RESEARCH PAPER

Effect of Structured Physiotherapy on Cognitive Function, Motor Recovery and Inflammatory Blood Biomarkers in Patients with Ischemic Stroke: A 6-Month Clinical Study

Dr. Versha Prasad[1*], Ankit Tiwari[2], Satyam Kushwaha[2], Agam Singh[2]

[1*]M.B.B.S., M.B.A. (Gold Medalist), Assistant Professor, School of Health Sciences, C.S.J.M University, Kanpur, UP, India (Corresponding Author)

[2]M.Sc. MLT Pathology, School of Health Sciences, C.S.J.M University, Kanpur, UP, India

ABSTRACT

INTRODUCTION: Ischemic stroke is a major cause of long-term neurological disability, commonly affecting motor control, balance, cognition, and functional independence. Inflammation has been identified as an important biological factor influencing post-stroke recovery. Physiotherapy remains the primary intervention for neurorehabilitation; however, limited longitudinal evidence is available correlating functional outcomes with inflammatory blood markers in non-diabetic stroke patients. To evaluate the effect of a structured physiotherapy rehabilitation program on motor function, balance, cognitive performance, functional independence, and inflammatory blood markers in non-diabetic ischemic stroke patients over a six-month period. A prospective interventional study of six months' duration was conducted on 155 non-diabetic ischemic stroke patients recruited from GSVM Medical College, Kanpur, and the School of Health Sciences, CSJM University, Kanpur. All participants received a standardized physiotherapy program focusing on motor relearning, balance training, functional task practice, and cognitive facilitation. Clinical outcome measures were recorded at baseline, 1st month, 3rd month, and 6th month. Inflammatory biomarkers, including C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR), were analyzed predominantly in the Pathology Laboratory of the School of Health Sciences, CSJM University, Kanpur. A consistent improvement was observed across all clinical outcome measures during the six-month rehabilitation period. Motor function scores increased from 38 at baseline to 45 at 1st month, 56 at 3rd month, and 68 at 6th month. Balance scores demonstrated progressive improvement from 22 at baseline to 30, 38, and 48 at subsequent follow-ups. Functional independence scores improved from 42 at baseline to 55 at 1st month, 68 at 3rd month, and 82 at 6th month. Cognitive performance also showed gradual enhancement, with scores increasing from 20 at baseline to 23, 26, and 28 over the study duration. Inflammatory biomarker analysis revealed a steady reduction, with CRP levels decreasing from 9.2 mg/L at baseline to 7.8 mg/L, 5.6 mg/L, and 3.9 mg/L, while ESR values reduced from 32 mm/hr to 28 mm/hr, 22 mm/hr, and 18 mm/hr by the end of six months. The findings demonstrate that a structured physiotherapy rehabilitation program leads to significant improvement in motor, balance, cognitive, and functional outcomes in non-diabetic ischemic stroke patients. The parallel reduction in inflammatory markers suggests a favorable association between physiotherapy intervention and modulation of post-stroke inflammatory responses. These results support the importance of integrated functional and biochemical assessment in stroke rehabilitation.

Keywords: Ischemic Stroke, Physiotherapy, Rehabilitation, Functional Independence, Balance Training, Cognitive Recovery, C-Reactive Protein, Erythrocyte Sedimentation Rate, Inflammation

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INTRODUCTION

With regard to 16.9 million individuals having their first stroke each year, 5.9 million stroke-related deaths, and an estimated loss of 102 million Disability Adjusted Life Years, stroke is a major cause of disability (1) enhanced primary care interventions, enhanced neuroimaging diagnosis, and improved stroke management special stroke units, thrombolytic, and endovascular treatments) each lead to an enormous decrease in stroke mortality in recent decades.(2) Beyond this, personalised rehabilitation programs with multidisciplinary teams working under

