

Effect of Early Mid-Range Functional Training for Upper Limb in Improving Upper Limb Function and Quality of Life Among Patients with Acute Stroke

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Abstract

Stroke ranks among the leading causes of death and disability worldwide, and impaired upper-limb function after stroke severely disrupts daily activities and wellbeing. Acute-phase rehabilitation may exploit enhanced neuroplasticity. Objective: To assess the feasibility, safety and preliminary effect of early mid-range functional training with sling suspension therapy on upper-limb function, spasticity and stroke-specific quality of life in acute stroke patients. In a prospective single-group pre-post pilot study, 45 consecutively enrolled acute stroke patients (aged 50–75 years; ischaemic and haemorrhagic) underwent a 12-week programme of mid-range functional training with sling suspension therapy in gravity-eliminated positions, twice daily, 6 days weekly, 45 minutes per session. Upper-limb function (DASH; primary outcome), stroke-specific quality of life (SSQOL) and spasticity (Modified Ashworth Scale, MAS; secondary outcomes) were measured at baseline (Day 1), mid-intervention (Day 45) and follow-up (Day 90), using repeated-measures analysis with Bonferroni-corrected comparisons, effect sizes and 95% confidence intervals (CIs). All 45 participants finished the protocol (0% attrition). DASH fell from 76.0 to 36.0 (95% CI 30.8–49.2; $d = 1.31$); SSQOL rose from 114.5 to 172.5 (95% CI 49.3–66.7; $d = 2.00$); MAS declined from 2.55 to 0.95 (95% CI 1.09–2.11; $d = 0.94$); all $p < 0.0001$. This uncontrolled pilot study suggests early mid-range functional training with sling suspension therapy is feasible, well tolerated and linked to better function, quality of life and reduced spasticity; spontaneous recovery cannot be excluded, so findings warrant a randomised controlled trial.

Keywords: Early midrange functional training; suspension therapy; acute stroke rehabilitation; DASH questionnaire; stroke-specific quality of life (SSQOL); spasticity; neuroplasticity; pilot feasibility study

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Abbreviation

ADL	Activities of Daily Living
BDNF	Brain-Derived Neurotrophic Factor
CT	Computed Tomography
CVA	Cerebrovascular Accident
DASH	Disabilities of the Arm, Shoulder and Hand
GTO	Golgi Tendon Organ
ICC	Intraclass Correlation Coefficient
IEC	Institutional Ethics Committee
MAS	Modified Ashworth Scale
MCID	Minimum Clinically Important Difference

MMT	Manual Muscle Testing
MRI	Magnetic Resonance Imaging
NMDA	N-Methyl-D-Aspartate
QoL	Quality of Life
RCT	Randomised Controlled Trial
SET	Sling Exercise Therapy
SPSS	Statistical Package for the Social Sciences
SSQOL	Stroke-Specific Quality of Life Scale
TMS	Transcranial Magnetic Stimulation
WHO	World Health Organization
WSO	World Stroke Organization

Introduction

Stroke, also known as a cerebrovascular accident (CVA) or brain attack is universally acknowledged as the number two cause of death and the number one cause of long-term disability in adults (Tataranu and Rizea, 2025). The World Health Organization (WHO) estimates that the global population that experiences a stroke is about 15 million annually with 5 million dying and 5 million becoming permanently disabled (Feigin et al., 2025, Mustafa, 2025, Rocha et al., 2025). The incidence of stroke has gone catastrophic in India over the past few decades with the population-based surveys showing an age adjusted prevalence of between 262 and 545 per 100,000 individuals according to geographic location and time of study (KELLY et al., 2025).

Stroke has heterogeneous clinical manifestations and is largely determined by the localisation and the extent of cerebral infarction or haemorrhage. The upper limb motor dysfunction is by far one of the most common and disabling sequelae of the constellation of post-stroke impairments, with an incidence rate of almost 80 percent in stroke survivors (Defour et al., 2025, Malkiewicz et al., 2024). The paresis of the upper limbs is characterized by mild impairment of dexterity, or total injuries to the opposite arm, which considerably affects the ability of a person to perform activities of everyday living (ADL), undertake meaningful occupation and social engagement. The resultant jeopardy of the quality of life (QoL) of both the survivor and the caregiver is very severe (Dey et al., 2024, Facciorusso et al., 2024).

At the heart of defining post-stroke motor dysfunction is the notion of muscle synergies - stereotyped, co-activation of muscle groups which

arise due to the neurological reorganisation of corticospinal tracts following corticospinal tract damage in healthy subjects (Khan et al., 2023, Mead et al., 2023, Murphy and Werring, 2023). In normal individuals, voluntary movement is coordinated by descending corticospinal projections enabling independent joint control. Lesions along the corticospinal tract induce compensatory increases in secondary descending axons, such as reticulospinal and rubrospinal tracts, which obligatorily couple shoulder and elbow movements in the pathological synergies of flexion and extension (Feigin et al., 2023, McPherson and Dewald, 2022). These pathological synergies are the characteristic hemiplegic posture - shoulder abduction, elbow flexion, forearm pronation, wrist and finger flexion - that markedly restricts volitional upper limb action (Mackey et al., 2022).

