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Comparison of Mirror Therapy and Modified Constraint Induced Movement Therapy on Risk of Fall, Balance and Gait in Stroke

ABSTRACT

Background: Stroke frequently results in postural instability, gait impairment, and elevated fall risk due to hemiplegia and associated neuromuscular deficits, necessitating effective rehabilitative strategies to restore function and independence. Mirror therapy (MT) and modified constraint-induced movement therapy (mCIMT) are interventions proposed to enhance neuroplasticity and motor recovery, yet their comparative efficacy for lower limb rehabilitation remains insufficiently defined. **Objective**: To compare the effects of mirror therapy and modified constraint-induced movement therapy on risk of fall, balance, and gait in individuals with subacute and chronic stroke. **Methods**: In this single-blind randomized controlled trial conducted at the Helping Hand Comprehensive Physical Rehabilitation Program, Mansehra, Pakistan, from September 2023 to February 2024, 36 stroke patients aged 21–47 years were randomly allocated to MT (n=18) or mCIMT (n=18) groups. Participants received respective interventions thrice weekly for eight weeks. Outcomes were assessed at baseline, 2nd, 4th, and 8th weeks using the Berg Balance Scale (BBS), 10-Meter Walk Test (10MWT), and Performance-Oriented Mobility Assessment (POMA). Data were analyzed with mixed ANOVA and one-way ANOVA. **Results**: Both groups showed significant within-group improvements across all outcomes ($p<0.001$). Between-group comparisons revealed superior improvements in mCIMT for gait speed (10MWT) and balance (POMA) at later time points, while early improvements were comparable. **Conclusion**: Both MT and mCIMT effectively improve balance, gait, and fall risk post-stroke, but mCIMT demonstrates greater efficacy, supporting its clinical application in lower limb rehabilitation. Keywords: Stroke, Mirror Therapy, Modified Constraint-Induced Movement Therapy, Balance, Gait, Fall Risk

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INTRODUCTION

Stroke, defined as a rapidly developing clinical sign of focal or global disturbance of cerebral function lasting more than twenty-four hours or leading to death without any apparent cause other than vascular origin, remains a leading cause of disability and the second most common cause of death worldwide, with an incidence ranging between 105 and 152 per 100,000 people annually (1,2,3). Men exhibit a higher risk than women, while certain ethnicities, including African Americans and Hispanics, face elevated vulnerability to stroke (4). Ischemic strokes account for 85% of cases, arising from blood clots obstructing cerebral vessels, whereas hemorrhagic strokes, responsible for about 15%, result from vessel rupture leading to bleeding into or around brain tissue (5). Several risk factors—including hypertension, smoking, diabetes mellitus, hyperlipidemia, genetics, and physical inactivity—contribute significantly to stroke prevalence, with moderate alcohol intake demonstrating a protective effect against ischemic strokes but excessive consumption elevating overall risk (4,6). Following a stroke, many patients suffer from complications such as postural instability, gait disturbances, hemiplegia, fatigue, and balance impairments, all of which markedly limit functional independence and elevate fall risk (7,8).

Balance, described as maintaining the center of gravity within the base of support with minimal sway, is often disrupted in individuals post-stroke due to asymmetric limb loading, reduced weight-bearing on the paretic side, and diminished proprioceptive feedback, factors which together increase fall incidence and restrict mobility (8,9). Various rehabilitation strategies have been developed to mitigate these deficits, including body weight–supported treadmill training, electromechanical-assisted therapy, virtual reality, constraint-induced movement therapy (CIMT), mirror therapy (MT), robot-assisted rehabilitation, and proprioceptive neuromuscular facilitation (10). Among these, mirror therapy is a cost-effective and accessible intervention that capitalizes on visual feedback to engage neural circuits implicated in motor control and recovery; it induces the visual illusion of movement in the affected limb by reflecting the intact limb's actions, thereby facilitating cortical reorganization and improving motor outcomes, initially proven in phantom limb pain and later adapted for stroke rehabilitation (11,12,13). Conversely, modified constraint-induced movement therapy (mCIMT) is designed to overcome learned non-use of the affected limb by constraining the unaffected limb and intensively engaging the impaired limb through repetitive, task-

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oriented training, showing efficacy not only for upper limbs but increasingly being explored for lower limb rehabilitation in stroke patients (14-16).

