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Effectiveness of Neuromuscular Electrical Stimulation Combined with Conventional Physiotherapy on Motor Recovery in Patients with Acute Ischemic Stroke: A Comparative Study

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Acute Ischemic Stroke, Neuromuscular Electrical Stimulation, Conventional Physiotherapy, Motor Recovery, Fugl-Meyer Assessment, Barthel Index, Modified Ashworth Scale.

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Abstract

Background: Stroke is one of the leading causes of long-term disability worldwide, with ischemic stroke accounting for the majority of cases. Motor impairment, spasticity, and reduced functional independence are common consequences that negatively affect quality of life. Conventional physiotherapy is widely used in stroke rehabilitation, while Neuromuscular Electrical Stimulation (NMES) has been proposed as an adjunctive intervention to enhance motor recovery.

Objective: To compare the effectiveness of Neuromuscular Electrical Stimulation combined with conventional physiotherapy versus conventional physiotherapy alone in improving motor recovery among patients with acute ischemic stroke.

Methods: A comparative study was conducted on 50 patients with acute ischemic stroke. Participants were divided into two groups: NMES with conventional physiotherapy (n=25) and conventional physiotherapy alone (n=25). Outcome measures included the Fugl-Meyer Assessment (FMA) for motor recovery, Modified Ashworth Scale (MAS) for spasticity, and Barthel Index (BI) for functional independence. Assessments were performed before and after the intervention period. Statistical analysis was carried out to evaluate within-group and between-group differences.

Results: Significant improvement was observed within both groups following intervention. In the NMES group, FMA scores improved from 30.7 ± 3.5 to 38.6 ± 6.2, BI scores improved from 40.3 ± 3.9 to 48.8 ± 5.0, and MAS scores decreased from 2.3 ± 0.49 to 1.8 ± 0.41. In the conventional physiotherapy group, FMA scores improved from 30.6 ± 3.5 to 37.6 ± 5.8, BI scores improved from 39.6 ± 3.5 to 49.0 ± 6.5, and MAS scores decreased from 2.3 ± 0.4 to 1.6 ± 0.5. However, no statistically significant differences were found between the two groups in post-intervention FMA, BI, or MAS scores ($p > 0.05$).

Conclusion: Both NMES combined with conventional physiotherapy and conventional physiotherapy alone were effective in improving motor recovery, reducing spasticity, and enhancing functional independence in patients with acute ischemic stroke. However, the addition of NMES did not demonstrate a statistically significant advantage over conventional physiotherapy alone.

INTRODUCTION

Stroke is a major global health problem and remains one of the leading causes of mortality and long-term disability worldwide. It is characterized by the sudden onset of neurological deficits resulting from an interruption of cerebral blood flow due to either ischemia or hemorrhage. Among the different types of stroke, ischemic stroke accounts for approximately 80–85% of all cases and occurs when blood flow to a specific region of the brain is obstructed by thrombosis or embolism. The resulting deprivation of oxygen and nutrients leads to neuronal injury, impaired neurological function, and varying degrees of physical disability.

Advances in acute medical management have significantly improved survival rates among stroke patients. However, many survivors continue to experience persistent impairments affecting motor function, balance, gait, muscle strength, coordination, and activities of daily living. These deficits often limit independence, reduce participation in social and occupational activities, and negatively impact quality of life. Motor impairment, particularly hemiparesis and hemiplegia, is among the most common consequences of stroke and is a major target of rehabilitation interventions.

Recovery following stroke is largely dependent on neuroplasticity, which refers to the brain's ability to reorganize and form new neural connections in response to injury and therapeutic stimulation. Early rehabilitation plays a crucial role in promoting neuroplastic changes and preventing secondary complications such as muscle atrophy, joint stiffness, contractures, pressure sores, and deconditioning. Physiotherapy is considered the cornerstone of stroke rehabilitation and aims to restore functional mobility, improve motor control, enhance muscle strength, and maximize independence.

Conventional physiotherapy interventions commonly include positioning, range of motion exercises, stretching, strengthening exercises, balance and coordination training, gait training, transfer training, and task-oriented functional activities. These interventions are designed to facilitate motor relearning through repetitive practice and active participation. Although conventional physiotherapy has been shown to improve functional outcomes after stroke, many patients continue to experience incomplete motor recovery, highlighting the need for adjunctive rehabilitation strategies that may enhance recovery outcomes.

Neuromuscular Electrical Stimulation (NMES) has emerged as a promising therapeutic modality in neurological rehabilitation. NMES involves the application of electrical impulses to peripheral nerves to produce muscle contractions. These electrically induced contractions mimic voluntary muscle activity and help activate weakened or paretic muscles. In addition to improving muscle performance, NMES provides sensory input to the central nervous system, which may facilitate cortical reorganization and enhance neuroplasticity. Through these mechanisms, NMES has the potential to improve motor control, reduce spasticity, increase muscle strength, and enhance functional performance.

Several studies have investigated the effectiveness of NMES in stroke rehabilitation. Previous research has reported beneficial effects on motor recovery, muscle activation, gait performance, upper limb function, and functional independence. However, findings remain inconsistent, with some studies demonstrating significant advantages while others report limited additional benefits compared to conventional rehabilitation alone. Furthermore, evidence regarding the

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effectiveness of NMES in patients with acute ischemic stroke remains limited, particularly within the Indian population.

Considering the increasing burden of stroke-related disability and the need for evidence-based rehabilitation approaches, it is important to evaluate whether the addition of NMES to conventional physiotherapy provides superior outcomes compared to conventional physiotherapy alone. Therefore, the present study was undertaken to compare the effectiveness of Neuromuscular Electrical Stimulation combined with conventional physiotherapy and conventional physiotherapy alone in improving motor recovery among patients with acute ischemic stroke. The findings of this study may contribute to the development of more effective rehabilitation protocols and support clinical decision-making in stroke rehabilitation.

MATERIALS AND METHODS

Study Design

A comparative experimental study was conducted to evaluate the effectiveness of Neuromuscular Electrical Stimulation (NMES) combined with conventional physiotherapy versus conventional physiotherapy alone in improving motor recovery among patients with acute ischemic stroke.

Study Setting

The study was conducted in the Department of Physiotherapy at Pacific Medical University and its associated clinical settings, Udaipur, Rajasthan.

Study Population

Patients diagnosed with acute ischemic stroke and referred for physiotherapy rehabilitation were recruited for the study.

Sample Size

A total of 50 patients with acute ischemic stroke were included in the study. Participants were divided into two groups:

• Group A (NMES + Conventional Physiotherapy): 25 patients

• Group B (Conventional Physiotherapy Alone): 25 patients

Sampling Technique

Participants fulfilling the inclusion criteria were selected using a convenient sampling method and allocated into two treatment groups.

Inclusion Criteria

1. Patients diagnosed with acute ischemic stroke.
2. Male and female patients aged between 30 and 80 years.
3. Patients who were medically stable and able to participate in physiotherapy.
4. Patients presenting with motor deficits following stroke.
5. Patients willing to participate and provide informed consent.

Exclusion Criteria

1. Hemorrhagic stroke.
2. Severe cognitive impairment affecting participation.
3. Unstable cardiovascular conditions.
4. Presence of pacemakers or contraindications to electrical stimulation.
5. Severe musculoskeletal disorders affecting mobility.
6. Other neurological disorders influencing motor performance.

