

Effectiveness of Repetitive Transcranial Magnetic Stimulation Combined with Physical Therapy in Post-Ischemic Stroke Rehabilitation: A Quasi-Experimental Study

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ABSTRACT:

Background: Recovery after ischemic stroke requires a multimodal rehabilitation approach to restore neurological function. Repetitive transcranial magnetic stimulation (rTMS) and physical therapy (PT) have demonstrated effectiveness in enhancing neuroplasticity and improving functional outcomes. Nurses play a key role in coordinating care, monitoring patient progress, ensuring safe intervention delivery, and supporting patient education and adherence to rehabilitation programs.

Aim: This study aimed to evaluate the effectiveness of physical therapy alone compared with combined rTMS and physical therapy in improving neurological recovery among post-ischemic stroke patients using the National Institutes of Health Stroke Scale (NIHSS).

Methods: A quasi-experimental, multiple-group pre-post intervention study was conducted at Shar Hospital, Sulaimani, Iraq. Sixty patients with ischemic stroke were purposively allocated into two groups: PT alone and rTMS combined with PT. Interventions were implemented over six months duration, with the combined group receiving 20 rTMS sessions alongside routine physical therapy. Neurological outcomes were assessed at pre-, mid-, and post-intervention stages using the NIHSS.

Results: Mean NIHSS scores decreased significantly from 10.87 at baseline to 6.58 at mid-intervention and 4.17 post-intervention, reflecting a clinically meaningful reduction of 6.70 points ($p < 0.001$). Both groups showed improvement, with greater reductions observed in the combined therapy group.

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Conclusion: Combined rTMS and physical therapy was associated with greater neurological improvement than physical therapy alone, suggesting that integrating neuromodulation may enhance post-stroke rehabilitation outcomes.

Keywords: Ischemic stroke, repetitive transcranial magnetic stimulation, physical therapy, NIH Stroke Scale.

Introduction

Stroke is a major cerebrovascular disease and is recognized as one of the leading global causes of death and long-term disability, consistently ranking among the top five worldwide [1]. It typically presents with the sudden onset of neurological signs and symptoms reflecting focal cerebral dysfunction. Common manifestations include unilateral weakness or numbness of the face, arm, or leg, often with characteristic facial drooping and impaired motor control. Other symptoms may include speech disturbances, such as dysarthria or aphasia; sudden visual impairment in one or both eyes; loss of coordination; imbalance; dizziness; severe headache; and confusion [2]. Stroke is generally classified into ischemic stroke, hemorrhagic stroke, and transient ischemic attack (TIA). Ischemic stroke, which results from arterial obstruction caused by a thrombus or embolus, is the most common type and accounts for approximately 85% of all stroke cases [3]. In contrast, hemorrhagic stroke results from bleeding into brain tissue or the subarachnoid space, most commonly due to vascular rupture or anticoagulation-related coagulopathy. Hemorrhagic stroke may be further subdivided into intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH); ICH is bleeding into the brain parenchyma, and SAH is bleeding into the subarachnoid space. Hemorrhagic stroke is associated with severe morbidity and high mortality [4]. TIA is a medical emergency. It is defined as a transient episode of neurologic dysfunction due to focal brain, spinal cord, or retinal ischemia without acute infarction or tissue injury [5]. The pathophysiology of cerebrovascular accident (CVA), commonly known as stroke, occurs when blood flow to the brain is disrupted either by arterial blockage in ischemic stroke or by vascular rupture

in hemorrhagic stroke, resulting in potential brain injury or death [6].

Physiotherapy programs emphasizing functional exercise and movement therapy have randomized trial support for rapid gains in balance and activities of daily living. One seven-day randomized trial found a combined neuro-restoration physiotherapy protocol improved Berg Balance Scale and Barthel Index scores compared with conventional physiotherapy in stroke patients, produced statistically significant improvements in balance and functional performance versus control group [7]. Several trials are testing or piloting combinations of exercise with electrical or magnetic stimulation to boost neuroplasticity and gait/balance outcomes, indicating a research focus on synergy rather than replacement of physiotherapy [8, 10]. Evidence shows that early rehabilitation interventions, such as mobilization within 24–72 hours after stroke onset, significantly enhance functional recovery, improve activities of daily living (ADLs), and reduce complications associated with immobility [9].

Evidence indicates that recovery begins immediately after the onset of stroke due to spontaneous brain repair mechanisms, followed by a critical period in the first days to weeks where neurological recovery is most rapid and responsive to rehabilitation. Over time, recovery continues into the chronic phase, although improvements become slower and more dependent on structured neurorehabilitation strategies [11]. However, research does not define a single optimal timeframe within the broader 7–90-day period. Instead, it highlights a flexible, early phase of neuroplastic potential, where the timing of rehabilitation should be tailored to the type of intervention and the patient's individual condition [12].