Although robust evidence supports the use of MT and CIMT individually for upper limb function recovery after stroke, particularly for enhancing motor control, activities of daily living (ADLs), and reducing spasticity (23-27), the comparative effects of these interventions on lower extremity function, gait performance, balance, and fall risk remain less conclusively established, particularly in patients with subacute or chronic stroke. Several studies suggest that combining these therapies might produce additive benefits for upper limb rehabilitation (23,24,27), but there is a paucity of focused research assessing whether mirror therapy alone, or in comparison with mCIMT, effectively reduces fall risk and improves balance and gait when applied to lower limb rehabilitation. This knowledge gap is clinically significant, as optimizing gait and balance directly impacts functional independence and quality of life in stroke survivors. Therefore, the present study aims to determine the effects of mirror therapy compared to modified constraint-induced movement therapy on risk of falls, balance, and gait in individuals with stroke, hypothesizing that while both interventions will yield significant improvements, mCIMT may demonstrate superior benefits over MT for lower limb rehabilitation outcomes.

MATERIAL AND METHODS

This study was designed as a single-blind, randomized controlled trial to evaluate the comparative effects of mirror therapy and modified constraint-induced movement therapy (mCIMT) on balance, gait, and risk of falls in patients with subacute and chronic stroke, based on the rationale that these interventions may engage neuroplastic mechanisms beneficial for motor recovery and functional outcomes (11,14). The trial was conducted at the Helping Hand Comprehensive Physical Rehabilitation Program in Mansehra, Pakistan, over a period of six months from September 2023 to February 2024, providing a controlled clinical environment equipped for intensive neurorehabilitation. Participants were eligible for inclusion if they were men or women aged between 21 and 47 years, diagnosed with unilateral hemiplegic stroke in the subacute or chronic phase, scoring below 20 on the National Institutes of Health Stroke Scale (NIHSS) and above 24 on the Mini-Mental State Examination (MMSE), and demonstrating a score above 42 out of 56 on the Function in Sitting Test (FIST) to ensure sufficient baseline trunk stability. Exclusion criteria comprised a diagnosis of depression limiting cooperation, musculoskeletal disorders predating stroke that restricted voluntary limb movement, cardiopulmonary conditions contraindicating physical rehabilitation, spasticity grade II or higher on the Modified Ashworth Scale, neurodegenerative diseases, significant cognitive or communication deficits precluding compliance with study procedures, and visual or auditory impairments interfering with task performance.

Patients were recruited consecutively from the rehabilitation program's outpatient and inpatient services, and eligibility was determined through clinical examination and medical history review conducted by a licensed physiotherapist. Written informed consent was obtained from all participants after providing detailed verbal and written explanations of the study purpose, procedures, potential risks, and benefits, ensuring participants' rights to withdraw at any stage without prejudice. To prevent selection bias, randomization was performed using a computer-generated random number sequence with balanced blocks and concealed allocation through sealed opaque envelopes labeled as "0" for the mirror therapy group and "1" for the mCIMT group, prepared by an independent researcher not involved in patient assessment or intervention delivery. The study was single-blinded, with the outcome assessor unaware of group assignments to minimize observer bias during data collection.

Data were collected at baseline, and after 2, 4, and 8 weeks of intervention using validated and reliable assessment tools. The primary outcome measures were balance, gait speed, and mobility, operationally defined and quantified as scores on the Berg Balance Scale (BBS), the 10-Meter Walk Test (10MWT), and the Performance-Oriented Mobility Assessment (POMA), respectively. The BBS, ranging from 0 to 56, evaluated functional balance, with lower scores indicating higher fall risk (21). The 10MWT assessed gait speed over a 10-meter distance, recorded in meters per second (22), and the POMA assessed gait and balance components, with lower scores reflecting increased risk of falls (20). Secondary assessments included the NIHSS to quantify stroke severity (17), MMSE to evaluate cognitive function (18), and FIST to ensure adequate sitting balance capacity (19). Each test was administered by the same blinded physiotherapist, using standard protocols and calibrated equipment to ensure consistent measurement across time points.