Outcome Measures

The following standardized outcome measures were used:

1. Fugl-Meyer Assessment (FMA)
   - Used to assess motor recovery and sensorimotor function following stroke.
2. Modified Ashworth Scale (MAS)
   - Used to assess muscle spasticity.
3. Barthel Index (BI)
   - Used to evaluate functional independence in activities of daily living.

Procedure

After obtaining institutional ethical clearance and informed consent from all participants, baseline assessments were performed using FMA, MAS, and BI. Demographic details including age, gender, occupation, and residential area were recorded.

Participants were then allocated into two groups:

Group A: NMES with Conventional Physiotherapy

Participants received Neuromuscular Electrical Stimulation in addition to conventional physiotherapy rehabilitation. Conventional physiotherapy included positioning, range of motion exercises, stretching, strengthening exercises, balance training, gait training, transfer training, and task-oriented functional activities.

Group B: Conventional Physiotherapy Alone

Participants received conventional physiotherapy consisting of positioning, passive and active range of motion exercises, stretching, strengthening exercises, balance and coordination training, gait training, transfer training, and functional task-oriented activities.

At the completion of the intervention period, all outcome measures were reassessed using the same evaluation tools.

Statistical Analysis

Data were analyzed using appropriate statistical methods. Descriptive statistics were expressed as mean, standard deviation, frequency, and percentage. Paired t-tests were used for within-group comparisons between pre- and post-intervention values. Independent t-tests were used for between-group comparisons. Chi-square tests were applied for demographic variables. A p-value less than 0.05 was considered statistically significant.

RESULTS

Table 1 Distribution of Age NMES

Age	Number of Patients	Percentage
30-40	1	4%
40-50	8	32%
50-60	7	28%
60-70	8	32%
70-80	1	4%
Total	25	100%

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The majority of patients belonged to the 40–50 years and 60–70 years age groups, each contributing 32% of the total study population. Patients aged 30–40 years and 70–80 years were least represented, accounting for only 4% each.

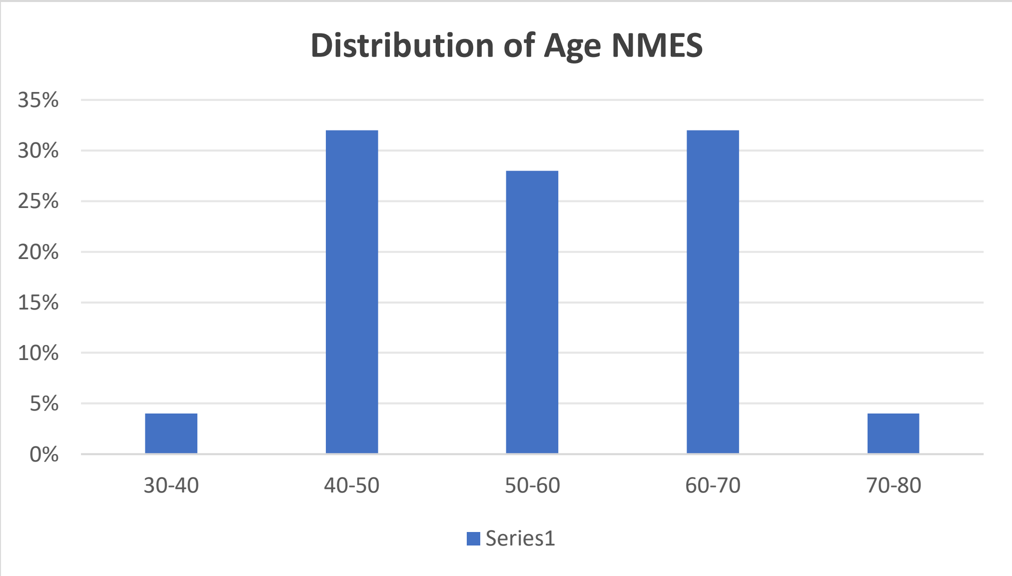


Table 2 Distribution of Gender

Gender	Number of Patients	Percentage
Male	15	60%
Female	10	40%
Total	25	100%

Male patients constituted the majority of the study population, accounting for 60% of the total cases. Female patients represented 40% of the participants included in the study.

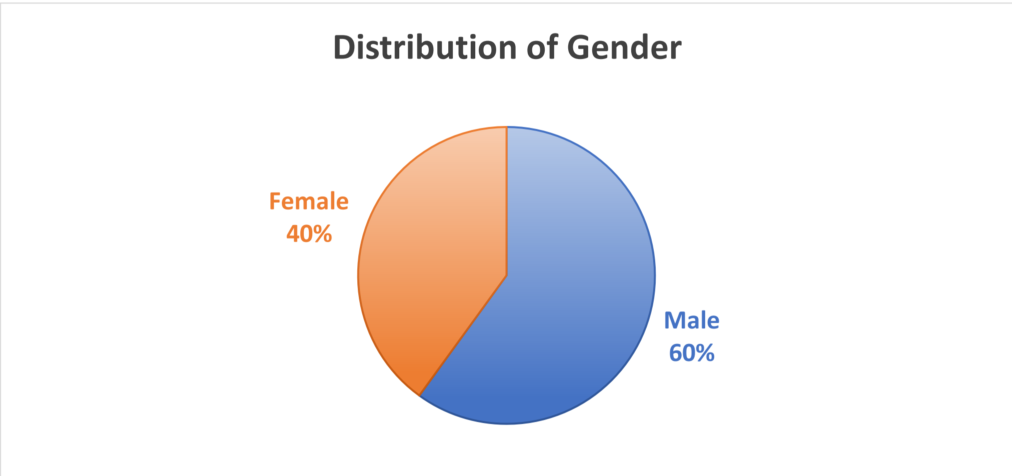


Table 3 Distribution of Occupation

Occupation	Number of Patients	Percentage
Housewife	10	40%
Buisnessman	7	28%
Unemployed	5	20%
Retd	3	12%
Total	25	100%

Housewives formed the largest occupational group in the study, comprising 40% of the total participants. Retired individuals were the least represented group at 12%, while businessmen and unemployed participants accounted for 28% and 20% respectively.