Recovery following ischemic stroke is largely mediated by neuroplasticity, whereby intact brain regions recognize and compensate for damaged neural networks. Repetitive transcranial magnetic stimulation (rTMS) is a non-invasive neuromodulation technique that modulates cortical excitability, and has been shown to enhance neuroplasticity, thereby supporting motor recovery in stroke survivors [13, 14]. Physical therapy remains the cornerstone of stroke rehabilitation, promoting recovery through task-specific practice, strengthening sensory and motor re-education. Initial evidence suggests that collective physical therapy approaches integrating rTMS with physical therapy leverage the neurophysiological benefits of both modalities [15]. Neurorehabilitation and neurotherapy play a critical role in enhancing recovery following stroke by promoting neuroplasticity, restoring motor function, and improving activities of daily living (ADLs). Stroke commonly results in long-term disability, with more than half of survivors experiencing persistent functional impairments, particularly in motor control and upper-limb function [16]. Evidence indicates that structured rehabilitation approaches, including motor learning and task-oriented therapy, facilitate functional recovery by optimizing remaining neural pathways and compensatory mechanisms. In addition, neurotherapy techniques such as repetitive transcranial magnetic stimulation (rTMS) provide non-invasive cortical modulation, enhancing cortical excitability and promoting synaptic reorganization depending on stimulation parameters such as frequency and intensity [17]. Another study concluded that combining high frequency rTMS and cognitive rehabilitation significantly improves cognitive function, promotes physical activity recovery, enhances daily self-care ability, and effectively reduces the patients experiencing cognitive impairment after an ischemic stroke. This triple combination therapy yielded the most pronounced therapeutic benefits [18].

Nurses play a central role in stroke recovery by monitoring neurological status, preventing complications, and delivering evidence-based care. They support rehabilitation through mobility assistance and ADL training, provide patient and

family education on prevention and risk management, and offer psychological support. Nurses also coordinate care, ensure safety, and advocate for patients. Their role in neurological rehabilitation is essential in promoting neuroplasticity, enhancing functional independence, and improving quality of life for stroke survivors. This study exemplifies advanced nursing practice in integrating neuromodulation technology into holistic patient care to reduce long-term dependency.

Objectives

The study aimed to determine the sociodemographic and clinical characteristics of post-ischemic stroke patients admitted to the Neurology Department of Shar Hospital. It also sought to implement neurological rehabilitation interventions, including physical rehabilitation alone and a combined approach. Furthermore, the study aimed to evaluate and compare the effectiveness of physical therapy alone versus combined rTMS and physical therapy in improving neurological recovery among ischemic stroke patients, using the National Institutes of Health Stroke Scale (NIHSS) tool to assess the severity of neurological deficit in stroke patients.

Methods and materials

Study Design and Setting This study employed a quasi-experimental, multiple-group pre-post-intervention design. A total of 60 patients diagnosed with ischemic stroke were recruited using a non-probability purposive sampling technique, in which participants were selected based on predefined eligibility criteria, rather than randomization. The study was conducted at the Neurology Department of Shar Hospital, located in Sulaimani city, Kurdistan Region of Iraq, which serves as the major and only referral center for neurological care in the city.

Study Population and Sampling: The study population consisted of post-ischemic stroke participants who were allocated equally into two groups (30 patients per group), Physical therapy (PT) Group and Combined Therapy Group (rTMS + PT). with a National Institutes of Health Stroke

Scale (NIHSS) for assessment. Participants were categorized into two severity levels: moderate stroke (NIHSS 5–15) and moderate-to-severe stroke (NIHSS 16–20).

Inclusion Criteria

- Participants aged between 20 and 80 years
- Diagnosed with ischemic stroke
- NIHSS score between 5 and 20
- Medically stable and able to participate in rehabilitation sessions and clinical assessments.

Exclusion Criteria

- Hemorrhagic stroke or transient ischemic attack (TIA)
- Severe comorbid medical conditions that could interfere with rehabilitation
- Age greater than 80 years
- NIHSS score below 5 and above 20

Intervention protocol

The intervention consisted of a structured neurorehabilitation program, delivered over a six-month period for total process being performed. Participants were allocated into two intervention groups:

1. Standardized Physical Therapy (PT) Group

Each participant received 20-25 structured physical therapy sessions based on established stroke rehabilitation guidelines, supervised by the researcher and conducted five times per week for about 45 minutes. The program aimed to improve motor function, coordination, independence, and cognitive performance through exercises such as range of motion, strengthening, balance training, gait training, and task-oriented activities. Participants were recruited sequentially over a study period of more than six months, and each completed the required sessions according to an individualized schedule, ensuring consistent exposure to the intervention.