the supervision of two physiatrists have been implemented as an evidence-based strategy to achieve functional improvement in daily-life activities and reduce disability in stroke survivors.(3) creating socioeconomic challenges for both healthcare systems and families in the long term. In this context, early, well-coordinated, and multidisciplinary rehabilitation is crucial for facilitating neurological recovery in sensory, motor and speech areas following a stroke(4) Conventional stroke rehabilitation typically involves physical therapy, occupational therapy and speech therapy, but despite these approaches, many stroke survivors continue to experience residual functional disabilities that hinder their capacity to carry out daily life activities. A wide range of factors, including therapy dosage, cutting-edge technologies, motivation and engagement, and objective feedback, are taken into consider for significant functional improvement.(5) After completing cardiac rehabilitation, the monitoring of this peptide has been advocated as a biomarker of prediction of recovery in patients having ST-segment elevation myocardial infarction with the objective to predict after that critical adverse cardiac events.(6) in peripartum cardiomyopathy to predict death since its levels are connected to improved left ventricular ejection fraction recovery or patient survival free from problems.(7) Decades of inquiry have found the mechanisms of acute harm with a stroke, which has resulted in the discovery of feasible biomarkers for improved diagnosis or prognosis.(8) It is still an ongoing engage in discussion over the biologic basis of stroke recovery, the relation to poststroke rehabilitation, and the potential use of biomarkers. We had previously looked into the function of molecules expressed in the poststroke brain and coupled with vascular reshaping mechanisms, such as certain matrix metalloproteinases or angiogenin, proteins with comparable ribonuclease and endopeptidase reasons.(9) Previous studies demonstrated that u PA and u PAR expression rises in the brain during the acute cerebral injury recovery phase, and that this binding facilitates neurological recovery associated with actin cytoskeleton reorganisation and neurite reconstruction in the periinfarct region26. also during the recovery phase from hypoxic injury, neurones release uPA, and astrocytes recruit u PAR to their plasma membrane via a process independent of plasmin production. This wonderful crosstalk mechanism even encourages astrocytic activation and synaptic recovery of neurones. (10) Stroke gives significant issues to patients, which influence not only their physical and emotional well-being but also severely simplifying their entire quality of life. It is a major cause of both severe disability and premature mortality globally as well.(11) It is of paramount importance form a clinical and ethical place to find effective ways to improve cognitive function in stroke patients. Cognitive function includes one's ability to gather, analyse, store, and use information in a variety of domains, such as language, executive functions, attention, and memory.(12) The moment it's derived to stroke patients' recovery of cognitive function, both pharmaceutical and non-pharmacological treatments have distinct advantages and characteristics to share.(13) Previous research demonstrated that physical activity therapies may vastly enhance stroke survivors' ability to think, particularly across sectors like executive function, memory, and attention. Walking, cycling, tai chi, and yoga are examples of aerobic workouts that have been shown to be particularly effective for enhancing cognitive performance.(14) These forms of therapy, like resistance, aerobic, and multimodal exercise, By raising BDNF levels, they safeguard brain tissue, advance motor function and activities of daily living, improve post-stroke robust spasticity, and play a vital part of encouraging cognitive recovery.(15) all of these studies support the general advantages of getting active, typical meta-analyses in this area are restricted to direct comparisons between particular interventions and controls, failing to analyse the evidence across various intervention types. They are unable to address the respective effectiveness of various physical activity regimens due to this crucial gap, which leaves matters regarding the most effective modalities. focused on stroke patients. We hope to offer a reference for improving cognitive function in this population and evidence-based suggestions to enhance their cognitive recovery by competing and ranking various physical activity cures In this sense, knowing the uses particular biomarkers in conditional brain modifications may act as a link between basic science and clinical patient care, including regulating rehabilitation outcomes and intervention duration.(16) They lower the risk of moderate cognitive impairment and Alzheimer's disease by promoting angiogenesis in particular brain regions, improving cerebral blood circulation and flow, and urging neurobiological responses that nourish brain cells and remove metabolic waste or β-amyloid plaques.(17)

AIM OF STUDY

To analyse, over a six-month period, the impact of an organised physiotherapy rehabilitation program on functional independence, motor recovery, cognitive performance, and inflammatory blood biomarkers in non-diabetic ischaemic stroke patients.