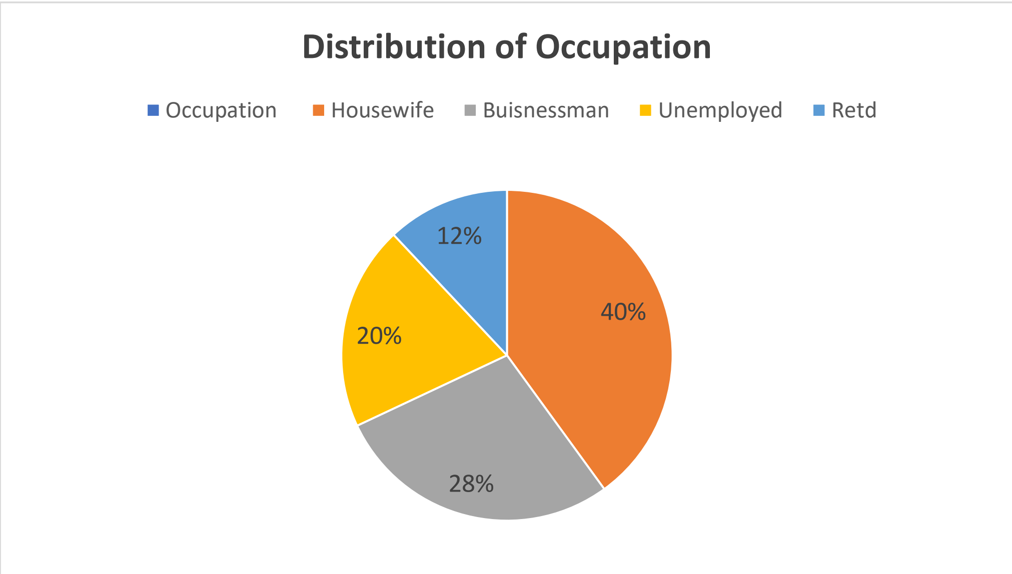
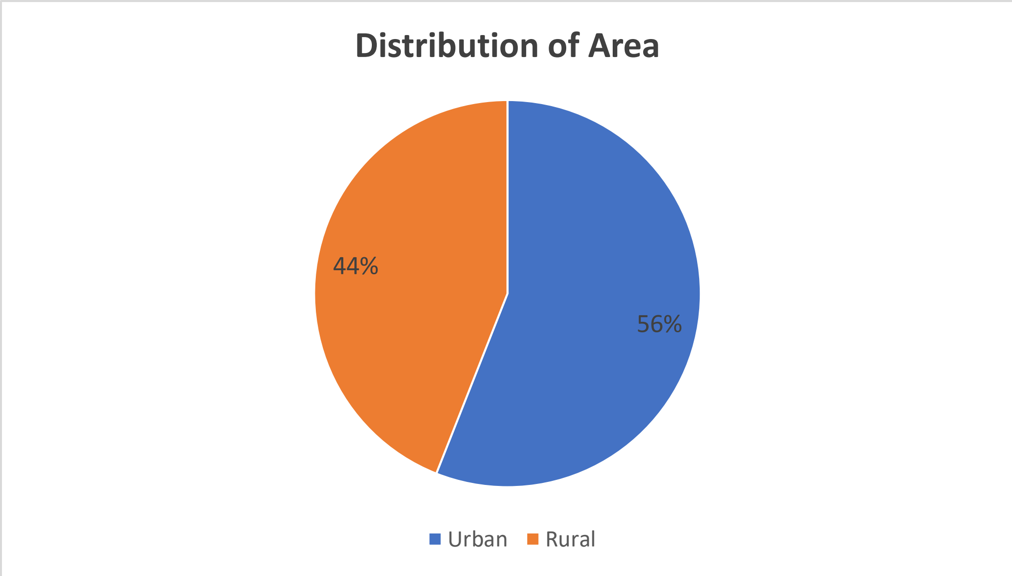


Table 4 Distribution of Area

Area	Number of Patients	Percentage
Urban	14	56%
Rural	11	44%
Total	25	100%



The majority of patients belonged to urban areas, accounting for 56% of the study population. Rural participants constituted 44% of the total patients included in the study.

Table 5 Distribution of MAS

MAS	Mean ± SD (n=25)	Range	Maximum	Minimum
Pre MAS	2.3 ± 0.49	1	3	2
Post MAS	1.8 ± 0.41	1	2	1

The mean MAS score decreased from 2.3 ± 0.49 before treatment to 1.8 ± 0.41 after treatment, indicating an improvement in muscle spasticity.

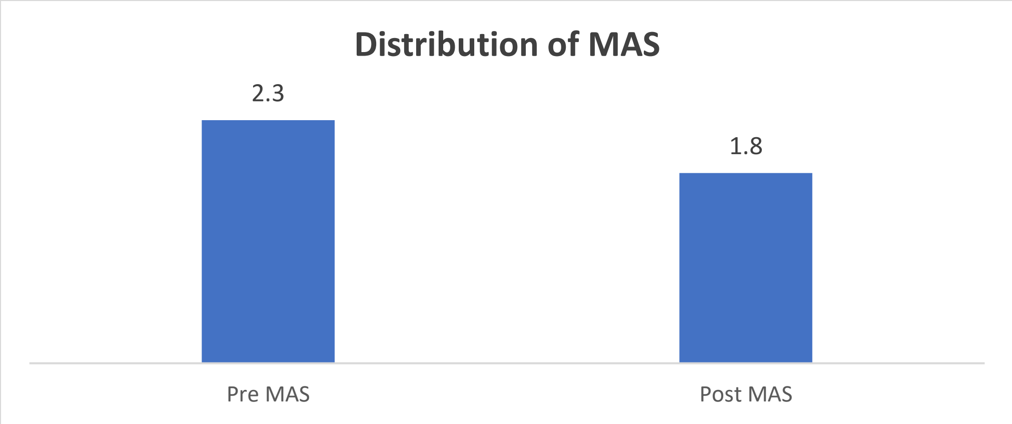


Table 6 Distribution of BI

BI	Mean ± SD (n=25)	Range	Maximum	Minimum
Pre BI	40.3 ± 3.9	14	48	34
Post BI	48.8 ± 5.0	22	57	35

The mean BI score increased from 40.3 ± 3.9 before treatment to 48.8 ± 5.0 after treatment

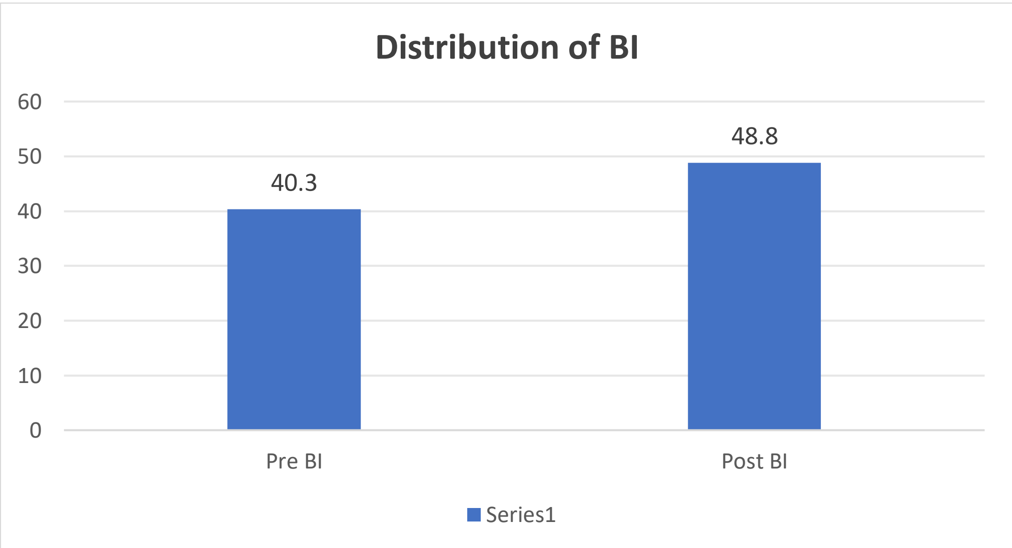


Table 7 Distribution of FMA

FMA	Mean ± SD (n=25)	Range	Maximum	Minimum
Pre FMA	30.7 ± 3.5	13	38	25
Post FMA	38.6 ± 6.2	22	50	28