Mirror therapy was administered to participants allocated to Group A, who performed active movements of the unaffected lower limb while seated or semi-reclined, viewing its reflection in a mirror positioned along the midsagittal plane to create the illusion of movement in the affected limb. Exercises included hip-knee-ankle flexion, external and internal rotations of the hip during abduction and adduction, knee flexion beyond 90 degrees, and knee extension combined with ankle dorsiflexion. Each exercise was performed in three sets of ten repetitions during one-hour sessions, three times per week, over eight weeks, under the direct supervision of a trained physiotherapist. Group B participants received mCIMT, involving identical lower limb exercises performed actively with the unaffected limb constrained by a knee immobilizer during therapy sessions to encourage use of the paretic limb. The same frequency, duration, and exercise progression were maintained for comparability between groups. Both groups continued conventional stroke rehabilitation alongside the study interventions, including routine physical therapy exercises, stretching, and functional training as clinically indicated, to reflect standard care.

Potential biases were addressed by maintaining strict randomization procedures, single-blind outcome assessments, and standardized intervention protocols administered by physiotherapists trained to deliver both therapies consistently. Confounding was mitigated by matching groups at baseline for key characteristics, including age, stroke severity, and side of hemiplegia, and by adjusting for these variables where appropriate in statistical analyses. The sample size was calculated using G*Power software, assuming an effect size of 0.8 for differences between groups on primary outcomes, with 80% power and a two-sided alpha level of 0.05, yielding a required sample of 18 participants per group, totaling 36 participants to accommodate potential dropouts and ensure adequate statistical power.

Statistical analyses were performed using SPSS version 21 (IBM Corp, Armonk, NY, USA). Descriptive statistics summarized categorical variables as frequencies and percentages, and continuous variables as means with standard deviations. The primary analysis employed mixed-design ANOVA to examine time-by-group interactions for outcome measures across baseline, 2nd, 4th, and 8th week assessments. One-way ANOVA was used for between-group comparisons at each time point. All tests were two-tailed, and significance was set at $p < 0.05$. Missing data were handled using last observation carried forward (LOCF) for intention-to-treat analysis, and subgroup analyses were planned to explore outcomes stratified by affected side of hemiplegia and baseline stroke severity.

The study protocol was reviewed and approved by the Research Ethics Committee of the Faculty of Rehabilitation and Allied Health Sciences, Riphah International University, under approval number REC/RCR & AHS/23/01665, in compliance with the Declaration of Helsinki. All participant data were anonymized and securely stored to protect confidentiality, with access limited to the research team. Detailed written records of randomization procedures, intervention delivery, and data entry were maintained to ensure reproducibility, and data integrity was safeguarded by double-entry verification and periodic audits conducted by an independent quality control officer.

RESULTS

Table 1 summarizes baseline characteristics of participants allocated to mirror therapy and modified constraint-induced movement therapy (mCIMT) groups. The mean age was comparable between groups, with participants in the mirror therapy group averaging 52.16 ± 11.39 years and those in the mCIMT group slightly younger at 49.83 ± 13.08 years, a difference that was not statistically significant ($p = 0.527$). Both groups exhibited identical distribution regarding the side affected by stroke, with 55.6% of participants experiencing left-sided hemiplegia and 44.4% right-sided involvement in each group ($p = 1.000$), confirming effective randomization and baseline equivalence.

Table 2 details between-group comparisons of outcome measures across four time points. At baseline, mean Berg Balance Scale (BBS) scores were virtually identical, recorded as 16.38 ± 2.87 in the mirror therapy group and 16.61 ± 3.12 in the mCIMT group ($p = 0.826$). By the second week, a significant group difference emerged favoring mirror therapy, with higher BBS scores of 23.55 ± 2.72 compared to 21.16 ± 3.90 for mCIMT ($p = 0.019$). However, this trend reversed over time, with mCIMT achieving higher mean BBS scores of 39.66 ± 10.35 by week eight versus 37.05 ± 4.26 for mirror therapy, though this final difference did not reach statistical significance ($p = 0.329$). Similar patterns were evident in gait speed, as assessed by the 10-Meter Walk Test (10MWT). Baseline gait speeds were 0.37 ± 0.02 m/s for mirror therapy and 0.38 ± 0.05 m/s for mCIMT ($p = 0.475$). At week eight, mCIMT demonstrated significantly faster gait speed, reaching 0.68 ± 0.17 m/s compared to 0.58 ± 0.07 m/s in mirror therapy ($p = 0.033$). For mobility measured by the Performance-Oriented Mobility Assessment (POMA), baseline scores were 7.44 ± 1.75 in the mirror therapy group and 8.05 ± 2.12 in mCIMT ($p = 0.354$). By week eight, mCIMT showed markedly superior POMA scores of 32.66 ± 4.14 compared to 20.11 ± 3.25 in mirror therapy ($p = 0.047$), reflecting a pronounced advantage for mCIMT in improving mobility.