OBJECTIVES OF THE STUDY

Primary Objectives

1. To evaluate changes in cognitive performance in non-diabetic ischemic stroke patients following six months of structured physiotherapy rehabilitation
2. To determine the effectiveness of physiotherapy intervention on motor recovery voluntary movement and control in affected limbs.
3. To assess improvement in functional independence and activities of daily living over the rehabilitation period

Secondary Objectives

1. To analysed changes in stability balance and postural during the course of rehabilitation.
2. To measure variations in systemic inflammatory blood biomarkers (C-reactive protein and erythrocyte sedimentation rate**)** from baseline to six months.
3. To examine the association between functional recovery outcomes and changes in inflammatory biomarkers**.**
4. To study the pattern and progression of neurological recovery at different follow-up intervals (baseline, 3 months, and 6 months).
5. To evaluate patient compliance and retention during long-term physiotherapy intervention.

HYPOTHESIS

Null Hypothesis (H_0)

There is no significant change in cognitive function, motor recovery, functional independence, balance performance, or inflammatory blood biomarkers in non-diabetic patients with ischemic stroke following six months of structured physiotherapy rehabilitation.

Alternative Hypothesis (H_1)

Structured physiotherapy rehabilitation administered over six months leads to significant improvement in cognitive function, motor recovery, balance, and functional independence, along with a reduction in systemic inflammatory blood biomarkers, in non-diabetic patients with ischemic stroke.

METHODOLOGY

Study Design

This study was designed as a prospective, longitudinal, interventional clinical study with repeated outcome measurements conducted over a period of six months. A single-group design was selected to allow detailed observation of recovery trends following physiotherapy intervention in a real-world clinical setting.

Study Setting

The study was conducted collaboratively at the Department of Physiotherapy, School of Health Sciences, Chhatrapati Shahu Ji Maharaj University, Kanpur, with clinical coordination and patient recruitment supported by GSVM Medical College, Kanpur. The majority of blood sample processing and biochemical analysis was carried out in the Pathology Laboratory of the School of Health Sciences, CSJM University, Kanpur**.** Selected confirmatory and cross-verification investigations were performed in the Department of Pathology, GSVM Medical College, Kanpur. All laboratory procedures followed standardized operating protocols to maintain consistency and accuracy of biochemical measurements throughout the study period.

Study Duration

The total duration of the study was six months for each participant, excluding the initial recruitment and screening phase.

Sample Size

A total of 155 non-diabetic ischemic stroke patients fulfilling the eligibility criteria were included in the study. The sample size was considered adequate to observe meaningful clinical and biochemical changes over the intervention period**.**

Sampling Technique

A purposive sampling technique was employed for the selection of participants in the present study. Patients clinically diagnosed with non-diabetic ischemic stroke were screened based on predefined inclusion and exclusion criteria. Eligible participants were recruited from the collaborating clinical and rehabilitation facilities. This sampling approach was considered appropriate due to the specific clinical characteristics required for the study and the interventional nature of the rehabilitation program. Purposive sampling enabled the inclusion of participants who were medically stable and capable of actively participating in structured physiotherapy sessions over the six-month study period.

ELIGIBILITY CRITERIA

Inclusion Criteria

Clinically diagnosed cases of non-diabetic ischemic stroke

Age between 40 and 75 years

Both male and female participants

Patients in sub-acute stage of stroke

Medically stable and able to participate in physiotherapy rehabilitation

- Willingness to provide informed consent

Exclusion Criteria

- Patients with diabetes mellitus
- Haemorrhagic stroke cases
- Severe cognitive impairment affecting cooperation
- Unstable cardiovascular conditions
- Severe musculoskeletal or orthopaedic limitations

STUDY PROCEDURE

After obtaining ethical clearance, eligible participants were recruited from the collaborating institutions. Baseline demographic and clinical data were recorded prior to initiation of the intervention. Participants then underwent a structured physiotherapy rehabilitation program for a period of six months. Functional, cognitive, and balance-related assessments were performed at baseline and at monthly intervals. Blood samples were collected at baseline, third month, and sixth month for biochemical analysis. All assessments were conducted by trained personnel following standardized procedures to maintain uniformity.

Intervention Protocol

All participants underwent a structured and supervised physiotherapy rehabilitation program for a duration of six months. The intervention was administered five days per week, with each session lasting approximately 60 minutes. The rehabilitation program was individualized based on patient tolerance, stage of recovery, and functional ability.