The mean FMA score improved from 30.7 ± 3.5 before treatment to 38.6 ± 6.2 after treatment,

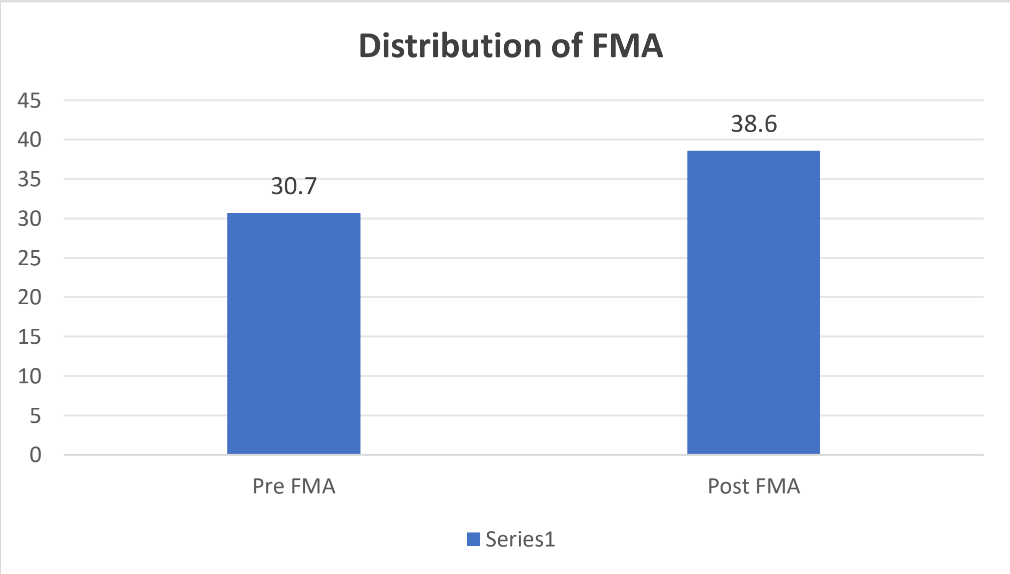


Table 8 Distribution of Age NON NMES

Age	Number of Patients	Percentage
30-40	0	0%
40-50	9	36%
50-60	8	32%
60-70	7	28%
70-80	1	4%
Total	25	100%

The majority of patients in the NON-NMES group belonged to the 40–50 years age group (36%), followed by the 50–60 years group (32%).

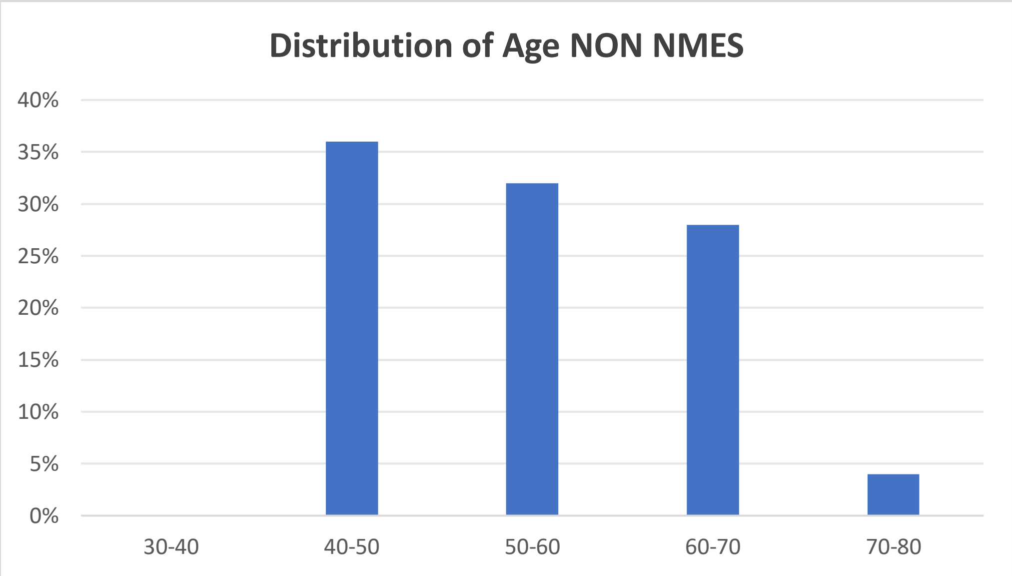


Table 9 Distribution of Gender

Gender	Number of Patients	Percentage
Male	10	40%
Female	15	60%
Total	25	100%

Female patients constituted the majority of the study population, accounting for 60% of the total participants.

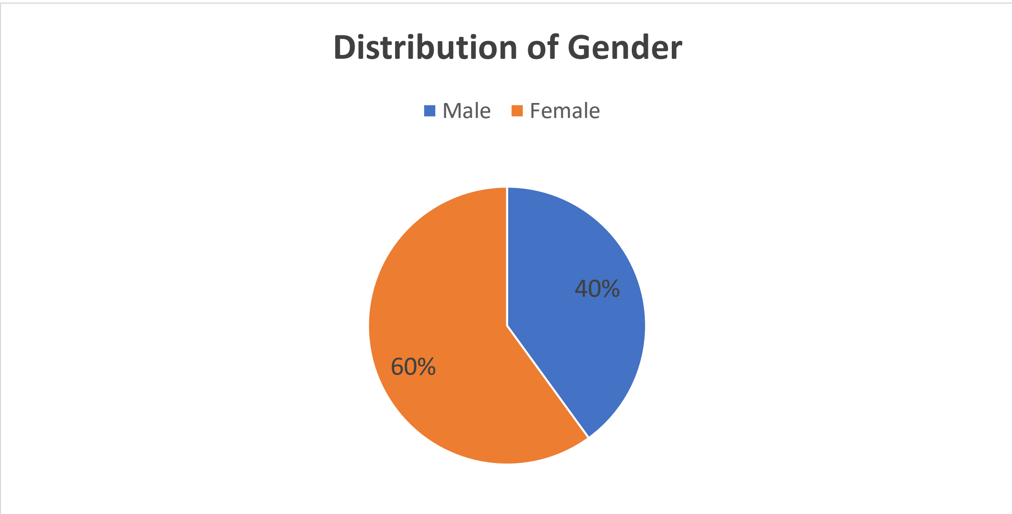


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Table 10 Distribution of Occupation

Occupation	Number of Patients	Percentage
Housewife	12	48%
Buisnessman	8	32%
Unemployed	0	0%
Retd	5	20%
Total	25	100%

Housewives constituted the largest occupational group in the study, accounting for 48% of the participants. No unemployed participants were observed, while retired individuals represented 20% of the total study population.