2. Combined Therapy Components Group (rTMS + Physical therapy)

The combined intervention group received a structured and integrated neurorehabilitation program delivered over approximately 25 days for each participant.

Device and Stimulation Approach, the intervention was delivered using a brain electrical and magnetic combined stimulation device (HB-500 series, Haobro Medical Device), Coil Model HB-HW500 which integrates: Repetitive transcranial magnetic stimulation (rTMS) via a therapeutic cap, electrical stimulation (FNS and NMES), frequency vibration stimulation, as described in the device manual, the system applies alternating electromagnetic fields through a multi-point therapeutic cap to stimulate cortical regions and promote neuroplasticity. The protocol comprised 20 sessions of repetitive transcranial magnetic stimulation (rTMS), administered at a frequency of five sessions per week with scheduled rest intervals between treatment phases to optimize cortical responsiveness and prevent neural fatigue. Each rTMS session lasted approximately 30–45 minutes, consistent with standard neuromodulation protocols. This combined therapeutic approach was designed to enhance neuroplasticity, improve cortical reorganization, and accelerate functional recovery in post-stroke patients through synergistic neuromodulator and rehabilitative mechanisms.

Repetitive transcranial magnetic stimulation (rTMS) Protocol and Parameters rTMS is a non-invasive neuromodulation technique that utilizes time-varying electromagnetic fields to induce electric currents within targeted cortical regions, thereby modulating neuronal excitability and promoting synaptic plasticity. In this study, rTMS was delivered using a multifunctional brain stimulation device capable of combining magnetic stimulation with adjunctive electrotherapy and neuromuscular activation. The stimulation protocol incorporated multiple operational modes, including regular, impulse, and continuous modes, allowing flexibility in neuromodulation patterns based on patient-specific neurological status. Treatment intensity was progressively titrated from low to moderate and higher levels according to patient tolerance and clinical progression, ensuring both safety and therapeutic efficacy.

Key stimulation parameters included:

Session duration: 30–45 minutes per session.
Treatment frequency: 5 sessions per week, rTMS

head cap and focus on primary motor cortex (M1) of the brain region. Magnetic intensity modulation: Gradual increase from low to high levels and Magnetic field characteristics: Approximately 3–17 Motor threshold with controlled oscillatory output.

Treatment modes: Regular, continuous, and impulse stimulation, all stimulation modes were applied, with continuous mode used most frequently. Adjunctive vibration stimulation: Applied at low, medium, and high levels to facilitate neuromuscular activation and enhance cortical-sensorimotor integration. Importantly, the device incorporates a dynamic randomized frequency modulation system, in which four unique therapeutic frequencies are delivered in a non-repetitive pattern: Total Pulses: approximately 3,000 pulses (commonly 10 Hz). This randomized frequency paradigm is designed to prevent cortical habituation to fixed stimulation patterns, thereby maintaining sustained neuromodulator efficacy and enhancing long-term neuroplastic adaptation. Such variability in stimulation frequency may contribute to broader activation of neural networks and improved functional recovery outcomes. adverse events were monitored throughout the rTMS intervention. Participants were screened before each session for contraindications (e.g., seizures, implanted devices, major cardiac conditions) and clinical stability. Patients were observed during and after treatment for headache, dizziness, scalp discomfort, fatigue, nausea, mood changes, or neurological deterioration.

Assessment Time Points (Standardized Definition):

Pre-intervention (Baseline): Conducted prior to the first treatment session (Session 0) Mid-intervention: Conducted after completion of 10 sessions in 10 days. And 5 days' rest also Post-intervention: Conducted immediately after completion of 20 sessions (approximately 5 sessions per Week). This standardized framework has been applied consistently across both study arms: Physical Therapy (PT) group: 20 sessions of conventional rehabilitation rTMS + PT group: 20 sessions of combined rTMS and physical therapy delivered within the same session schedule.

Therapeutic Rationale

The integration of rTMS with conventional physical therapy and adjunctive electro-neuromodulation techniques provides a comprehensive rehabilitation strategy. This multimodal approach targets both central and peripheral components of neurological recovery, promoting cortical excitability, improving synaptic efficiency, enhancing motor relearning, and ultimately accelerating functional independence in post-ischemic stroke patients.

Outcome Measure

Neurological status was evaluated using the National Institutes of Health Stroke Scale (NIHSS), a validated and widely used clinical instrument for assessing stroke severity by the nurses for initial assessment.