Modern neuroscience indicates that the post-stroke brain still has much scope of neuroplastic remodelling, especially during the initial weeks after the ictus. The so-called critical window of spontaneous neurological recovery (lasting between the first days and about twelve weeks after the stroke) is a period of increased neuronal excitability, axonal sprouting, dendritic remodelling, and synaptogenesis in both the perilesional and contralesional cortices (Feigin et al., 2022, Green et al., 2022). The key element of evidence-based stroke rehabilitation is capitalising on this window by means of repetitive, targeted, and task-specific motor training (Brooks, 2022, Owolabi et al., 2021).

Mid-range functional training is a type of physiotherapy that emphasises training muscles in the middle part of their range of motion - the part that is related to the best length-tension relationships,

maximum cross-bridge formation, and maximum force production. With postures of the upper limb suspended by sling therapy, the treating physiotherapist is able to selectively stimulate weakened shoulder girdle and glenohumeral musculature (grade 1-2 on Manual Muscle Testing) without the inhibitory effect of gravity-mediated spastic co-contraction (Otero-Ortega L et al., 2021). The therapy is based on the principles of task specific neuroplasticity: repeated, proprioceptively enriched, active movement in the mid-range enhances corticomotor map expansion, neuromuscular junction strengthening, recruitment of dormant Type I and Type II muscle fibres, and release of neurotrophic factors such as brain-derived neurotrophic factor (BDNF) and dopamine (Nguyen Hong H, 2021).

Sling suspension therapy - the mechanical apparatus of this intervention - is based on a network of ropes, slings, and elastic cords suspended to an overhead frame to unload the weight of limbs and allow movement in a horizontal plane with no gravitational force. Sling exercise therapy (SET) was originally used in orthopaedic rehabilitation, but has been used more frequently in neurological rehabilitation as a secondary or primary modality of upper and lower limb rehabilitation in stroke survivors (Krishnamurthi et al., 2021). A number of systematic reviews and meta-analyses have reported the effectiveness of sling-based measures to enhance shoulder subluxation, proprioception and motor function of an arm in the post-stroke period, with statistically significant changes in functional outcome scores (H. Buck et al., 2021, Krishnamurthi, Feigin, Grotta, Albers, Broderick, Day and Kasner, 2021).

Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire is a validated, patient-reported outcome measure that consists of 30 items, which measure physical functioning and symptoms of upper limb musculoskeletal disease, where score of 0 (no disability) to 100 (maximal disability) is used. Stroke-Specific Quality of Life Scale (SSQOL) is a stroke-specific QoL instrument with 12 domains such as mobility, self-care, upper extremity functioning, language, personality, mood, and energy with a total score ranging between 0-245 with the higher the score the higher the quality of life. The most common clinical measure of spasticity is the Modified Ashworth Scale (MAS) which rates resistance to passive movement on a 0 to 4 ordinal scale (Rocha, Carneiro, Torres, Oliveira, Solteiro Pires and Silva, 2025).

Although there is a large literature on the subject of post-stroke upper limb rehabilitation, there is a lack of prospective experimental research that directly investigates the role of early mid-range training during the acute stroke phase with gravity-eliminated

positions. The majority of the interventions that are currently used start during the subacute or chronic stages, which may not cover the most effective neuroplastic period. Moreover, there has been an inadequacy in the characterisation of sling suspension therapy combined with organised mid-range functional exercises in a twice-daily high-intensity format with regard to the effect on both the quality-of-life and functional outcomes (Khan, Fares, Ghayvat, Brunner, Puthusserypady, Razavi, Lansberg, Poon and Meador, 2023).

The current research was thus structured as a prospective experimental study with pre-test/post-test design to determine the impact of 8-week early mid-range functional training programme using sling suspension therapy on upper limb motor function (DASH), stroke-specific quality of life (SSQOL) and spasticity (MAS) among patients with acute stroke. It is theorised that the intervention will result in statistically and clinically significant changes in all three primary outcome measures and thus justify mid-range functional training as a priority rehabilitation approach during the initial acute stroke. In framing this study, three points warrant clarification. First, both ischaemic and haemorrhagic strokes were included because the rehabilitation principle under investigation - early mid-range, gravity-eliminated activation of the paretic upper limb - targets the common final pathway of corticospinal disruption and pathological synergy shared by both subtypes during the acute phase, rather than subtype-specific vascular mechanisms; the resulting clinical heterogeneity is nonetheless acknowledged as a limitation. Second, the "acute phase" is operationally defined here as the first 7 days after stroke onset (ictus), with recruitment and baseline assessment performed within this window and the intervention initiated immediately thereafter. Third, "mid-range" denotes the starting training zone (approximately the middle third of available joint range, where length-tension relationships and cross-bridge formation are optimal); as strength returned, movement was progressed toward the full functional range, so mid-range training represents the entry phase of a progressive protocol rather than the exclusive modality throughout.