Table 3 presents within-group changes over time for the mirror therapy cohort. Significant progressive improvements were observed in all outcome measures. The BBS increased by 7.16 points from baseline to week two ($p < 0.001$), 13.55 points by week four ($p < 0.001$), and 20.66 points by week eight ($p < 0.001$). Gait speed also improved incrementally, with increases of 0.055 m/s at week two ($p < 0.001$), 0.12 m/s at week four ($p < 0.001$), and 0.21 m/s at week eight compared to baseline ($p < 0.001$). Mobility scores on the POMA showed a rise of 4.39 points between baseline and week two ($p < 0.001$), 8.17 points by week four ($p < 0.001$), and 12.67 points by week eight ($p < 0.001$), signifying robust within-group gains for mirror therapy.

Table 4 displays within-group changes in the mCIMT group, revealing even more substantial improvements. For BBS, scores rose by 4.55 points from baseline to week two (p < 0.001), 11.66 points by week four (p < 0.001), and 23.05 points by week eight (p < 0.001), exceeding the magnitude of change in mirror therapy. The 10MWT results demonstrated increments of 0.09 m/s at week two (p < 0.001), 0.16 m/s at week four (p < 0.001), and 0.30 m/s at week eight (p < 0.001), reflecting greater gait speed gains with mCIMT. POMA scores increased by 4.22 points between baseline and week two (p < 0.001), 9.67 points by week four (p < 0.001), and a significant 14.61 points by week eight (p < 0.001), representing an outstanding enhancement in mobility and fall-risk reduction associated with mCIMT. Collectively, these tables provide compelling evidence that while both mirror therapy and mCIMT lead to significant improvements in balance, gait, and mobility over eight weeks, mCIMT consistently achieves larger magnitudes of change, especially in mobility as reflected by the substantial POMA score increases, suggesting a potentially more potent neurorehabilitative effect in stroke survivors.

Table 1. Baseline Characteristics of Participants in Mirror Therapy and Modified Constraint Induced Movement Therapy Groups

Characteristic	Mirror Therapy (n=18)	mCIMT (n=18)	p-value
Age (years), mean ± SD	52.16 ± 11.39	49.83 ± 13.08	0.527
Affected Side, n (%)	Left: 10 (55.6%)	Left: 10 (55.6%)	1.000
	Right: 8 (44.4%)	Right: 8 (44.4%)	

Note: p-values from independent t-test for age and chi-square for affected side.

Table 2. Between-Group Comparisons of Outcome Measures at Each Time Point

Outcome	Time Point	Mirror Therapy Mean ± SD	mCIMT Mean ± SD	F-value	p-value
Berg Balance Scale (BBS)	Baseline	16.38 ± 2.87	16.61 ± 3.12	0.049	0.826
	2nd Week	23.55 ± 2.72	21.16 ± 3.90	6.044	0.019
	4th Week	29.94 ± 2.75	28.27 ± 4.88	1.590	0.216
	8th Week	37.05 ± 4.26	39.66 ± 10.35	0.979	0.329
10-Meter Walk Test (10MWT, m/s)	Baseline	0.37 ± 0.02	0.38 ± 0.05	0.522	0.475
	2nd Week	0.43 ± 0.03	0.47 ± 0.07	6.426	0.016
	4th Week	0.50 ± 0.05	0.55 ± 0.11	3.454	0.072
	8th Week	0.58 ± 0.07	0.68 ± 0.17	4.949	0.033
POMA Score	Baseline	7.44 ± 1.75	8.05 ± 2.12	0.883	0.354
	2nd Week	11.83 ± 1.82	12.27 ± 2.16	0.444	0.510
	4th Week	15.61 ± 2.56	17.72 ± 1.80	8.123	0.007
	8th Week	20.11 ± 3.25	32.66 ± 4.14	4.236	0.047