The intervention protocol included:

1. Neuro-facilitation and motor relearning techniques aimed at improving voluntary motor control.
2. Task-oriented training focusing on functional movements relevant to daily activities.
3. Balance and postural control exercises to enhance stability and reduce fall risk.
4. Gait training incorporating assistive devices where necessary.
5. Cognitive engagement activities integrated with motor tasks to promote neural plasticity.

The intensity and complexity of exercises were progressively modified on a monthly basis to ensure continuous challenge and adaptation**.**

Outcome Measures

Motor Function

- Fugl-Meyer Assessment (Upper and Lower Extremity)

Balance

- Berg Balance Scale

Functional Independence

- Modified Barthel Index

Cognitive Assessment

- Mini-Mental State Examination (MMSE)

Blood Biomarkers

- C-Reactive Protein (CRP)
- Erythrocyte Sedimentation Rate (ESR)

Blood Sample Collection and Analysis:

Venous blood samples were collected at baseline, third month, and sixth month under aseptic precautions. Samples were analysed using standardized laboratory procedures. Quality control measures were maintained consistently throughout the study period.

Data Collection Procedure

Baseline data were recorded prior to intervention. Follow-up assessments were conducted monthly for functional parameters and at defined intervals for blood biomarkers

Statistical Analysis:

Data were analyzed using appropriate descriptive and inferential statistical methods. Mean, standard deviation, and percentage changes were calculated. Repeated-measures comparisons were performed to evaluate progression over time.

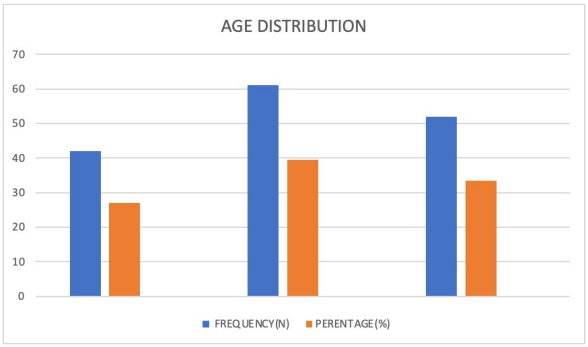
RESULTS

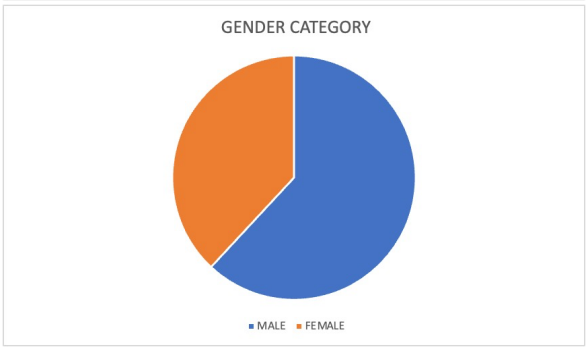
Demographic Characteristics of Participants (n = 155)

A total of 155 non-diabetic ischemic stroke patients were included in the study. The demographic distribution showed representation of both male and female participants across the selected age range. The majority of participants belonged to the middle-aged and elderly population, which is consistent with the epidemiological profile of ischemic stroke

Variable	Category	Frequency (n)	Percentage (%
Gender	male	96	61.9
	female	59	38.1
Age (years)	40–50	42	27.1
	51–60	61	39.4
	61–70	52	33.5
Stroke Side	Right hemisphere	88	56.8
	Left hemisphere	67	43.2