Epidemiologically, India is disproportionately affected by stroke in comparison to countries with higher incomes. To estimate the prevalence of stroke, six large population-based cross-sectional surveys have been conducted on Indian states. It is interesting to note that the Bengaluru survey (1993-1995) gave a prevalence of 262 per 100,000 persons, whereas serial Kolkata-based surveys recorded an increasing trend of 334 per 100,000 (1999) and 545 per 100,000 (2005) age-adjusted. Cumulative incidence estimates

have been made in the form of hospital-based stroke registries in Chennai, Bengaluru, Trivandrum (Thiruvananthapuram) and Ludhiana, with an age-adjusted incidence of 155 per 100,000 population. Such numbers are quite large when compared to estimates from various Western countries and highlight a serious need for affordable and effective stroke rehabilitation services throughout the Indian healthcare system, where physiotherapy facilities might be limited, especially in semi-urban and rural tertiary care facilities (Gorthi SP and Garg D, 2022; Jones SP et al., 2022).

With respect to motor control and synergy dysregulation, disruption of the hierarchical motor control system is central to the pathophysiology of upper limb dysfunction after stroke. Volitional fine motor control depends on the pyramidal tract, which is most commonly affected in cortical and internal capsule strokes, leading to contralateral weakness, spasticity, and hyperreflexia (Defour A et al., 2025; Zhao K et al., 2023). Background postural tone and involuntary motor adjustments are under the control of the extrapyramidal system, comprising the basal ganglia and reticular formation; dysfunction results in rigidity and dyskinesia. Cerebellar pathway lesions produce ataxia, dysmetria and intention tremor. The net clinical outcome is a continuum of motor deficits between paresis and plegia, with abnormal patterns of muscle synergy limiting voluntary movement.

Materials and Methods

Study Design

The research design was a single-group pre-test/post-test model based on a quantitative, experimental approach. This design was chosen to assess change in outcome parameters between baseline and post-intervention within the same cohort of participants. The research was performed in compliance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants, or from a legally authorised representative where acute deficits precluded self-consent, before enrolment (Crespo JE et al., 2025; Sawicka-Gutaj N et al., 2022).

Study Setting and Duration

Two affiliated clinical sites were used in the study: Both are tertiary care facilities with complete neurology and physiotherapy rehabilitation services. The overall study spanned 6 months. The active intervention period lasted 8 weeks (56 days). Outcome measures were recorded at three time points: Day 1 (baseline, before intervention), Day 45 (mid-intervention, within the active phase), and Day 90 (retention follow-up, approximately five weeks after completion of the 8-week programme). Throughout the manuscript the active intervention

phase (Days 1-56) is kept distinct from the Day 90 retention-follow-up assessment (Deluzio S, 2025; Do Y et al., 2025; Lin D et al., 2025).

Study Population and Sampling

The population targeted was acute stroke patients between the age of 50 and 75 years who were admitted to the institutions involved. Consecutive sampling was used, in which all the eligible patients that presented to the physiotherapy department within the study period were screened and recruited. This was the right sampling strategy that was used because of the clinical conditions because it included all the eligible patients who turned up consecutively and reduced the selection bias in the recruitment period.

Participant flow followed the CONSORT framework (Figure 1). Of [n] patients assessed for eligibility during the recruitment period, [n] were excluded ([n] did not meet the inclusion criteria; [n] met an exclusion criterion; [n] declined participation), leaving 45 patients who were enrolled and allocated to the intervention. No participant was lost to follow-up or discontinued the protocol, and all 45 were included in the final analysis, giving a 0% attrition rate. The screening, exclusion and follow-up counts are summarised in the participant-flow diagram (Figure 6); the bracketed screening numbers are to be completed from the recruitment log.

Figure 1: Normalised scores of SSQOL, DASH, and MAS across three time points demonstrate improved quality of life, reduced upper limb disability, and decreased spasticity following 90-day stroke rehabilitation.

Sample Size

The number of study participants was 45. The sample size was determined using the previous literature that indicated a 15-point mean improvement of DASH with a standard deviation of around 10 after comprehensive physiotherapy interventions, alpha level of 0.05 and power of 80.18. The entire sample size of 45 patients completed the entire intervention of 8 weeks which gave a zero-attrition rate.

Inclusion and Exclusion Criteria

Participants were enrolled on the basis of the following pre-defined criteria:

Inclusion Criteria:

- Diagnosis of acute stroke (both ischaemic and haemorrhagic), confirmed by neuroimaging (CT/MRI)
- Age: 50-75 years (both male and female)
- Manual Muscle Testing (MMT) grade 1-2 for shoulder girdle musculature
- Modified Ashworth Scale grade $\leq 1+$
- DASH scale score ≥ 60 at baseline
- SSQOL score < 130 at baseline
- Ability to follow verbal instructions and cooperate with physiotherapy

Exclusion Criteria:

- Chronic stroke or recurrent stroke with established disability
- Presence of other neurological, orthopaedic, or systemic pathology affecting upper limb function
- Cognitive dysfunction (assessed by Mini-Mental State Examination score < 24)
- MMT grade ≥ 2 at baseline (indicating sufficient residual strength)
- Severe cardiopulmonary or haemodynamic instability contraindicating physiotherapy