The NIHSS measures multiple neurological domains, including:

- Level of consciousness
- Motor strength
- Sensory function
- Visual fields, speech and Coordination.

NIHSS scores range from 0 to 42, with higher scores indicating greater neurological impairment.

Stroke severity was classified as follows:

- Mild: 1–4
- Moderate: 5–15
- Moderate to severe: 16–20
- Severe: 21–42

Ethics approval and consent to participate

All patients provided informed consent directly or via a legal proxy. The study was ethically approved by the College of Nursing at the University of Raparin and the General Directorate of Health in Sulemani. The study protocol was reviewed and approved by the local medical ethics board of the College of Nursing from the University of Raparin and an ethical committee from the General Directorate of Health in Sulemani. Ethical approval was granted by the College of Nursing, Scientific and Ethical Committees, University of Raparin (Approval No. 14, August 15, 2024 – IRB).

Data Collection procedure Data were collected using a structured questionnaire covering sociodemographic and clinical characteristics, NIHSS assessment tool, and intervention-related information. Measurements were conducted at three time points pre-, mid-, and post-intervention. All data were recorded, verified, and entered for statistical analysis.

Sample Size The sample size for this quasi-experimental pre–post intervention study was determined based on feasibility and consistency with similar neurorehabilitation studies. A total of 60 post-ischemic stroke patients were equally allocated into two groups: physical therapy (PT) and combined rTMS with PT. Each participant received 20 structured sessions, with the combined group integrating rTMS and rehabilitation under close supervision. This resulted in approximately 600 sessions per group and 1,200 sessions overall during the six-month study period. Participants were enrolled sequentially, with each patient completing the intervention over 25 to 30 days. The intensive and complex nature of the protocol supports the adequacy of the selected sample size.

Data analysis: The data were collected through the standard questionnaire consisting of four parts: socio-demographic characteristics, clinical characteristics, NIHSS assessment tool, and intervention part regarding rTMS and PT. All data were summarized using descriptive statistics. Categorical variables were described using frequencies and percentages. Continuous variables were described using means and SDs (standard deviations) and ranges. The data was analyzed by SPSS, version 28.

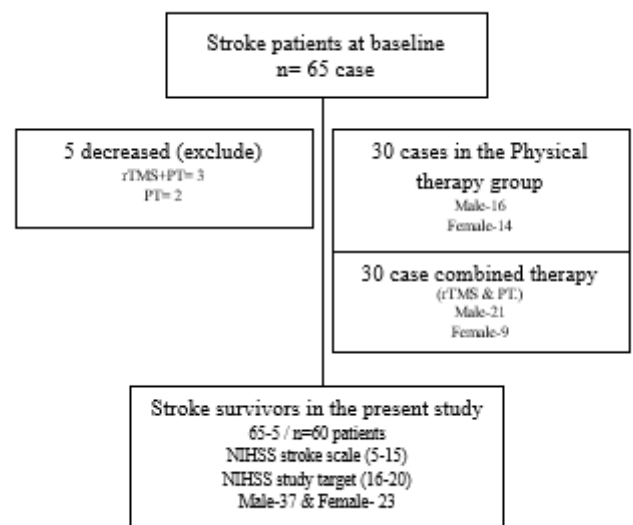


Figure. 1: The flow chart of the article illustrates the map of the study work.

This flowchart illustrates the participant selection and group allocation process. Initially, 65 stroke patients were assessed, and 5 were excluded due to incomplete procedures. The final sample included 60 patients, equally assigned to two groups: a physical therapy (PT) group and a combined rTMS + PT group. The PT group included both male and female participants receiving conventional rehabilitation, while the combined group received both rTMS and physical therapy. Overall, the sample consisted of more males than females, with participants presenting mild to moderately severe stroke based on NIHSS scores.

Results:

Table (1): Sociodemographic characteristics of participants.

Socio demographic			Fr. (%)		
Age Group	< 60	26(43.3)	Occupational Status	Employed	8(13.3)
	60 – 70	18(30.0)		Unemployed	52(86.7)
	> 70	16(26.7)	Smoking Cigarette	Current smoker	10(16.7)
Gender	Male	37(61.7)		Ex-smoker	20(33.3)
	Female	23(38.3)		Never smoker	30(50.0)
Level of Education	No official schooling	36(60.0)	How Many Cigarettes per Day	1–10 cig.	3(5.0)
	Basic/High school	20(33.3)		11–20 cig.	13(21.7)
	University level	4(6.7)		Over 20 cigs.	14(23.3)

