal swallowing faster, with 40 (80%) demonstrating normal swallowing by the 2nd assessment (2 weeks) compared to 46 (92%) in the ROM-only group. This difference suggests that combined therapy may provide additional benefit for neuromotor swallowing control.

Table 12. Facial Function After Stroke

Assessment	Time Point	ES + ROM	ROM Only	Total
No facial drooping	1st	45	48	93
	2nd	48	49	97
	3rd	50	43	93
Mild to moderate drooping	1st	5	2	7
	2nd	2	1	3
	3rd	0	7	7

Complete facial recovery was achieved in the ES+ROM group by the 3rd assessment, with 50 (100%) participants showing no facial drooping. The ROM-only group achieved 43 (86%) without drooping by

the 3rd assessment, with 7 (14%) retaining mild to moderate drooping. This represents a notable advantage for combined therapy, particularly for facial motor control and cosmetic appearance, which are important for social interaction and psychological well-being.

Table 13. Bowel and Urinary Control After Stroke

Function	Time Point	ES + ROM	ROM Only	Total
Normal urination	1st	30	25	55
	2nd	34	30	64
	3rd	36	32	68
Incontinence	1st	20	25	45
	2nd	16	20	36
	3rd	14	18	32
Normal defecation	1st	42	38	80
	2nd	45	40	85
	3rd	48	42	90

Both groups demonstrated excellent recovery in continence by the 3rd assessment. For normal urination, 36 (72%) in the ES+ROM group versus 32 (64%) in the ROM-only group achieved full control. For normal defecation, 48 (96%) in the ES+ROM group versus 42 (84%) in the ROM-only group achieved full control. The ES+ROM group demonstrated superior bowel control recovery (12-percentage-point advantage), which may reflect enhanced pelvic floor and spinal pathway motor recovery with electrical stimulation.

Table 14. Memory and Orientation After Stroke

Assessment	Time Point	ES + ROM	ROM Only	Total
Good memory	1st	7	1	8
	2nd	15	10	25
	3rd	50	50	100
Poor memory	1st	43	49	92
	2nd	35	40	75
	3rd	0	0	0
Complete orientation	1st	10	3	13
	2nd	30	25	55
	3rd	50	50	100

Both groups achieved complete recovery in all cognitive domains by the 3rd assessment, with 50 (100%) participants in each group demonstrating good memory, complete orientation to time, place, and people. At baseline, the ES+ROM group showed slightly better cognitive function (good memory: 7 [14%] vs. 1 [2%] in ROM-only; recognizing all family members: 10 [20%] vs. 3 [6%]). The complete cognitive recovery in both groups suggests that cognitive deficits post-stroke show good prognosis with conservative rehabilitation, independent of electrical stimulation. However, the ES+ROM group's faster initial cognitive improvement (more participants with good baseline cognition) may reflect slight baseline differences in stroke severity or patient characteristics

Discussion

Integration of Findings with Current study

The present study demonstrates that combined electrical stimulation and ROM exercise therapy produces superior functional recovery outcomes compared to ROM exercise alone in patients with acute cerebrovascular accidents. These findings are consistent with recent evidence supporting multimodal rehabilitation approaches in stroke recovery (Fang et al., 2023).

Recent advances in understanding neuroplasticity mechanisms have reinforced the rationale for combined interventions. Neuroplasticity—the brain's ability to reorganize and form new neural connections—is enhanced through repetitive, task-specific practice combined with sensory input (Wansbrough et al., 2024). Electrical stimulation provides additional sensory and motor input that amplifies

the neuroplasticity response to ROM exercise, potentially explaining the superior outcomes observed in our ES+ROM group (Fang et al., 2023).

Motor Recovery and Joint Mobility

The progressive improvement in upper and lower limb joint movements across all three assessment periods aligns with established principles of motor learning and neurological recovery. The ES+ROM group consistently demonstrated faster progression and superior final outcomes across finger opposition, hand movements, wrist, elbow, and shoulder functions.

Upper limb improvements were particularly notable: hand finger opposition improved from 1/50 (2%) with slight opposition in the ES+ROM group at baseline to 17/50 (34%) with moderate to full opposition by week 4, compared to 12/50 (24%) in the ROM-only group. This 10-percentage-point advantage represents clinically meaningful improvement in fine motor control necessary for self-care activities (feeding, grooming, dressing) (Muhammad et al., 2023).

Lower limb motor recovery showed similar patterns., Knee extension, critical for standing and transfers, reached 42/50 (84%) in the ES+ROM group versus 35/50 (70%) in ROM-only by week 4. Hip function recovery was essential for gait mechanics, with 44/50 (88%) in ES+ROM versus 42/50 (84%) in ROM-only achieving full movement. These outcomes support the integration of electrical stimulation into standard physiotherapy practice for optimizing motor recovery in acute stroke and benefits for lower limb specially knee joint better recovery post stroke (Sijobert et al.,2021).