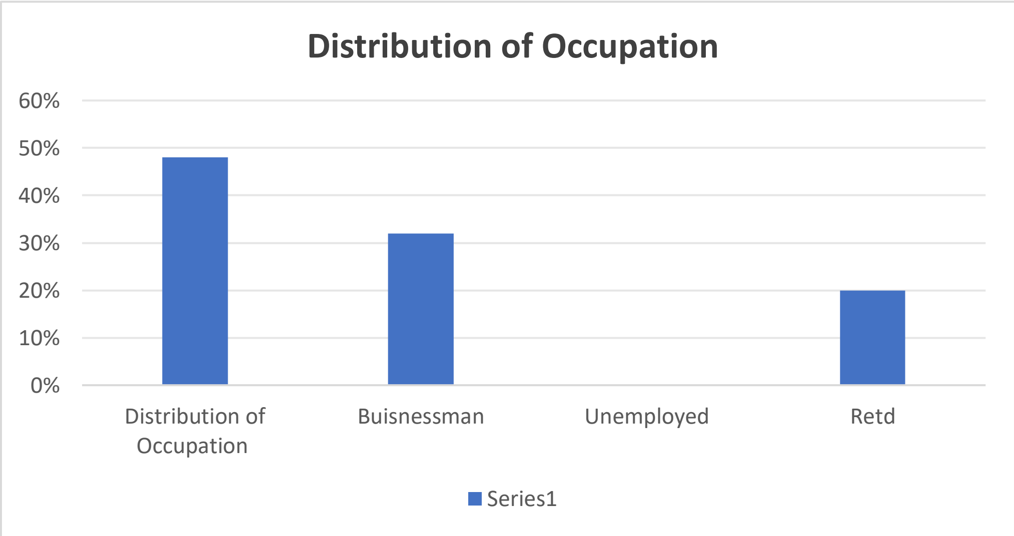

Table 11 Distribution of Area

Area	Number of Patients	Percentage
Urban	14	56%
Rural	11	44%
Total	25	100%

The majority of patients belonged to urban areas, accounting for 56% of the study population. Rural participants constituted 44% of the total patients included in the study.

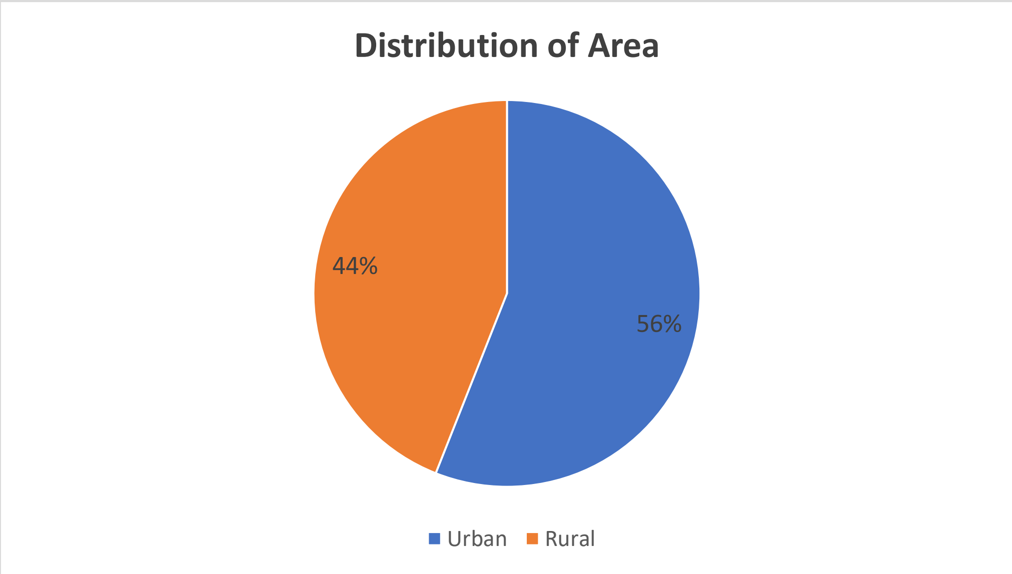

Table 12 Distribution of MAS

MAS	Mean ± SD (n=25)	Range	Maximum	Minimum
Pre MAS	2.3 ± 0.4	1	3	2
Post MAS	1.6 ± 0.5	2	3	1

The mean MAS score decreased from 2.3 ± 0.4 before treatment to 1.6 ± 0.5 after treatment, indicating improvement in muscle spasticity among patients

Table 13 Distribution of BI

BI	Mean ± SD (n=25)	Range	Maximum	Minimum
Pre BI	39.6 ± 3.5	13	47	34
Post BI	49.0 ± 6.5	26	65	39

The mean BI score increased from 39.6 ± 3.5 before treatment to 49.0 ± 6.5 after treatment

Table 14 Distribution of FMA

FMA	Mean ± SD (n=25)	Range	Maximum	Minimum
Pre FMA	30.6 ± 3.5	13	38	25
Post FMA	37.6 ± 5.8	19	48	29

The mean FMA score increased from 30.6 ± 3.5 before treatment to 37.6 ± 5.8 after treatment

Table 15 Comparison of Age-wise Distribution between NMES and NON NMES

Age	NMES (n=25)		Non NMES (n=25)		Statistical Test Value
	Number of Patients	Percentage	Number of Patients	Percentage	X2 = 1.1 P = 0.7 P<0.01(NS)
30-40	1	4%	0	0%	
40-50	8	32%	9	36%	
50-60	7	28%	8	32%	
60-70	8	32%	7	28%	
70-80	1	4%	1	4%	
Total	25	100	25	100%	

There was no statistically significant difference in age-wise distribution between the NMES and NON-NMES groups (P > 0.01).

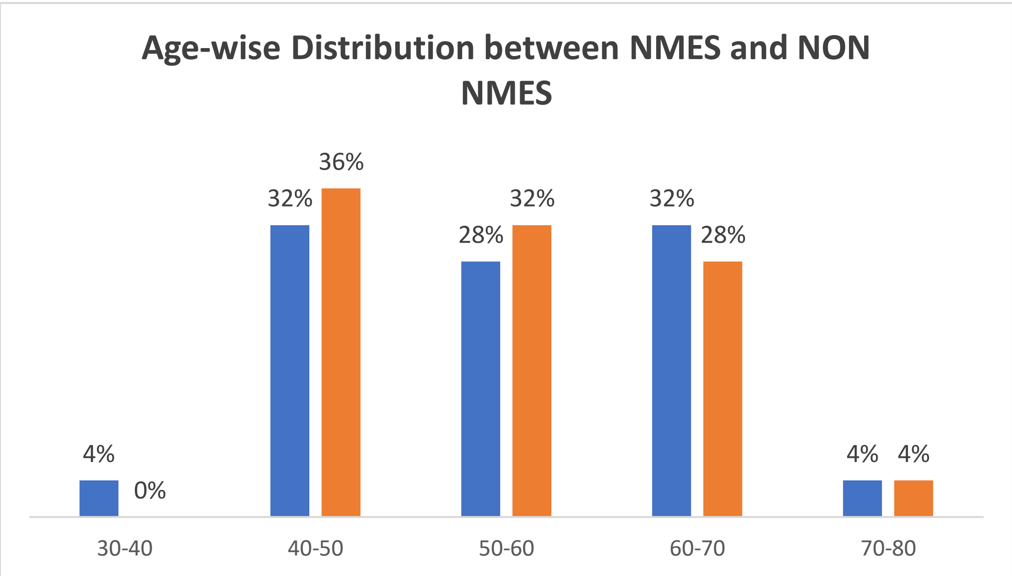

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Table 16 Gender-wise Distribution of Patients in NMES and NON NMES

Gender	NMES (n=25)		Non NMES (n=25)		Statistical test value
	Number of Patients	Percentage	Number of Patients	Percentage	X2 = 2 P = 0.1 P<0.01(NS)
Male	15	60%	10	40%	
Female	10	40%	15	60%	
Total	25	100%	25	100%	

There was no statistically significant difference in gender-wise distribution between the NMES and NON-NMES groups (P > 0.01).