Marital Status	Single	1(1.7)	Type of Smoking	None (0 cig.)	30(50.0)
	Married	59(98.3)		Cigarette	30(50.0)
Types of Job	Office job	3(5.0)		Years of Smoking	None
	Labor job	28(46.7)	5–10 years		3(5.0)
	Jobless	2(3.3)	11–20 years		14(23.3)
	Retired	7(11.7)	21–30 years		8(13.3)
	Housewife	19(31.7)	31–40 years		5(8.3)
	Student	1(1.7)	None		30(50.0)
	Economic Status	Exceeds needs	6(10.0)		Alcohol Drinking
Sufficient		19(31.7)	Occasionally	1(1.7)	
Barely sufficient		34(56.7)	Non-drinker	57(95.0)	
Insufficient		1(1.7)			
Total		60 (100)	Total		60(100)

Table (1) shows that the participants were mainly middle-aged males, married, and of low educational and economic status. Most were unemployed, with limited income, and had no formal education. About half were non-smokers, while the rest were

current or former smokers, and alcohol use was rare. Overall, the sample reflects low socioeconomic status with minimal alcohol use but varied smoking behaviors.

Table (2): Compare the Total score of the NIHSS between (Pre. Middle and Post)

NIHSS	N	Mean	S. D	T-test	P-value	Results
Pre	60	10.87	4.428	14.378	<0.001	Significant
Middle	60	6.58	4.126			
Pre	60	10.87	4.428	18.948	<0.001	Significant
Post	60	4.17	3.678			
Middle	60	6.58	4.126	12.394	<0.001	Significant
Post	60	4.17	3.678			

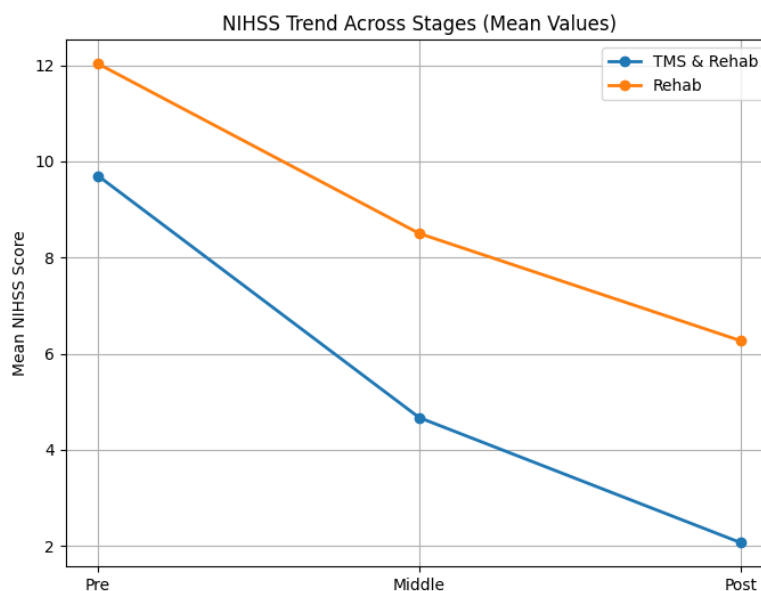
Table (2) presents a comparison of NIHSS total scores across three assessment periods: pre-intervention, middle, and post-intervention demonstrating a statistically significant enhancement over time. The findings demonstrate a progressive and statistically significant reduction in NIHSS scores across all assessment phases, indicating continuous improvement in neurological status. All comparisons between assessment stages were highly significant, confirming that the intervention effectively reduced neurological impairment and enhanced patient recovery over time.

Table (3): Compare the Total score of the NIHSS between groups in (Pre. Middle, Post)

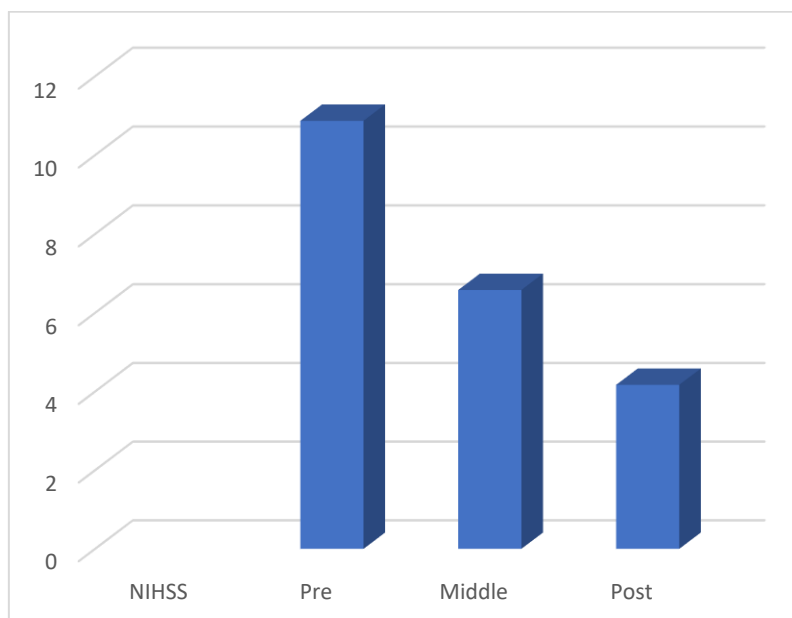
NIHSS		N	Mean	S. D	t-test	P-value	Results
Pre	TMS & Rehab.	30	9.70	3.515	-2.099	0.04	Significant
	Rehab.	30	12.03	4.972			
Middle	TMS & Rehab.	30	4.67	2.928	-4.038	0.002	Significant
	Rehab.	30	8.50	4.297			
Post	TMS & Rehab.	30	2.07	2.348	-5.362	0.001	Significant
	Rehab.	30	6.27	3.591			