AGE





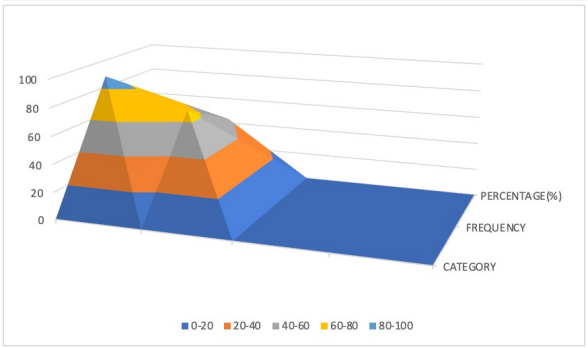
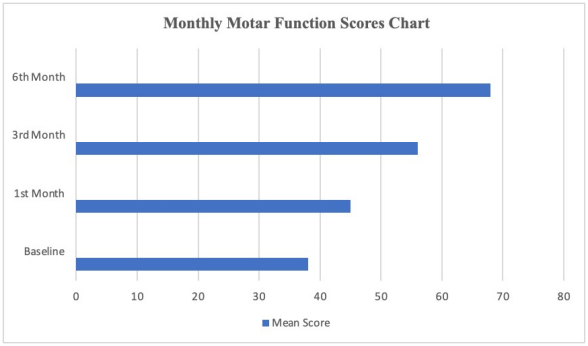
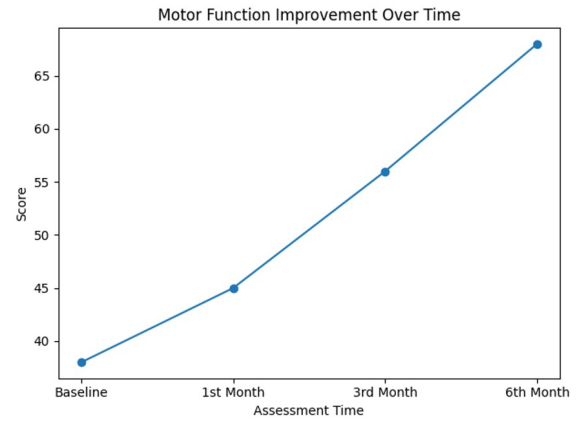


Table 1- Monthly Motar Function Scores (fugl - Meyer Assessment)

Progressive improvement in motor function was observed over the six-month intervention period. Monthly assessment scores indicated gradual enhancement in voluntary movement control, coordination, and limb function. The most notable gains were observed between the third and sixth months of intervention.

Assessment Time	Mean Score
Baseline	38
1st Month	45
3rd Month	56
6th Month	68

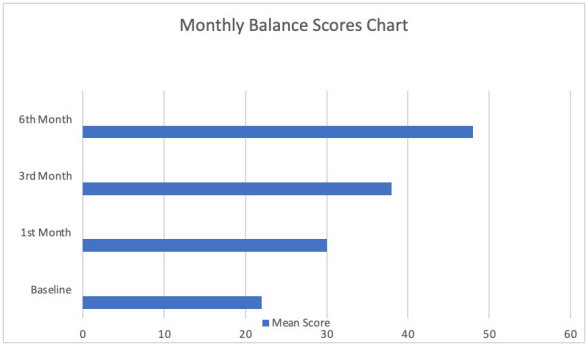


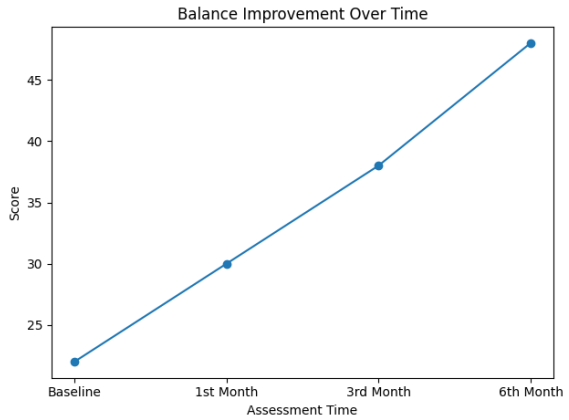


Monthly Balance Scores (Berg Balance scale)

Balance assessment scores demonstrated a consistent upward trend across successive monthly evaluations. Improvements in static and dynamic balance were evident, suggesting enhanced postural stability and reduced risk of falls