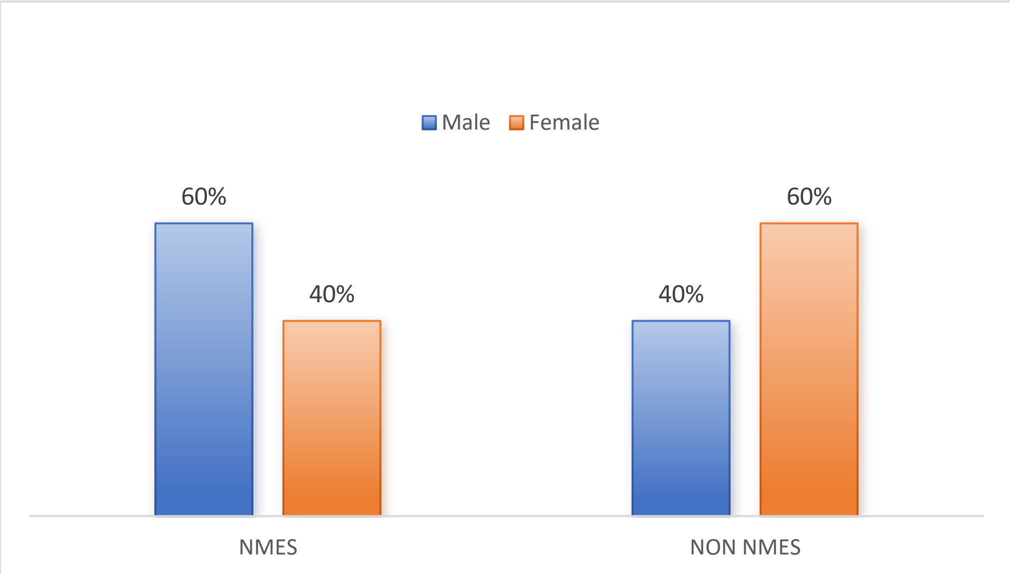

Table 17 Area-wise Distribution of Patients in NMES and NON NMES

Area	NMES (n=25)		Non NMES (n=25)		Statistical test value
	Number of Patients	Percentage	Number of Patients	Percentage	X2 = 0 P = 1 P<0.01(NS)
urban	14	56%	14	56%	
Rural	11	44%	11	44%	
Total	25	100	25	100	

There was no statistically significant difference in area-wise distribution between the NMES and NON-NMES groups (P > 0.01).

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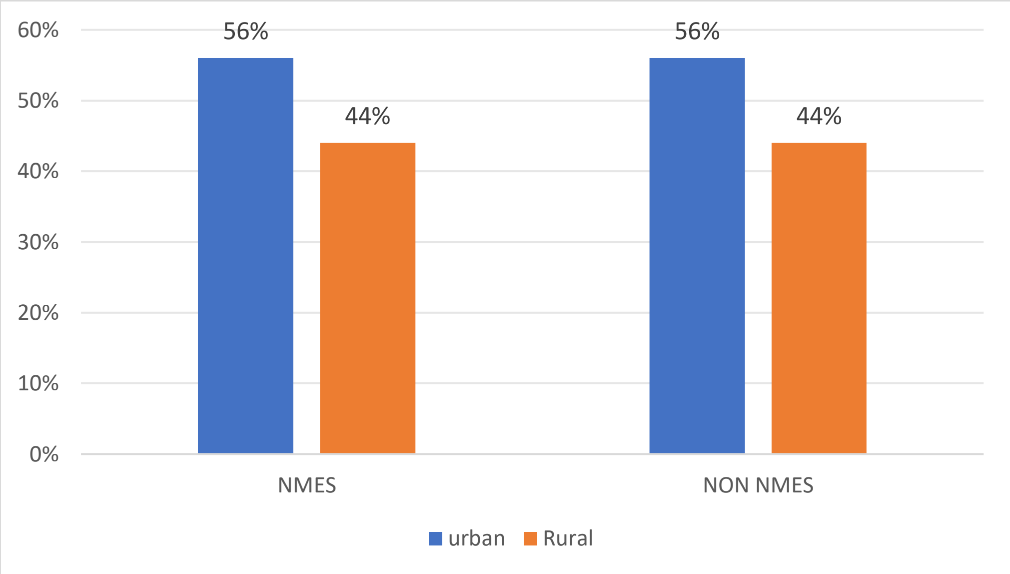

Table 18 Comparison of Age-wise Distribution between NMES and NON NMES

Occupation	NMES (n=25)		Non NMES (n=25)		Statistical Test Value
	Number of Patients	Percentage	Number of Patients	Percentage	X2 = 5.7 P = 0.1 P<0.01(NS)
Housewife	10	40%	12	48%	
Buisnessman	7	28%	8	32%	
Unemployed	5	20%	0	0%	
Retd	3	12%	5	20%	
Total	25	100	25	100%	

There was no statistically significant difference in occupational distribution between the NMES and NON-NMES groups (P > 0.01).

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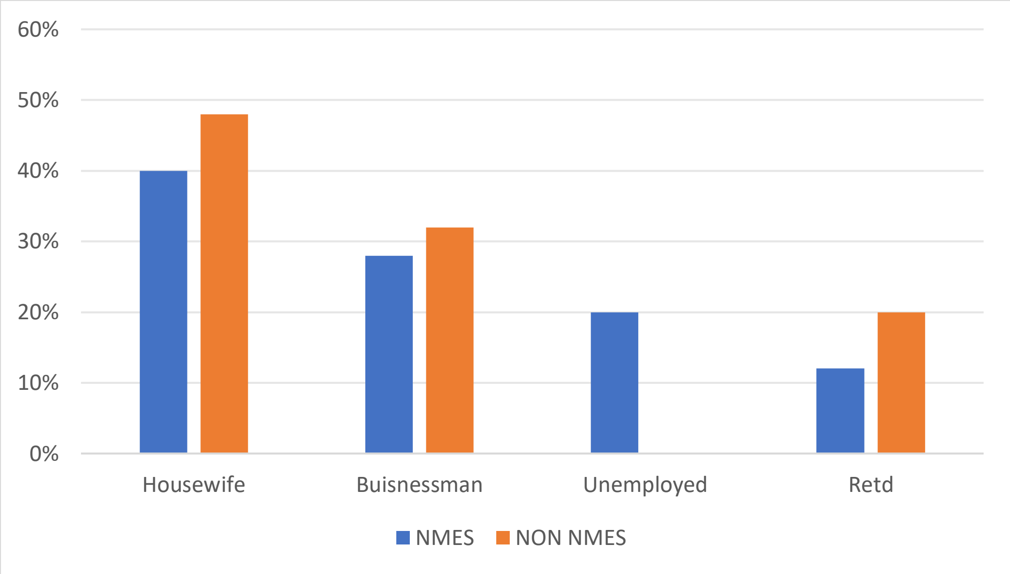

Table 19 Distribution of MAS in NMES and NON NMES pre and post Intervention

MAS	NMES (n=25)	Non NMES (n=25)
	Mean ± SD	Mean ± SD
Pre MAS	2.3 ± 0.49	2.3 ± 0.4
Post MAS	1.8 ± 0.41	1.6 ± 0.5

Both the NMES and NON-NMES groups showed a reduction in MAS scores after intervention compared to pre-intervention values, indicating improvement in muscle spasticity.