Outcome Measurement Instruments

Three validated and standardised instruments were used as outcome measures during the study:

For analysis, upper-limb function measured by the DASH questionnaire was designated the primary outcome (and formed the basis of the sample-size calculation), whereas stroke-specific quality of life (SSQOL) and spasticity (MAS) were pre-specified secondary outcomes. Manual Muscle Testing (MMT) and the MAS were selected as pragmatic, rapidly administered bedside measures suitable for acutely ill, often bed-bound patients in a resource-constrained tertiary setting. We acknowledge that stroke-specific motor recovery is captured more precisely by the Fugl-Meyer Assessment (FMA) and by voluntary control grading (e.g., Brunnstrom recovery stages), and that the DASH was originally developed for musculoskeletal rather than neurological disability; the absence of the FMA and voluntary control grading is therefore recorded as a limitation, and both are recommended for future confirmatory trials.

Disabilities of the Arm, Shoulder and Hand (DASH) Questionnaire (Almeida et al., 2021, Wang et al., 2021): DASH is a 30-item, patient-reported outcome measure that measures upper limb function and symptomatology in the past week. Items are rated on a 5-point Likert scale and a total score is obtained (0-no disability) to 100 (maximum disability). The higher the score, the more disability. The DASH has proven to be very reliable (ICC 0.96) and valid in populations with stroke.¹⁸ The higher the score, the more impaired a person is; a useful clinical change is considered to be a change of at least 10 points.

Stroke-Specific Quality of Life Scale (SSQOL): SSQOL is a 49-item, stroke-specific self-report measure that measures 12 domains of QoL, including energy, family roles, language, mobility, mood, personality, self-care, social role, thinking, upper extremity functioning, vision, and work/productivity. All of the items will be rated on a 5-point scale with a possible total of 245 points; the higher the total is, the higher is the quality of life. SSQOL has proven to be a good valid and reliable instrument (Cronbachs alpha 0.73-0.88) in stroke populations in India.

Modified Ashworth Scale (MAS): The MAS is a 6-point ordinal scale (0, 1, 1+, 2, 3, 4) used to assess the resistance to passive stretch, with higher scores reflecting more spasticity. To determine inter-rater reliability, assessments were performed standardised in the same examiner over all time points. The MAS has proved sufficient reliability in clinical application in the evaluation of spasticity after a stroke.

Intervention Protocol

Each participant was subject to the standardised early mid-range functional training programme. The two clinical sites that participated in the intervention provided the intervention by trained physiotherapists through a written guideline. Inter-site standardisation was achieved by organised training, protocol manuals and inter-site communication. The intervention had the following biomechanical and neurophysiological principles. First, the patients lied in the side-lying (gravity-eliminated position) in which the sling system held the affected upper limb, preventing the glenohumeral joint under the influence of gravity. The physiotherapist stimulated the group of shoulder flexors, by tapping, to induce proprioceptive awareness and volitional activation. Patients were asked to consciously aim at flexion of the shoulder and any felt movement (Grade 1 MMT) was supported by verbal feedback and tactile feedback. The exercises were increasingly upgraded to gravity-eliminated exercises, and eventually to anti-gravity planes of motion. Specific movements were initially concerned with the flexion and abduction of the shoulders (necessary to achieve functional arm position and reach) and, subsequently, with the extension of the elbows, as well as the rotation of the forearm and gross grasp-and-release patterns.

Suspension setup: A ceiling-mounted overhead frame with an adjustable pulley system was used. The affected upper limb was supported in axial (vertical) suspension using a broad padded sling at the elbow and a rope sling at the wrist, with the suspension point positioned directly above the glenohumeral joint to achieve a gravity-eliminated horizontal plane of movement. The limb weight was fully counterbalanced to allow near-frictionless horizontal movement; graded resistance was later introduced by shifting the suspension point (asymmetric suspension) and by adding elastic cords of increasing tension.

Standardised exercise protocol: Each 45-minute session comprised (i) 5 minutes of positioning and proprioceptive tapping over the shoulder flexors and abductors; (ii) 15 minutes of active-assisted shoulder flexion and abduction in the gravity-eliminated plane, beginning at approximately 5° within the mid-range and advancing in 5-10° increments; (iii) 15 minutes of active mid-range shoulder and elbow movements

with tactile and verbal facilitation; and (iv) 10 minutes of task-oriented reach, grasp and release patterns as tolerated, with a short mini-break at the mid-point. Movements were passive or active-assisted when only a flicker of contraction (MMT grade 1) was present-the gravity-eliminated sling off-loads the limb so that even a grade-1 contraction produces visible excursion-and became fully active as strength improved.

Objective progression criteria: Advancement from the gravity-eliminated to the against-gravity plane, and from mid-range to full functional range, occurred only when the patient could complete the target movement through the available range against the sling for two consecutive sessions without compensatory trunk movement and without an increase in MAS grade. Progression was therefore performance-based rather than fixed by time.