The results show that both groups improved over time; however, the TMS + rehabilitation group consistently had lower NIHSS scores compared to the rehabilitation-only group at all assessment stages. This indicates better neurological recovery in the combined therapy group. The differences

between groups were statistically significant at baseline, middle, and post-intervention, with the gap widening over time, demonstrating that rTMS enhances the effectiveness of conventional rehabilitation.



Graph 2: NIHSS score declined in both methods of intervention from both groups. Then combined group intervention shows accelerated post-stroke recovery. This indicates that both treatments are effective, Combined therapy appears to be more effective; rTMS enhances recovery over time and Improvement is progressive and sustained.



Graph 3: The downward NIHSS scores reflect a continuous improvement in neurological status among the patients. The most substantial improvement appears between the pre- and middle stages, with further gains observed by the end of the intervention. Overall, the chart demonstrates that the rTMS+PT program was effective in reducing stroke severity, leading to improved neurological outcomes over time.

Discussion: Main Findings

The present study investigated the comparative effectiveness of repetitive transcranial magnetic stimulation (rTMS) combined with Physical therapy (PT) versus physical therapy alone in the rehabilitation of post-ischemic stroke patients, as measured by changes in National Institutes of Health Stroke Scale (NIHSS) scores. The results demonstrated that both intervention groups experienced significant neurological improvement across the rehabilitation period. However, the group receiving the combined rTMS and physical therapy intervention achieved significantly greater reductions in NIHSS scores compared with the physical therapy-only group. These findings indicate that integrating neuromodulation techniques with conventional rehabilitation may enhance neurological recovery and improve functional outcomes in individuals with ischemic stroke. The progressive reduction in neurological deficits observed during the intervention period also suggests that structured rehabilitation programs play a critical role in promoting recovery by the nurses during the early and subacute phases following stroke.

In **Table 1** The study population was mainly middle-aged to older adults, with more males affected by post-ischemic stroke. Most participants had low education levels, were married, and lived with limited financial resources, indicating low socioeconomic status. Unemployment was common, and while alcohol use was low, smoking remained a notable risk factor. Overall, the findings reflect a vulnerable population in which socioeconomic constraints and lifestyle factors may influence stroke risk, access to care, and rehabilitation outcomes, highlighting the need for tailored and accessible interventions. The prevalence of middle-aged and older male participants is consistent with evidence indicating that males have a higher risk of ischemic stroke at younger ages, mostly due to greater exposure to modifiable vascular risk factors [3]. The higher proportion of married participants and participants with low educational attainment mirrors previous

findings showing that limited education is strongly associated with increased stroke incidents, poor health literacy and delayed care-seeking behaviors [19].

Regarding **Table (2)**, The comparison of NIHSS total scores across three assessment periods pre-intervention, middle, and post-intervention demonstrating a statistically significant improvement over time. The findings demonstrate a progressive and statistically significant reduction in NIHSS scores across all assessment phases, indicating continuous improvement in neurological status. All comparisons between assessment stages were highly significant, confirming that the intervention effectively reduced neurological impairment and enhanced patient recovery over time. The mean NIHSS score decreased markedly from baseline to middle and post-intervention, reflecting substantial recovery. The high t-value and highly significant p-value further confirm the robustness of this improvement. Overall, these results indicate a strong therapeutic effect of the intervention in reducing stroke severity. These findings are consistent with the present study, suggesting that the addition of neuromodulation techniques such as rTMS can accelerate and enhance functional recovery, particularly in activities of daily living. Previous research also supports this observation, highlighting that post-stroke motor impairments, especially lower limb dysfunction significantly affects mobility and quality of life. In this context, rTMS, particularly when applied using double-cone coils for deeper cortical stimulation, represents a promising approach for improving motor recovery, although its efficacy and safety still require further investigation [20].