Table 20 Distribution of BI left in NMES and NON NMES pre and post Intervention

BI	NMES (n=25)	Non NMES (n=25)
	Mean ± SD(n=30)	Mean ± SD(n=30)
Pre BI	40.3 ± 3.9	39.6 ± 3.5
Post BI	48.8 ± 5.0	49.0 ± 6.5

Both the NMES and NON-NMES groups demonstrated improvement in BI scores after intervention compared to pre-intervention values.

Table 21 Distribution of FMA in NMES and NON NMES pre and post Intervention

FMA	NMES (n=25)	Non NMES (n=25)
	Mean ± SD(n=30)	Mean ± SD(n=30)
Pre FMA	30.7 ± 3.5	30.6 ± 3.5
Post FMA	38.6 ± 6.2	37.6 ± 5.8

Both the NMES and NON-NMES groups showed improvement in FMA scores following intervention compared to pre-intervention values.

Table 22 Comparison of MAS Between and Within NMES and NON NMES

MAS	NMES (n=25)	Non NMES (n=25)	Statistics test value
	Mean ± SD	Mean ± SD	
Pre MAS	2.3 ± 0.49	2.3 ± 0.4	t=0.0,P=1.0,P<0.01(NS)
Post MAS	1.8 ± 0.41	1.6 ± 0.5	t=1.5,P=0.1,P<0.01(NS)
Statistics test value	t = 5.5,P= 0.0001,P<0.01	t = 5.0,P= 0.0001,P<0.01	

There was no statistically significant difference in pre- and post-treatment MAS scores between the NMES and NON-NMES groups (P > 0.05).

Table 23Comparison of BI Between and Within NMES and NON NMES

BI	NMES (n=25)	Non NMES (n=25)	Statistics test value
	Mean ± SD	Mean ± SD	
Pre BI	40.3 ± 3.9	39.6 ± 3.5	t = 0.6,P = 0.5,P<0.01(NS)
Post BI	48.8 ± 5.0	49.0 ± 6.5	t = 0.1,P = 0.9,P<0.01(NS)
Statistics test value	t = 6.6, P = 0.0001,P<0.001(S)	t = 6.4,P = 0.9,P<0.001(NS)	

There was no statistically significant difference in pre- and post-treatment BI scores between the NMES and NON-NMES groups (P > 0.05).

Table 24 Comparison of FMA Between and Within NMES and NON NMES

FMA	NMES (n=25)	Non NMES (n=25)	Statistics test value
	Mean ± SD	Mean ± SD	
Pre FMA	30.7 ± 3.5	30.6 ± 3.5	t = 0.1,P = 0.9,P<0.01(NS)
Post FMA	38.6 ± 6.2	37.6 ± 5.8	t = 0.5,P = 0.5,P<0.01(NS)
Statistics test value	t = 5.5, P = 0.0001,P<0.001(S)	t = 5.13,P = 0.0001,P<0.001(S)	

There was no statistically significant difference in pre- and post-treatment FMA scores between the NMES and NON-NMES groups (P > 0.05).

INTERPRETATION OF RESULTS

The present study was undertaken to compare the effectiveness of Neuromuscular Electrical Stimulation (NMES) combined with conventional physiotherapy and conventional physiotherapy alone in improving motor recovery among patients with subacute ischemic stroke. The outcomes were assessed using the Modified Ashworth Scale (MAS), Barthel Index (BI), and Fugl-Meyer Assessment (FMA). The results demonstrated that both intervention groups showed significant improvement following the treatment period.

A reduction in MAS scores was observed in both groups, indicating a decrease in muscle spasticity after rehabilitation. This improvement may be attributed to the combined effects of stretching exercises, range of motion exercises, positioning, weight-bearing activities, and functional movement training provided during physiotherapy sessions. These interventions are known to improve muscle flexibility, reduce abnormal muscle tone, and enhance neuromuscular control. Although patients in the NMES group showed improvement in spasticity, the difference between the two groups was not statistically significant. This finding suggests that conventional physiotherapy alone was also effective in reducing spasticity in patients with subacute ischemic stroke.

Similarly, both groups demonstrated improvement in Barthel Index scores following the intervention period. The increase in BI scores indicates better functional independence in activities of daily living such as feeding, dressing, grooming, mobility, and transfers. Improvement in functional performance may be explained by regular participation in task-oriented exercises, gait training, balance activities, strengthening exercises, and repeated practice of functional tasks. Since no statistically significant difference was found between the two groups, it appears that both rehabilitation approaches were equally effective in improving functional independence.

Motor recovery assessed using the Fugl-Meyer Assessment also improved significantly in both groups. Improvement in FMA scores reflects enhanced voluntary motor control, improved movement coordination, and better functional use of the affected limbs. Recovery of motor function following stroke is largely dependent on neuroplastic changes occurring within the central nervous system. Early rehabilitation encourages repetitive motor practice and sensory stimulation, which facilitate cortical reorganization and motor relearning. Although the NMES group demonstrated slightly greater improvement in motor recovery scores, the difference was not statistically significant when compared to the conventional physiotherapy group.

The absence of statistically significant differences between the groups may be due to several reasons. Conventional physiotherapy itself is considered one of the most effective treatment approaches for stroke rehabilitation and may have contributed substantially to recovery in both groups. Furthermore, spontaneous neurological recovery commonly occurs during the subacute stage of stroke and may have influenced treatment outcomes. The duration of intervention, sample size, and variability in individual patient characteristics such as stroke severity, lesion location, age, and recovery potential may also have contributed to the findings.

Another possible explanation is that the benefits of NMES may require a longer treatment duration or specific stimulation parameters to produce measurable advantages over conventional physiotherapy alone. While NMES provides additional sensory input and muscle activation, these effects may not always translate into significantly superior functional outcomes within a short rehabilitation period.

Overall, the findings of the present study indicate that both NMES combined with conventional physiotherapy and conventional physiotherapy alone are effective in improving motor recovery, reducing spasticity, and enhancing functional independence in patients with subacute ischemic stroke. Although NMES showed positive clinical effects, it did not demonstrate statistically significant superiority over conventional physiotherapy alone. Therefore, conventional physiotherapy remains a highly effective rehabilitation approach, while NMES may be considered a useful adjunctive treatment modality in selected stroke patients.

DISCUSSION

The present study was conducted to compare the effectiveness of Neuromuscular Electrical Stimulation (NMES) combined with conventional physiotherapy and conventional physiotherapy alone in improving motor recovery among patients with subacute ischemic stroke. Stroke is one of the leading causes of long-term disability worldwide and often results in motor impairments, spasticity, and reduced functional independence. Therefore, identifying effective rehabilitation interventions is essential for maximizing recovery and improving quality of life.