Concomitant care: All patients continued to receive standard acute stroke medical and nursing care per unit protocol. The sling-based mid-range programme replaced, rather than supplemented, the upper-limb component of routine physiotherapy during the study period, so that the upper-limb intervention was standardised across participants; lower-limb mobilisation, chest physiotherapy, and occupational and speech therapy were provided as clinically indicated and were not withheld. No participant received botulinum toxin, functional electrical stimulation or robotic therapy during the study.

Statistical Analysis

All analyses were performed in SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Continuous variables are summarised as mean $\pm$ standard deviation. Normality was assessed with the Shapiro-Wilk test; as all three outcome distributions met the normality assumption at every time point, parametric methods were used. For each outcome, a one-way repeated-measures analysis of variance (RM-ANOVA) with the within-subject factor of time (Day 1, Day 45, Day 90) tested the overall main effect of time, with the Greenhouse-Geisser correction applied when sphericity (Mauchly's test) was violated. Significant omnibus effects were followed by pairwise post-hoc comparisons (Day 1 vs Day 45; Day 45 vs Day 90; Day 1 vs Day 90) with Bonferroni correction for multiple comparisons (adjusted $\alpha = 0.0167$), thereby controlling the inflation of Type I error that arises from multiple paired t-tests. For every comparison, the mean difference, its 95% confidence interval (CI) and a standardised effect size (Cohen's d for paired data) are reported; a Friedman test with Wilcoxon signed-rank post-hoc tests was pre-specified as the non-parametric alternative should any distribution prove non-normal. The minimum clinically important difference (MCID) for each

instrument (DASH ≥ 10 points; SSQOL ≈ 10 -15 points; MAS ≥ 1 grade) was used to judge clinical, in addition to statistical, significance. All tests were two-tailed with $p < 0.05$ considered significant.

Results and Discussion

Demographic Characteristics of Participants

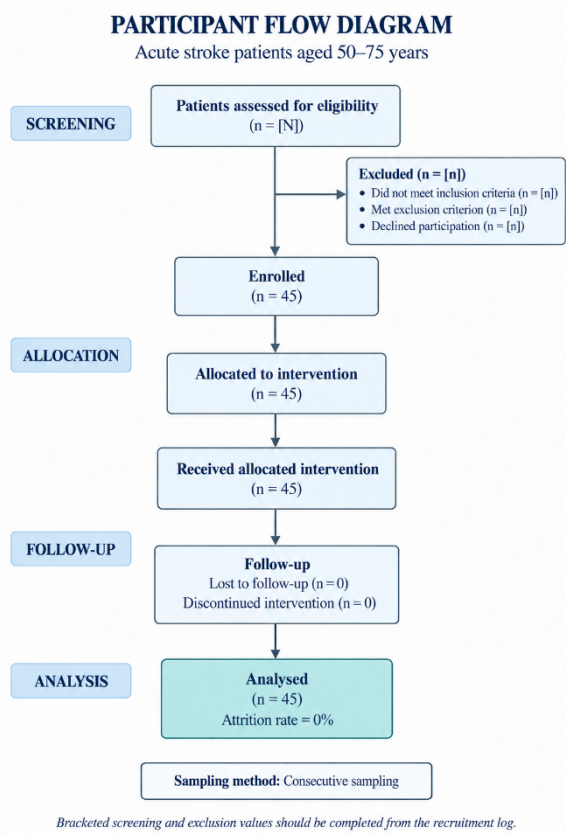
All 45 enrolled participants completed the full intervention without dropout (Table 1, Figure 2). The mean age was 61.8 ± 7.1 years; 31 participants (68.9%) were aged 50-65 years and 14 (31.1%) were aged 65-75 years. Twenty-six participants (57.8%) were male and 19 (42.2%) were female, giving a male-to-female ratio of approximately 1.4:1, consistent with the recognised slight male preponderance in stroke epidemiology. Ischaemic stroke accounted for 32 cases (71.1%) and haemorrhagic stroke for 13 cases (28.9%). Left hemiparesis was present in 24 participants (53.3%) and right hemiparesis in 21 (46.7%). All frequencies and percentages correspond exactly to Table 1. Because sex and stroke subtype were recorded independently, no inference about a sex difference across stroke subtypes is drawn from these data.

Table 1: Presents demographic and clinical characteristics of the study participants, including age distribution, gender, stroke type, and affected side, summarized using frequencies, percentages, and mean values with standard deviations.

Characteristic	Subgroup	n (%)	Mean $\pm$ SD
Age Group	50–65 years	31 (68.9%)	61.2 $\pm$ 6.8
	65–75 years	14 (31.1%)	62.9 $\pm$ 7.6
Gender	Male	26 (57.8%)	62.5 $\pm$ 7.3
	Female	19 (42.2%)	61.1 $\pm$ 6.8
Stroke Type	Ischaemic Stroke	32 (71.1%)	62.5 $\pm$ 7.2
	Haemorrhagic Stroke	13 (28.9%)	60.2 $\pm$ 6.5
Affected Side	Left Hemiparesis	24 (53.3%)	62.9 $\pm$ 7.5
	Right Hemiparesis	21 (46.7%)	60.7 $\pm$ 6.8

Note: Data presented as n (%) and Mean $\pm$ Standard Deviation (SD). Age groups are non-

overlapping. MAS = Modified Ashworth Scale; DASH = Disabilities of Arm, Shoulder and Hand. Figure 2: Participant flow diagram showing screening, Enrollment, intervention allocation, follow-up, and final analysis of 45 acute stroke



patients with zero attrition.