Assessment Time	Mean Score
Baseline	22
1st Month	30
3rd Month	38
6th Month	48

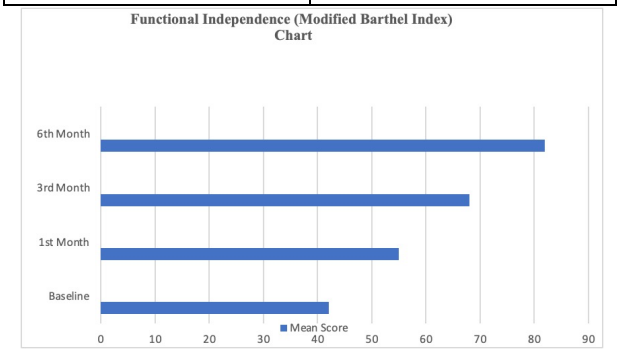


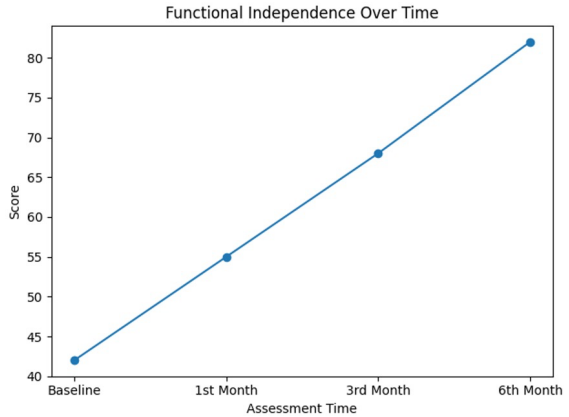


Functional Independence (Modified Barthel Index)

Functional independence measures revealed a steady increase over the study duration. Participants showed improved ability to perform activities of daily living with reduced dependence, indicating meaningful functional recovery

Assessment Time	Mean Score
Baseline	42
1st Month	55
3rd Month	68
6th Month	82

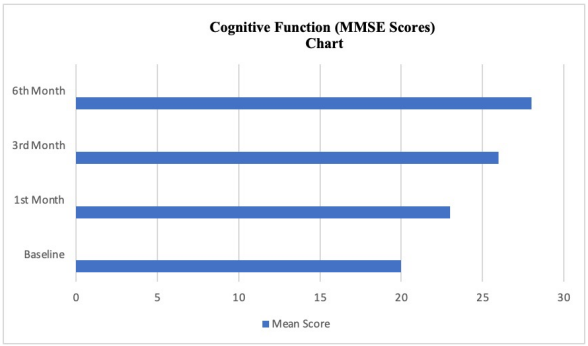


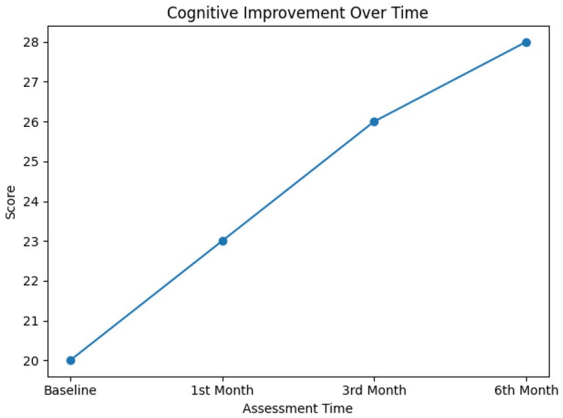


Cognitive Function (MMSE Scores)

Cognitive performance showed gradual improvement over time. Enhanced attention, orientation, and task execution abilities were noted during follow-up assessments.