In the present study, motor recovery was assessed using the Fugl-Meyer Assessment (FMA), spasticity was assessed using the Modified Ashworth Scale (MAS), and functional independence was assessed using the Barthel Index (BI). The results demonstrated significant improvements in all outcome measures within both groups following the intervention period. However, no statistically significant difference was found between the NMES group and the conventional physiotherapy group.

The findings showed that participants in both groups experienced significant improvement in motor recovery. In the NMES group, the mean FMA score increased from 30.7 ± 3.5 to 38.6 ± 6.2, whereas in the conventional physiotherapy group it improved from 30.6 ± 3.5 to 37.6 ± 5.8. Improvement in motor function may be attributed to repetitive task-oriented training, strengthening exercises, gait training, balance activities, and motor relearning strategies used during rehabilitation. Recovery of motor function following stroke is strongly associated with neuroplasticity, which allows the brain to reorganize neural pathways and regain lost functions through repetitive practice and sensory stimulation.

NMES has been suggested to enhance motor recovery by stimulating peripheral nerves and producing muscle contractions that mimic voluntary movement. The sensory feedback generated through electrical stimulation may facilitate cortical reorganization and improve motor relearning. The findings of the present study are consistent with those of Kimberley et al. (2003), Powell et al. (1999), and Yan et al. (2005), who reported positive effects of electrical stimulation on motor performance and functional recovery in stroke patients. However, despite the observed improvement, the difference between the NMES and conventional physiotherapy groups was not statistically significant.

Spasticity is one of the common impairments following stroke and often interferes with voluntary movement and functional performance. In the present study, both groups demonstrated a reduction in MAS scores following treatment. The mean MAS score decreased from 2.3 ± 0.49 to 1.8 ± 0.41 in the NMES group and from 2.3 ± 0.4 to 1.6 ± 0.5 in the conventional physiotherapy group. This improvement may be due to the effects of stretching exercises, weight-bearing activities, positioning techniques, and active movement training, which help reduce abnormal muscle tone and improve neuromuscular control. Although NMES is believed to reduce spasticity through reciprocal inhibition and improved muscle activation patterns, the present study did not demonstrate a significant advantage over conventional physiotherapy alone. Similar findings were reported by Setianto et al. (2024), who found improvements in spasticity following NMES treatment but no significant superiority when compared with conventional rehabilitation.

Functional independence is one of the primary goals of stroke rehabilitation. In the present study, both groups demonstrated significant improvement in Barthel Index scores after intervention. The mean BI score improved from 40.3 ± 3.9 to 48.8 ± 5.0 in the NMES group and from 39.6 ± 3.5 to 49.0 ± 6.5 in the conventional physiotherapy group. Improvement in functional independence may be explained by enhanced mobility, improved balance, increased muscle strength, and better motor control achieved through rehabilitation. Repetitive practice of activities of daily living, transfer training, and gait training likely contributed to these positive outcomes. The findings support previous research indicating that structured rehabilitation programs are effective in improving functional abilities among stroke survivors.

Although NMES is widely used as an adjunctive rehabilitation technique, the present study did not demonstrate statistically superior outcomes compared to conventional physiotherapy alone. One possible explanation is that conventional physiotherapy itself is highly effective during the subacute phase of stroke recovery. During this stage, spontaneous neurological recovery and neuroplastic changes are actively occurring, which may contribute significantly to improvements in motor function regardless of additional interventions. As a result, both groups may have benefited substantially from the rehabilitation program, making it difficult to detect additional effects of NMES.

Another possible reason for the lack of significant between-group differences could be the duration of treatment and sample size. It is possible that a longer intervention period or a larger sample size may have demonstrated greater differences between the groups. Individual variations in stroke severity, lesion location, age, motivation, and recovery potential may also have influenced the outcomes. Furthermore, the effectiveness of NMES may depend on factors such as stimulation parameters, treatment intensity, and timing of application, which may vary across studies.

The findings of the present study are in agreement with Busk et al. (2021), who reported that the addition of NMES did not provide significant benefits beyond those achieved through exercise therapy alone. Similarly, Guo et al. (2018) found limited additional effects of NMES in improving upper limb function following stroke. These findings suggest that while NMES may be beneficial as a supplementary rehabilitation modality, its superiority over conventional physiotherapy remains uncertain.

Overall, the present study demonstrated that both NMES combined with conventional physiotherapy and conventional physiotherapy alone were effective in improving motor recovery, reducing spasticity, and enhancing functional independence in patients with subacute ischemic stroke. Although NMES produced positive clinical improvements, it did not show statistically significant superiority over conventional physiotherapy. Therefore, conventional physiotherapy continues to play a central role in stroke rehabilitation, while NMES may be considered as an adjunctive treatment option based on individual patient needs and clinical judgment.

CONCLUSION

The present study compared the effectiveness of Neuromuscular Electrical Stimulation (NMES) combined with conventional physiotherapy and conventional physiotherapy alone in patients with subacute ischemic stroke. The results showed significant improvement in motor recovery, reduction in spasticity, and enhancement of functional independence within both groups following intervention.

However, no statistically significant differences were observed between the two groups in Fugl-Meyer Assessment (FMA), Modified Ashworth Scale (MAS), or Barthel Index (BI) scores. Therefore, the addition of NMES did not demonstrate superior outcomes compared to conventional physiotherapy alone.

It can be concluded that both NMES combined with conventional physiotherapy and conventional physiotherapy alone are effective rehabilitation approaches for improving motor recovery and functional outcomes in patients with subacute ischemic stroke.

CLINICAL IMPLICATIONS

1. Conventional physiotherapy remains an effective and essential intervention for improving motor recovery, reducing spasticity, and enhancing functional independence in patients with subacute ischemic stroke.
2. Neuromuscular Electrical Stimulation may be used as an adjunctive treatment modality in stroke rehabilitation to facilitate muscle activation and motor relearning.
3. Rehabilitation programs focusing on task-oriented training, strengthening exercises, balance training, gait training, and functional activities can significantly improve patient outcomes.
4. Physiotherapists can consider NMES as a supplementary intervention when clinically indicated; however, its routine use may not provide additional benefits beyond those achieved through conventional physiotherapy alone.
5. Early rehabilitation remains crucial for promoting neuroplasticity, preventing secondary complications, and maximizing functional recovery after stroke.

LIMITATIONS

1. The study was conducted on a relatively small sample size, which may limit the generalizability of the findings.
2. The duration of intervention and follow-up period were limited.
3. Long-term effects of NMES on motor recovery and functional outcomes were not evaluated.
4. Participants were recruited from a single clinical setting, which may limit external validity.
5. Variations in stroke severity, lesion characteristics, and individual recovery potential may have influenced the outcomes.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. Future studies should include larger sample sizes to improve the generalizability of findings.

2. Long-term follow-up studies are recommended to evaluate the sustained effects of NMES on stroke recovery.
3. Multicenter trials involving diverse patient populations should be conducted.
4. Future research should investigate different NMES parameters, treatment durations, and stimulation protocols to determine optimal therapeutic effects.
5. Studies comparing NMES with other advanced rehabilitation techniques such as mirror therapy, robotic rehabilitation, virtual reality training, and task-specific training are recommended.
6. Further research should explore the effectiveness of NMES in different stages of stroke recovery and among patients with varying levels of motor impairment.

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