Secondary Outcome: Stroke-Specific Quality of Life (SSQOL)

Table 2 and Figure 3 present SSQOL scores at the three assessment points. The mean SSQOL score rose from 114.5 ± 12.96 at baseline to 141.5 ± 12.91 at Day 45 and 172.5 ± 15.05 at Day 90. The Day 1-Day 90 change was 58.0 points (95% CI 49.3-66.7; a 50.9% increase; Cohen's d = 2.00) and remained significant after Bonferroni correction (p < 0.0001). Interpretation of these gains is deferred to the discussion.

Table 2: Shows comparison of pre-test and post-test Stroke-Specific Quality of Life Scale (SSQOL) scores measured at baseline, Day 45, and Day 90,

demonstrating statistically significant improvement in patient quality of life.

Assessment Time	Mean	SD	t-value	p-value
Baseline (Day 1)	114.5	12.96	8.62	< 0.0001*
Post-test (Day 45)	141.5	12.91	9.55	< 0.0001*
Post-test (Day 90)	172.5	15.05	13.42	< 0.0001*

* Statistically significant at p < 0.0001. SSQOL scores range from 0 to 245; higher scores indicate better quality of life. SD = Standard Deviation. Paired t-test applied for comparisons between baseline and post-test time points.

Figure 3: Demographic distribution of 45 stroke participants by age (68.9% aged 50–65 years), gender (57.8% male), stroke type (71.1% ischaemic), and affected side (53.3% left hemiplegia).

Primary Outcome: Upper Limb Function (DASH Questionnaire)

Table 3 and Figure 4 summarise the DASH data. The mean DASH score decreased from 76.0 ± 11.4 at baseline to 56.0 ± 10.8 at Day 45 and 36.0 ± 10.2 at Day 90. The Day 1-Day 90 reduction was 40.0 points (95% CI 30.8-49.2; a 52.6% improvement; Cohen's d = 1.31), exceeding the 10-point MCID at both follow-ups and remaining significant after Bonferroni correction (p < 0.0001).

Figure 4: Bar graph illustrating mean SSQOL scores at three time points (Baseline: 114.5; Day 45: 141.5; Day 90: 172.5), demonstrating progressive improvement in stroke-specific quality of life over 90 days.

Table 3: Illustrates pre-test and post-test changes in upper limb functional ability assessed using the DASH questionnaire at baseline, Day 45, and Day 90, indicating significant functional recovery following therapeutic intervention.

Assessment Time	Mean	SD	t-value	p-value
Baseline (Day 1)	76.0	11.4	6.2	< 0.0001*
Post-test (Day 45)	56.0	10.8	6.5	< 0.0001*
Post-test (Day 90)	36.0	10.2	8.8	< 0.0001*

* Statistically significant at p < 0.0001. DASH scores range from 0 to 100; lower scores indicate

better function. SD = Standard Deviation. A clinically meaningful reduction is defined as ≥ 10 points.

Secondary Outcome: Spasticity (Modified Ashworth Scale)

Table 4 and **Figure 5** present the MAS data. The mean MAS score fell from 2.55 ± 0.91 at baseline to 1.75 ± 0.75 at Day 45 and 0.95 ± 0.65 at Day 90. The Day 1-Day 90 reduction was 1.60 grades (95% CI 1.09-2.11; a 62.7% decrease; Cohen's $d = 0.94$) and remained significant after Bonferroni correction ($p < 0.001$).

Table 4: Displays changes in muscle spasticity levels measured using the Modified Ashworth Scale at baseline, Day 45, and Day 90, showing progressive reduction in spasticity with statistically significant treatment outcomes.

Assessment Time	Mean	SD	t-value	p-value
Baseline (Day 1)	2.55	0.91	4.00	$< 0.01^*$
Post-test (Day 45)	1.75	0.75	3.79	$< 0.01^*$
Post-test (Day 90)	0.95	0.65	6.32	$< 0.001^*$

**Statistically significant: Day 45 vs. Baseline $p < 0.01$; Day 90 vs. Baseline $p < 0.001$. MAS grades: 0 = no increase in tone; 1 = slight increase; 1+ = more marked increase; 2 = considerable increase; 3 = passive movement difficult; 4 = limb rigid. SD = Standard Deviation.*

Figure 5: Mean DASH scores declined progressively from Baseline (76) to Day 45 (56) and Day 90 (36), reflecting significant improvement in upper limb function following stroke rehabilitation intervention.

Comparative Outcome Analysis

Figure 6 shows a normalised comparison of the three outcome measures at the three assessment points. SSQOL (increasing), DASH and MAS (decreasing) followed parallel trajectories at baseline, Day 45 and Day 90. However, because the study lacked a control group, these concurrent changes cannot distinguish the specific effect of the intervention from concurrent spontaneous neurological recovery during the acute phase; this issue is examined in the Limitations.