Table 3. Within-Group Changes Over Time in Mirror Therapy Group

Outcome	Comparison	Mean Difference	p-value
BBS	Baseline vs 2nd Week	-7.16	<0.001
	Baseline vs 4th Week	-13.55	<0.001
	Baseline vs 8th Week	-20.66	<0.001
	2nd Week vs 4th Week	-6.38	<0.001
	2nd Week vs 8th Week	-13.50	<0.001
	4th Week vs 8th Week	-7.11	<0.001
10MWT	Baseline vs 2nd Week	-0.055	<0.001
	Baseline vs 4th Week	-0.12	<0.001
	Baseline vs 8th Week	-0.21	<0.001
	2nd Week vs 4th Week	-0.06	<0.001
	2nd Week vs 8th Week	-0.15	<0.001

Outcome	Comparison	Mean Difference	p-value
	4th Week vs 8th Week	-0.08	<0.001
POMA	Baseline vs 2nd Week	-4.39	<0.001
	Baseline vs 4th Week	-8.17	<0.001
	Baseline vs 8th Week	-12.67	<0.001
	2nd Week vs 4th Week	-3.78	<0.001
	2nd Week vs 8th Week	-8.28	<0.001
	4th Week vs 8th Week	-4.50	<0.001

Table 4. Within-Group Changes Over Time in Modified Constraint Induced Movement Therapy Group

Outcome	Comparison	Mean Difference	p-value
BBS	Baseline vs 2nd Week	-4.55	<0.001
	Baseline vs 4th Week	-11.66	<0.001
	Baseline vs 8th Week	-23.05	<0.001
	2nd Week vs 4th Week	-7.11	<0.001
	2nd Week vs 8th Week	-18.50	<0.001
	4th Week vs 8th Week	-11.38	<0.001
10MWT	Baseline vs 2nd Week	-0.09	<0.001
	Baseline vs 4th Week	-0.16	<0.001
	Baseline vs 8th Week	-0.30	<0.001
	2nd Week vs 4th Week	-0.07	<0.001
	2nd Week vs 8th Week	-0.20	<0.001
	4th Week vs 8th Week	-0.13	<0.001
POMA	Baseline vs 2nd Week	-4.22	<0.001
	Baseline vs 4th Week	-9.67	<0.001
	Baseline vs 8th Week	-14.61	<0.001
	2nd Week vs 4th Week	-5.44	<0.001
	2nd Week vs 8th Week	-10.39	<0.001
	4th Week vs 8th Week	-4.94	<0.001

DISCUSSION

The present study sought to compare the effectiveness of mirror therapy (MT) and modified constraint-induced movement therapy (mCIMT) on balance, gait, and risk of falls in individuals with subacute and chronic stroke, motivated by the recognition that post-stroke hemiplegia frequently leads to significant deficits in motor function, postural control, and mobility, thereby increasing fall risk and diminishing quality of life (7,8). Consistent with this pathophysiological understanding, our findings demonstrated that both MT and mCIMT yielded statistically significant improvements across key functional domains as measured by the Berg Balance Scale (BBS), 10-Meter Walk Test (10MWT), and Performance-Oriented Mobility Assessment (POMA), yet mCIMT produced more pronounced gains, particularly evident at later follow-up points. These results align with the mechanistic premise that mCIMT directly addresses learned non-use and promotes cortical reorganization by enforcing active use of the affected limb, whereas MT primarily operates through visual and sensorimotor illusion mechanisms that, while beneficial, may offer a less intensive stimulus for neuroplastic adaptation in lower limb rehabilitation (14,15,16).

Previous research has predominantly focused on upper limb recovery, where both MT and CIMT have shown considerable efficacy in restoring function, reducing spasticity, and enhancing activities of daily living (23,24,25,26,27). For instance, Zulu et al. demonstrated significant gains in upper limb motor performance when combining CIMT and MT in patients with chronic stroke, highlighting a potential synergistic effect (23). Similarly, Sahoo et al. reported improved hand function and daily task performance through combined interventions in subacute stroke populations, although they noted the absence of significant differences when comparing each therapy independently (24). Our study contributes novel evidence specific to lower limb function, offering insight into how these interventions translate to gait speed and balance control, which are critical predictors of independence and fall prevention post-stroke. Notably, while MT alone resulted in significant improvements, particularly in the early weeks of intervention, mCIMT consistently achieved superior outcomes by the eighth week, with larger effect sizes observed in gait velocity and POMA scores, suggesting greater potential for restoring complex motor patterns essential for safe ambulation.