Table (3) the rTMS + rehabilitation group demonstrated significantly greater improvement in NIHSS scores compared with rehabilitation alone. Despite slightly lower baseline scores, the rTMS group showed faster neurological recovery, achieving significantly lower scores at both mid- and post-intervention stages. These findings indicate that adding rTMS enhances stroke recovery and leads to greater reductions in stroke severity than conventional rehabilitation alone. This meta-analysis of 68 randomized controlled trials found

that repetitive transcranial magnetic stimulation (rTMS) significantly improved upper limb motor function and reduced spasticity after stroke, but had no significant effects on lower limb outcomes [21].

Figure 2 illustrates a progressive decline in NIHSS scores across all assessment stages in both groups, indicating continuous neurological improvement over time. However, the TMS & Rehabilitation group demonstrates a more rapid and greater reduction in scores compared to the Rehabilitation-only group. While both interventions are effective, the combined approach results in superior recovery, suggesting that the addition of rTMS enhances neurological improvement and accelerates post-stroke recovery. In this article following stroke were compared and the results indicated that rTMS facilitates neuromodulation, which leads to more effective rehabilitation than with occupational therapy alone [20]. also, in other research combines repetitive transcranial magnetic stimulation (rTMS) with conventional rehabilitation therapies to enhance upper limb motor function recovery in three early subacute ischemic stroke patients, yielding significant gains and independence in daily activities [22].

The **graph-3** illustrates a steady decline in mean NIHSS scores from pre- to middle- and post-intervention stages, indicating continuous neurological improvement over time. This gradual reduction reflects effective recovery, with the most notable improvement observed by the post-intervention phase. The finding indicate that, in this trial, adding 1 Hz rTMS to conventional rehabilitation yielded larger early and sustained reductions in neurological deficit as measured by NIHSS compared with rehabilitation alone or other groups [23]. In other study shows that rTMS is an effective intervention for improving lower limb motor function and daily living activities (as measured by BI) in stroke patients, particularly when low-frequency stimulation is applied during the subacute phase (within 6 months) with a treatment duration of 15 days or less [24].

Neuroplasticity and Mechanisms of Improvement

The neurological improvements observed in the present study can be explained by the principles of activity-dependent neuroplasticity, which emphasize the brain's ability to reorganize neural pathways following injury. Repetitive transcranial magnetic stimulation acts as a non-invasive neuromodulation technique that modulates cortical excitability and facilitates synaptic plasticity within the motor cortex. When applied alongside structured physical therapy, rTMS may enhance corticospinal connectivity and improve interhemispheric balance between the affected and unaffected hemispheres. This neuromodulators effect can create a more favorable neural environment for motor relearning during rehabilitation exercises. Contemporary neurorehabilitation research indicates that combining cortical stimulation with task-specific training promotes long-term potentiation and facilitates the reorganization of neural networks involved in motor control [25]. Therefore, the greater neurological improvement observed in the combined therapy group may reflect the synergistic interaction between neuromodulation-induced cortical priming and repetitive motor practice.

Comparison with Previous Studies

The findings of the present study are consistent with a growing body of evidence supporting the use of rTMS as an adjunctive therapy in stroke rehabilitation. Previous clinical studies have reported that high frequency rTMS applied to the affected motor cortex can significantly improve motor function and neurological recovery among stroke survivors. For instance, this study demonstrated that rTMS enhances cortical reorganization and improves motor performance when integrated with rehabilitation programs [26]. Also this study reported that combining rTMS with task-oriented physical therapy resulted in greater improvements in functional independence compared with conventional rehabilitation alone [13]. Meta-analyses of neurostimulation interventions have also concluded that rTMS facilitates motor recovery by modulating cortical excitability and strengthening neural connectivity involved in motor control [27]. These findings align closely with the results of the present study, where

the combined therapy group exhibited greater neurological improvement across the intervention period.

Explanation for Superiority of Combined Therapy

The superior outcomes observed in the combined therapy group can be attributed to the complementary mechanisms of rTMS and physical rehabilitation. While rTMS modulates cortical excitability and promotes neuroplastic reorganization, physical therapy reinforces these neural adaptations through repetitive, task-specific motor training. This combination may enhance sensorimotor integration and facilitate more efficient motor relearning processes. Furthermore, the early initiation of rehabilitation in the acute and subacute phases of stroke recovery may have further optimized treatment outcomes, as neural plasticity is particularly active during this period [25]. The structured rehabilitation program implemented in the present study also ensured sustained therapeutic exposure, which may have contributed to the consistent neurological improvements observed across the assessment points. These findings support the growing consensus that multimodal rehabilitation strategies integrating neuromodulation and conventional therapy may offer greater benefits than single-modality interventions in post-stroke recovery [27].