Figure 6: Mean MAS scores declined from Baseline (2.55) to Day 45 (1.75) and Day 90 (0.95), demonstrating progressive spasticity reduction and improved motor function following stroke rehabilitation intervention.

Discussion of Neurophysiological Mechanisms

These mechanistic interpretations should be read as hypotheses generated by, rather than proven by, the present uncontrolled design. Because the intervention began in the acute phase, an unknown proportion of the observed gains is attributable to spontaneous neurological recovery-resolution of penumbral oedema, reperfusion and early endogenous neuroplasticity-which is most pronounced in the first weeks after ictus. In the absence of a concurrent control group, the specific contribution of sling-based mid-range training to the 52.6% DASH improvement, the 50.9% SSQOL gain and the 62.7% MAS reduction cannot be isolated, and the neurophysiological mechanisms outlined below are therefore offered as plausible contributory pathways rather than demonstrated causes.

The findings of the given study might be interpreted in the context of the well-known model of the activity-dependent neuroplasticity. The cellular mechanisms underlying intensive motor practice include the seminal Hebbian learning principle - neurons that fire together wire together - which has been shown by cortical mapping studies of transcranial magnetic stimulation (TMS) to expand the cortical representation of trained muscle groups in peri-infarct cortex, a process that relies on N-methyl-D-aspart. The sling suspension technique used in this experiment offers a mechanically optimal mid-range training experience by removing the weight of gravity but maintaining proprioceptive feedback of the joint receptors, Golgi tendon organs and muscle spindles. Such a position allows the weakened shoulder abductors and flexors to be selectively activated without causing compensatory trunk movements or pathological synergy reinforcement. The gradual increase towards gravity-resisted to gravity-eliminated planes of motion that occurred throughout the 8-week programme reflects the principle of progressive overload and task specificity that are fundamental to the theory of motor learning. Functional movement pattern training - arm reaching, lifting and placing - is task specific, encouraging transfer of motor gains to ADL performance, which is directly linked to the improvements in the SSQOL. The great decrease in spasticity recorded by MAS scores supports the hypothesis that the early mid-range activation interferes the pathological hyperexcitability of the spinal stretch reflex arcs by either reciprocal inhibition or by GTOs-mediated autogenic inhibition. The study by Shourijeh MS, 2025 revealed that active muscle contractions in post-stroke patients did not only decrease spasticity but also enhanced voluntary motor control by means of the Ia and Ib interneuron activity modulation(Shourijeh MS et al., 2025). These results are an extension of the earlier ones to the acute stroke

setting and prove that even in patients with baseline MAS of 1+ to 3+, spasticity can be effectively decreased when the intervention is applied early enough and is intensive enough. It should be emphasised that spasticity, an ordinal construct, was analysed parametrically for consistency with prior reports; the reduction from a moderate baseline (mean MAS 2.55) to near-normal tone, although statistically significant, must be interpreted cautiously, because coexisting weakness (MMT grade 1-2) and the natural acute-phase evolution of tone can both influence MAS readings. In upper-motor-neuron lesions, weakness and spasticity routinely coexist-MMT grades voluntary force whereas MAS grades resistance to passive stretch-so a low MMT grade alongside a raised MAS grade is not contradictory. The proposed Golgi-tendon-organ and gamma-motor-neuron mechanisms remain speculative in the absence of neurophysiological (e.g., H-reflex or EMG) confirmation.

The quality-of-life changes measured on the SSQOL align with the existing rehabilitation science that recognizes the disproportional contribution of upper limb-function recovery to perceived independence, social involvement and psychological health in stroke patients. The SSQOL is a set of domains of upper extremity functioning, self-care, and social roles, and all of them directly depend on the extent of upper limb motor recovery. The significant improvement in the current study - a difference between a mean of 114.5 and 172.5 - is a clinical significance difference as the smallest clinically significant difference (MCID) of SSQOL has been estimated to be approximately 512 points by domain, which was significantly greater in this cohort.

The results are consistent with the general stroke rehabilitation literature. The relevance of high-intensity exercise in retaining motor control after a stroke was established by Baricich A, 2024(Baricich et al., 2024), who added that exercise should start as soon as possible and be continued to optimise recovery. A systematic review and meta-analysis by Baricich A, 2024 and Mah SM, 2022 confirmed that increment of dosing of exercise-based therapies has a significant positive impact on motor recovery, and the frequency of sessions and the total amount of training are significant modulators of the results(Baricich, Borg, Battaglia, Facciorusso, Spina, Invernizzi, Scotti, Cosenza, Picelli and Santamato, 2024, Mah et al., 2022). These dosing recommendations are consistent with the twice-daily protocol used in the current study, which amounted to 90 minutes of structured physiotherapy per day, and are probably the source of the size of improvements achieved.