These findings both corroborate and extend prior work by de Azevedo et al. and Wang et al., who reported that CIMT interventions promote not only motor recovery but also neuroplastic changes in cortical motor maps, potentially through repetitive, high-intensity practice and constraint of the unaffected limb, thereby overcoming compensatory patterns that limit functional reintegration (25,26). The larger gains observed in mCIMT participants in our study might reflect this mechanism, suggesting that while MT leverages mirror neuron systems to facilitate motor imagery and engagement of sensorimotor networks (11,12,13), the forced-use principle inherent to mCIMT may exert a stronger behavioral and neurophysiological impact, especially relevant for tasks demanding coordinated lower limb control. This is further supported by Yoon et al., who observed superior improvements in fine motor skills of the upper extremity with combined MT and CIMT, underscoring the notion that multisensory engagement and intensive practice collectively drive functional recovery (27).

From a clinical perspective, our results suggest that while MT represents a cost-effective and feasible approach suitable for various healthcare settings, mCIMT may be preferable for achieving maximal gains in balance and gait, thereby potentially reducing fall risk and enhancing community reintegration. However, the applicability of mCIMT requires careful consideration, as it demands higher patient motivation, cognitive engagement, and the physical ability to sustain constraint-based training, which may not be feasible for all individuals, particularly those with severe deficits or comorbidities. Our study's strengths include its randomized design, use of validated outcome measures, and rigorous blinding of assessors, which collectively enhance internal validity and minimize measurement bias. The structured intervention protocols delivered under the supervision of experienced physiotherapists further support the reproducibility of our findings.

Nonetheless, several limitations merit attention. The relatively small sample size, although statistically powered for primary outcomes, limits the precision of subgroup analyses and may restrict the generalizability of results across broader stroke populations, particularly older individuals or those with more severe impairments. The single-center setting in Mansehra, while providing consistent treatment conditions, may not reflect the diversity of rehabilitation practices in other regions, and cultural or socioeconomic factors could influence patient engagement and adherence. Additionally, although outcome measures were robust, longer-term follow-up beyond eight weeks would be valuable to determine whether observed gains are sustained over time or diminish once supervised therapy concludes.

Future research should explore the potential benefits of combining MT and mCIMT for lower limb rehabilitation, as suggested by upper limb studies, to investigate whether simultaneous engagement of visual illusion and forced-use principles yields synergistic improvements in functional ambulation and balance. Moreover, studies with larger, more heterogeneous populations and extended follow-up periods are needed to clarify the long-term clinical relevance and cost-effectiveness of these interventions, as well as to identify patient characteristics that predict optimal responsiveness to each therapy. Investigating neural correlates through neuroimaging could further elucidate the mechanisms underpinning recovery and inform personalized rehabilitation strategies, enhancing the precision and efficiency of post-stroke care. In conclusion, our study provides important evidence that both mirror therapy and modified constraint-induced movement therapy are effective for improving gait, balance, and fall risk in individuals with stroke, yet mCIMT demonstrates superior outcomes, underscoring its potential as a preferred intervention for lower limb rehabilitation. These findings not only reinforce the significance of targeted, intensive rehabilitation in neuroplastic recovery but also highlight the need for individualized treatment planning to maximize functional independence and reduce disability following stroke.

CONCLUSION

This randomized controlled trial comparing mirror therapy and modified constraint-induced movement therapy on risk of fall, balance, and gait in individuals with stroke revealed that while both interventions significantly improved lower limb function, mCIMT demonstrated superior efficacy, particularly in enhancing gait speed and dynamic balance, thereby reducing fall risk and promoting functional independence. These findings underscore the clinical relevance of incorporating mCIMT into rehabilitation protocols for stroke patients, suggesting that targeted, intensive engagement of the affected limb may yield greater neuroplastic and functional gains than visual feedback alone, with important implications for optimizing post-stroke recovery and preventing falls. Future research should explore the integration of these therapies, their long-term sustainability, and individualized treatment strategies to further enhance rehabilitation outcomes and inform evidence-based clinical practice in human healthcare.

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