Study Limitations

Despite the encouraging findings, several limitations should be considered. The study used a quasi-experimental design with purposive sampling and non-randomized group allocation, which may introduce selection bias and limit generalizability. The relatively small sample size and single-center setting also reduce external validity. In addition, the study did not include long-term follow-up to determine whether the observed neurological improvements were sustained over time. Variations in stroke characteristics, lesion location, and patient adherence to rehabilitation may also have influenced the outcomes. Future research should employ larger multicenter samples and extended follow-up periods to strengthen the evidence regarding the long-term effectiveness of combined

neuromodulation and rehabilitation in stroke recovery.

Baseline Differences Between Groups

A statistically significant difference in baseline NIHSS scores between the two groups was observed. However, this difference may be explained by practical challenges in recruiting stroke patients with identical severity levels for both intervention groups. In a real clinical setting, recruitment of patients with comparable baseline severity was challenging in clinical practice. Patients in the combined therapy group (rTMS + physical therapy) were mainly selected from those with mild to moderate stroke severity who were physically able to attend repeated hospital sessions required for rTMS treatment. Patients with more severe neurological impairment often experience mobility limitations and may be unable to visit the hospital regularly for therapy. Therefore, the allocation reflects practical rehabilitation conditions rather than strict experimental selection. Despite the baseline difference, both groups showed significant neurological improvement during the rehabilitation program.

Conclusion

The findings of this study indicate that integrating repetitive transcranial magnetic stimulation (rTMS) with conventional physical therapy may contribute to improved neurological recovery in patients with post-ischemic stroke compared with physical therapy alone. While both interventions improved neurological status over time, greater reductions in stroke severity were observed in patients receiving combined therapy, suggesting additional benefits from neuromodulation within structured rehabilitation programs. In this context, nurses play a critical role in supporting the implementation of multimodal rehabilitation by monitoring neurological status, ensuring the safe delivery of rTMS sessions, coordinating interdisciplinary care, and reinforcing therapeutic activities. They also contribute to patient and family education, promote adherence to rehabilitation protocols, and facilitate recovery of activities of daily living. These findings support the importance of integrating nursing care within advanced rehabilitation strategies that

combine neural modulation and functional training to enhance neuroplasticity and accelerate post-stroke recovery.

Clinical Implications

From a clinical perspective, the findings highlight the potential value of incorporating non-invasive brain stimulation techniques such as rTMS into standard stroke rehabilitation protocols. Combining neuromodulation with task-oriented physical therapy may facilitate motor relearning, improve neurological outcomes, and enhance functional independence among stroke survivors. Nurses play a pivotal role in this integrated approach by coordinating care, monitoring patient responses, ensuring safety during rTMS sessions, and reinforcing rehabilitation activities. They are also essential in patient and family education, promoting adherence to therapy, and supporting early mobilization and self-care activities. Within multidisciplinary stroke teams, nurses contribute to the implementation and continuity of technology-assisted interventions, particularly during the early stages of recovery when neuroplasticity is most responsive. Therefore, integrating rTMS with rehabilitation not only enhances clinical outcomes but also strengthens the nursing role in delivering comprehensive, patient-centered stroke care.

Policy Implications for Stroke Rehabilitation Programs

The results of this study also carry important implications for healthcare policy and rehabilitation planning. With the increasing global burden of stroke-related disability, integrating cost-effective neuromodulation technologies into national stroke rehabilitation programs may help improve population-level recovery outcomes and reduce long-term disability. Investment in rehabilitation infrastructure, professional training, and access to advanced neurorehabilitation technologies could significantly strengthen stroke care systems, particularly in low- and middle-income regions

where rehabilitation resources are limited. The adoption of evidence-based multimodal rehabilitation strategies may therefore contribute to appears to be more effective and sustainable stroke rehabilitation services. Also, this study advances knowledge by introducing rTMS as a new neurorehabilitation service in Iraq and the Kurdistan Region, demonstrating its feasibility and effectiveness in resource-limited settings. It also emphasizes the essential role of nurses in patient assessment, monitoring, education, and care coordination, which supports neuroplasticity, improves functional recovery, and ensures the safe implementation of rTMS in clinical practice.

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Author Contributions

Peshraw Kh. Ibrahim contributed to the study conception and design, methodology development, data collection, statistical analysis and drafting of the manuscript, Pary M. Aziz and Zana A. Mohammed contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Data Availability

The data comes from Shar Hospital patients, Neurology Department.

Competing interests

The authors declare no competing interests.

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