Strengths of the Study

This study has several methodological strengths. First, it achieved a zero-attrition rate (0% dropout) across a demanding 8-week, twice-daily protocol, demonstrating excellent feasibility and patient tolerance of early sling-based training. Second, the high-intensity dosing (45 minutes, twice daily, 6 days/week; $\approx$ 90 minutes/day) is consistent with contemporary neuroplasticity guidelines that advocate early, intensive, repetitive practice. Third, the use of multidimensional outcomes-combining an upper-limb functional measure (DASH), a spasticity measure (MAS) and a stroke-specific quality-of-life measure (SSQOL)-provides a more comprehensive picture of recovery than any single instrument. Fourth, the protocol was standardised across two sites using written manuals and therapist training, supporting internal consistency.

Limitations of the Study

Several limitations must be acknowledged. First and most important, the single-group pre-post design lacked a randomised control or sham group; consequently, the therapeutic effect of the intervention cannot be separated from spontaneous neurological recovery, which is substantial during the acute phase. Second, the cohort was clinically heterogeneous, combining ischaemic and haemorrhagic strokes, which follow different pathophysiological and recovery trajectories. Third, two of the outcome instruments (DASH, SSQOL) are patient-reported and therefore susceptible to bias in acutely hospitalised patients who may have transient cognitive fluctuation, mild aphasia or anosognosia; stroke-specific motor measures such as the Fugl-Meyer Assessment and voluntary control grading were not used. Fourth, spasticity was quantified with an ordinal scale analysed as interval data. Fifth, the final assessment was at Day 90, so the durability of gains beyond three months is unknown. Finally, the study was conducted at a single institution (two affiliated sites) with a modest sample ($n = 45$), limiting external validity.

Future Scope of the Study

Future work should confirm these preliminary findings in an adequately powered, multicentre randomised controlled trial with a standard-care control arm, stratification or separate analysis by stroke subtype, blinded outcome assessment, stroke-specific motor measures (Fugl-Meyer Assessment, voluntary control grading) and longer follow-up (6 and 12 months) to establish retention of gains. Neuroimaging correlates of neuroplastic change (functional MRI or transcranial magnetic stimulation mapping) and cost-effectiveness analyses would further strengthen the evidence base.

Clinical Implications for Physiotherapy

If confirmed in controlled trials, early mid-range sling-suspension training could offer an inexpensive, equipment-light and readily teachable option for initiating upper-limb rehabilitation during the acute phase, particularly in resource-constrained Indian tertiary settings where robotic or electrical-stimulation systems are unavailable. In current practice the technique should be regarded as a feasible adjunct to, rather than a replacement for, established task-oriented and functional training approaches.

Conclusion

This prospective single-arm pilot study provides preliminary evidence that early mid-range functional training with sling suspension therapy is feasible, safe and well tolerated in acute stroke patients, and is associated with clinically meaningful improvements across all three outcomes over an 8-week programme at a tertiary-care institution in Tamil Nadu, India: upper-limb function (DASH -52.6%), stroke-specific quality of life (SSQOL +50.9%) and spasticity (MAS -62.7%), all $p < 0.0001$. Because the design lacked a control group, these associations cannot be attributed solely to the intervention and should be interpreted as hypothesis-generating.

The therapy concept is based on the principles of activity-dependent neuroplasticity, progressive motor learning, and spinal reflex modulation. The intervention capitalizes on the increased neuroplastic capacity of the acute recovery window to initiate the corticomotor map reorganisation, neuromuscular re-education, and neuromuscular synergy normalisation through placing the upper limb in gravity-eliminated positions; the use of structured mid-range activation with progressive loading.

More importantly, this research suggests that, even in patients with low initial MMT grades (grade 1-2) and moderate spasticity, meaningful functional and quality-of-life improvement may be attainable, supporting the consideration of early physiotherapy irrespective of the severity of upper-limb paresis at initial assessment. The gradual improvement between the mid-point and endpoint assessments suggests a need to maintain the training protocol beyond the acute period.

The results are relevant to clinical practice in stroke rehabilitation units in India and worldwide. Pending confirmation in randomised controlled trials, sling suspension therapy and mid-range functional training may be considered as a feasible early adjunct within the acute stroke physiotherapy plan. Future studies should investigate outcomes in a randomised controlled trial with a matched control group receiving conventional physiotherapy, the neuroimaging correlates of neuroplasticity associated with mid-range training using functional MRI, and

long-term (6-month and 1-year) functional outcomes after the intervention.

Data Availability Statement

The authors declare that all the data supporting the findings of this study are contained within the paper

Declaration Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Disclosure statement

All authors declare that there are no conflicts of interest associated with the publication of this manuscript.

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EthicsStatement:

The study was approved by the Institutional Ethics Committee (IEC) of Madhav University, Pindwara (Sirohi) (approval no. MU/IEC/24/01; dated 16/08/2024). In accordance with journal policy for clinical studies, the trial was registered with the Clinical Trials (Swamy Vivekanandha Medical College Hospital and Research Institute, Tiruchengode EC/NEW/INST/2024/TN/0529); dated 17/09/2024).

Patient Consent Statement:

Written informed consent was obtained from all participants prior to study enrollment, ensuring confidentiality, voluntary participation, and compliance with ethical standards for human subject research.

Data Availability Statement:

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request, in accordance with institutional policies and applicable data sharing regulations.

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