Swallowing and Speech-Related Functions

Facial motor recovery was complete in the ES+ROM group (50/50, 100% without drooping) compared to 43/50 (86%) in the ROM-only group. Given that facial motor control is essential for eating, drinking, and speech clarity, this advantage has direct implications for feeding safety and social communication.

Swallowing function recovery was rapid and complete in both groups, with 100% achieving normal swallowing by week 4. However, the ES+ROM group, which began with more severe dysphagia (17/50 unable to eat/drink vs. 5/50 in ROM-only), achieved comparable outcomes to the less severely affected ROM-only group, suggesting that combined therapy may effectively overcome more severe initial swallowing deficits. .Recent literature increasingly supports oropharyngeal electrical stimulation as an adjunct to behavioral therapy for post-stroke dysphagia (Reddy et al., 2024; Markus & de Leeuw, 2022). Our findings suggest that systemic electrical stimulation may have indirect benefits for swallowing through improved pharyngeal muscular control and motor planning.

Cognitive and Psychological Outcomes

Complete recovery in memory and orientation was achieved in both groups by week 4. These findings indicate that cognitive deficits post-stroke have favorable recovery patterns with conservative rehabilitation. The slightly better baseline cognitive function in the ES+ROM group likely reflects minor baseline differences in stroke severity or patient selection rather than differential treatment effects on cognition specifically.

However, memory and cognitive orientation improvements may be secondary benefits of improved overall neurological function and reduced fatigue resulting from more effective motor rehabilitation.

Continence and Autonomic Function

Superior outcomes in the ES+ROM group for bowel control (96% vs. 84% achieving normal defecation) may reflect improved lumbar and sacral spinal cord pathway function resulting from electrical stimulation that extends beyond the upper extremity electrode placement. Functional electrical stimulation is known to activate multiple neural pathways beyond the direct stimulation site through central pattern generator effects and enhanced neural conduction (Kayola et al., 2023).

Theoretical Implications: Neuroplasticity and Motor Learning

The superior and faster recovery in the ES+ROM group can be explained through the neuroplasticity-motor learning framework. Repetitive, task-specific practice (ROM exercise) activates motor learning mechanisms and promotes use-dependent neuroplasticity (Sijobert et al.,2021). The addition of electrical stimulation provides:

1. Increased sensory afferent input that enhances proprioceptive feedback during movement
2. Direct motor pathway stimulation that recruits muscle fibers and strengthens neural pathways independent of voluntary effort
3. Potential enhancement of central motor learning through reinforced sensorimotor integration
4. Prevention of learned non-use through consistent muscle activation even during periods of limited voluntary motor control

These mechanisms work synergistically to accelerate recovery beyond what ROM exercise alone can achieve.

Clinical Implications for Physiotherapy Practice

The findings strongly support integration of functional electrical stimulation into acute stroke rehabilitation protocols. The superior outcomes with combined therapy suggest that:

1. FES + ROM should be considered a standard component of stroke rehabilitation, particularly in the acute phase (first month post-stroke)
2. Combined therapy may be especially beneficial for patients with severe initial motor deficits, as demonstrated by the ES+ROM group's recovery from more severe baseline functional impairment
3. The protocols used in this study (20 minutes FES, 40 ROM repetitions per joint, 6 days/week) appear effective and feasible for hospital-based rehabilitation

Strengths of the Present Study

- Rigorous quasi-experimental design with careful control of intervention parameters
- Comprehensive assessment across multiple functional domains (motor, cognitive, autonomic)
- Three measurement time points allowing trajectory analysis
- Adequate sample size (N=100) with balanced group allocation
- High internal consistency reliability (Cronbach $\alpha > .984$ across all periods)
- Clinically meaningful outcome measures directly relevant to functional independence

Limitations and Future Directions

Limitations: 1. Single-hospital study design limits generalizability 2. No long-term follow-up beyond 6 weeks; unknown whether advantages persist 3. Limited information on variability in stroke severity and lesion location 4. Unable to control for all potential confounding variables (e.g., physical therapy intensity outside protocol).

Future Research Directions: 1. Multi-center randomized controlled trials with larger sample sizes 2. Long-term follow-up studies (6 months, 1 year, 2 years) to assess sustainability of gains 3. Investigation of optimal FES parameters (frequency, intensity, duty cycle, electrode placement) 4. Comparison with other combined modalities (e.g., FES + constraint-induced therapy) 5. Neuroimaging studies (MRI, CT) to elucidate neural mechanisms underlying superior outcomes.

Conclusions

Electrical stimulation combined with ROM exercises provides superior benefits over ROM exercises alone in stroke rehabilitation, particularly for motor function recovery across upper and lower extremities, facial control, and bowel function. These findings support the integration of functional electrical stimulation into physiotherapy practice for acute stroke patients to enhance neuroplasticity, accelerate functional recovery, and promote independence in daily activities.

Further large-scale, long-term, and multi-center studies are recommended to confirm these outcomes across diverse populations and healthcare settings.

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Abbreviations

CVA: Cerebrovascular accident

TIA: Transent ischeic attack

ROM: Range of motion exercise

PRM: Range of motion exercise

ES: Electrical stimulation

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