Assessment Time	Mean Score
Baseline	20
1st Month	23
3rd Month	26
6th Month	28

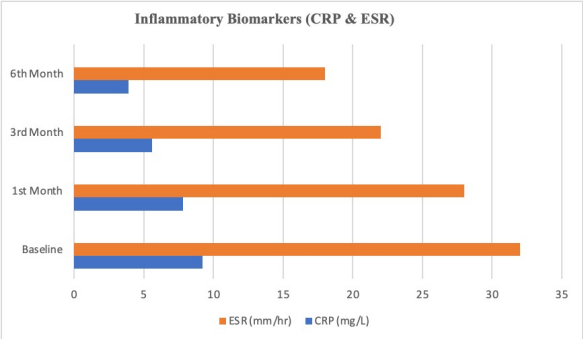


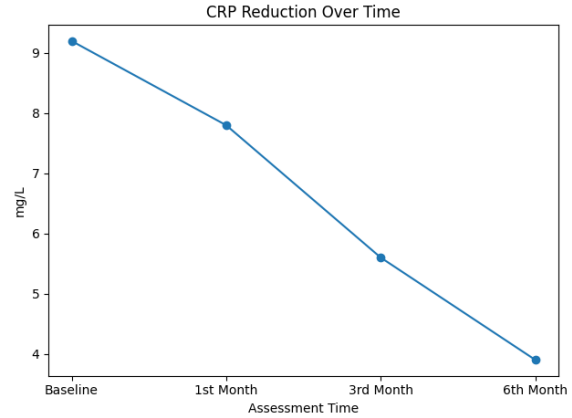


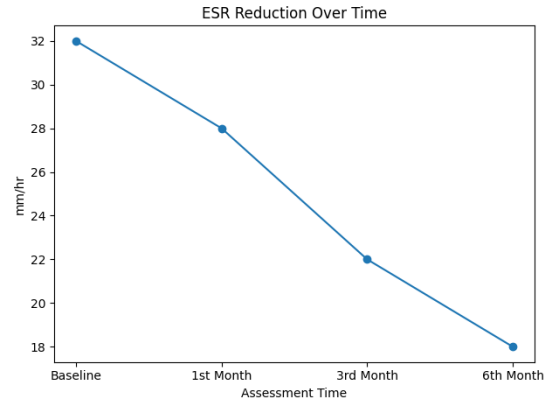
Inflammatory Biomarkers (CRP & ESR)

Inflammatory blood biomarkers demonstrated a progressive reduction over the six-month period. CRP and ESR values showed a declining trend from baseline to the final assessment, suggesting reduced systemic inflammation.

Assessment Time	CRP (mg/L)	ESR (mm/hr)
Baseline	9.2	32
1st Month	7.8	28
3rd Month	5.6	22
6th Month	3.9	18







RESULTS NARRATION

The results of the present study indicate a positive and sustained impact of structured physiotherapy rehabilitation on neural and functional recovery in non-diabetic ischemic stroke patients. Motor function improvements were observed consistently across all assessment points, reflecting enhanced neuromuscular control and motor relearning. Balance and postural stability improved progressively, which may be attributed to targeted balance training and task-oriented rehabilitation strategies. Improved balance contributed to enhanced functional mobility and safety during daily activities. Functional independence scores demonstrated clinically meaningful gains, highlighting the effectiveness of prolonged rehabilitation in restoring independence. Cognitive outcomes also showed favourable trends, suggesting that integrated motor and cognitive engagement may support neural recovery. The reduction in inflammatory biomarkers observed over time paralleled functional improvements, indicating a possible association between decreased systemic inflammation and recovery processes.

DISCUSSION

The findings of the present study demonstrate that structured physiotherapy rehabilitation administered over a six-month period can lead to significant improvements in motor function, balance, cognitive performance, and functional independence in non-diabetic ischemic stroke patients. These outcomes underscore the importance of sustained rehabilitation in promoting neural recovery. Motor recovery observed in this study may be explained by principles of neuroplasticity, whereby repetitive, task-specific training facilitates cortical reorganization and motor relearning. Balance improvements are likely associated with enhanced sensory integration and postural control strategies developed through targeted exercises. Functional independence gains reflect the cumulative effect of improved motor control, balance, and cognitive engagement. The observed cognitive improvements may be attributed to increased neural stimulation resulting from combined motor and cognitive tasks. The gradual reduction in inflammatory biomarkers suggests that physiotherapy intervention may contribute indirectly to modulation of systemic inflammatory responses following stroke. Reduced inflammation may support neural repair mechanisms and functional recovery. Overall, the integration of functional outcome measures with biochemical markers provides a comprehensive understanding of rehabilitation-induced recovery

CONCLUSION

The present study concludes that structured physiotherapy rehabilitation plays a vital role in enhancing neural recovery, functional independence, and cognitive performance in non-diabetic ischemic stroke patients. Concurrent improvement in inflammatory blood biomarkers further supports the therapeutic value of long-term rehabilitation.

Limitations of the Study

The study was limited to a single geographic region and did not include long-term follow-up beyond six months. Future studies may incorporate larger multi-centre samples and extended follow-up durations.

Future Scope

Further research may explore the integration of neuroimaging techniques and additional biomarkers to better understand the mechanisms underlying rehabilitation-induced neural recovery.

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