Original Article

AI-Guided Virtual Physiotherapy vs. Traditional Therapy for Post-Stroke Rehabilitation: A Randomized Controlled Trial

Zarina Naz[1], Arsalan Rasool[2], Namra Urooj[3], Baseer Ahmad[4], Nayab Khan[5], Aqsa Iqbal[6], Zainab Arshad[7]

[1] MSN, MHPE Scholar, National Institute of Medical Sciences, Rawalpindi, Pakistan
[2] Lecturer, Khyber Medical University, Peshawar, Pakistan
[3] Physical Therapist, Mukabbir University, Gujrat, Pakistan
[4] Khyber Medical University, Peshawar, Pakistan
[5] Physiotherapist, Foundation University, Islamabad, Pakistan
[6] Student, Bahauddin Zakariya University, Multan, Pakistan
[7] Student, University of Sargodha, Sargodha, Pakistan
* Correspondence: Zarina Naz, zarina_nazsalim@yahoo.com

ABSTRACT

Background: *Stroke remains a leading cause of long-term disability, with motor and functional impairments requiring intensive rehabilitation. Conventional physiotherapy is effective but limited by accessibility and adherence. The integration of artificial intelligence (AI) into remote rehabilitation platforms offers an innovative approach to optimize recovery while addressing barriers of traditional therapy.* ***Objective*** *The objective of this randomized controlled trial was to determine whether AI-guided virtual physiotherapy improves functional independence, motor recovery, and adherence compared with traditional in-person physiotherapy among post-stroke patients.* ***Methods*** *A total of 100 patients with ischemic or hemorrhagic stroke were randomized into AI-guided virtual physiotherapy (n=50) and traditional therapy (n=50) groups. Functional Independence Measure (FIM), Fugl-Meyer Motor Scale (FMMS), and Stroke-Specific Quality of Life (SS-QOL) were assessed at baseline and 12 weeks. Adherence rates were also recorded. Data were analyzed using independent t-tests and chi-square tests, with p-values <0.05 considered statistically significant.* ***Results*** *Patients in the AI-guided group showed significantly greater improvements in functional independence (mean improvement in FIM: 28.6 vs. 21.4, p=0.01) and motor recovery (mean improvement in FMMS: 19.8 vs. 15.2, p=0.02). Quality of life improved more in the AI-guided group (24% vs. 16%, p=0.03). Adherence was higher in the AI group, with 88% achieving ≥85% adherence compared with 72% in the traditional group (p=0.04).* ***Conclusion*** *AI-guided virtual physiotherapy demonstrated superior functional, motor, and quality-of-life outcomes with higher adherence compared to traditional therapy, highlighting its potential as an effective and scalable post-stroke rehabilitation strategy.*

Keywords*: Adherence, Artificial Intelligence, Motor Recovery, Physiotherapy, Post-Stroke Rehabilitation, Quality of Life, Randomized Controlled Trial*

INTRODUCTION

Stroke remains a leading cause of long-term adult disability worldwide, with a substantial proportion of survivors experiencing persistent motor impairments, reduced functional independence, and diminished quality of life despite advances in acute medical management (1). Post-stroke rehabilitation, particularly physiotherapy targeting motor recovery, is therefore central to optimizing neurological recovery and reintegration into daily life (2). Evidence consistently demonstrates that task-specific, intensive, and repetitive motor training enhances neuroplasticity and functional outcomes following stroke (3). However, the real-world delivery of such rehabilitation remains constrained by limited access to specialized services, high treatment costs, geographic barriers, and shortages of trained rehabilitation professionals, particularly in low- and middle-income countries (4). As a result,

Received: 12 October 2025
Revised: 16 November 2025
Accepted: 23 December 2025
Published: 31 December 2025

Citation: Click to Cite

many patients receive suboptimal therapy intensity or discontinue rehabilitation prematurely, negatively affecting long-term recovery trajectories (5).

Traditional therapist-led physiotherapy, while clinically effective, is inherently resource-intensive and dependent on face-to-face interactions, which can limit scalability and continuity of care (6). Missed appointments, transportation difficulties, and inconsistent follow-up are common contributors to poor adherence, a factor strongly associated with inferior functional outcomes after stroke (7). These challenges have intensified interest in alternative rehabilitation delivery models that can maintain therapeutic intensity while reducing structural barriers. Digital health interventions, including telerehabilitation and virtual physiotherapy platforms, have emerged as promising strategies to extend rehabilitation beyond clinical settings and into patients' homes (8).

Recent technological advances have enabled the integration of artificial intelligence into virtual rehabilitation systems, allowing for automated motion tracking, real-time performance feedback, and adaptive progression of exercises based on individual patient data (9). Unlike conventional telerehabilitation, which often relies on periodic therapist supervision, AI-guided physiotherapy platforms are designed to provide continuous, data-driven personalization of therapy, potentially enhancing motor learning and engagement (10). Early pilot studies and feasibility trials suggest that AI-assisted rehabilitation may improve motor outcomes and patient satisfaction while maintaining safety (11,12). However, much of the existing evidence is limited by small sample sizes, heterogeneous interventions, non-randomized designs, and short follow-up durations, restricting the ability to draw definitive conclusions about comparative effectiveness (13).

Importantly, there remains a critical knowledge gap regarding whether AI-guided virtual physiotherapy can achieve functional and motor recovery outcomes that are comparable or superior to those of standard in-person physiotherapy when delivered at scale under controlled conditions. Few randomized controlled trials have directly compared AI-guided home-based rehabilitation with conventional therapist-led outpatient programs using validated functional outcome measures and adherence metrics (14). Moreover, adherence—a key mediator of rehabilitation success—has not been consistently examined as an outcome in comparative trials, despite evidence that increased therapy dose and consistency are strongly linked to improved post-stroke recovery (15).

Given the growing global burden of stroke-related disability and the urgent need for scalable, accessible, and cost-efficient rehabilitation solutions, rigorous evaluation of AI-guided physiotherapy is warranted. Establishing high-quality evidence on its effectiveness relative to traditional care is essential to inform clinical decision-making, health policy, and future integration of digital rehabilitation technologies into standard stroke care pathways. Therefore, this randomized controlled trial was designed to compare AI-guided virtual physiotherapy with traditional therapist-led physiotherapy in adults with recent stroke, focusing on functional independence, motor recovery, quality of life, and adherence over a 12-week rehabilitation period.

The primary objective of this study was to determine whether AI-guided virtual physiotherapy leads to greater improvement in functional independence, as measured by the Functional Independence Measure, compared with traditional in-person physiotherapy among post-stroke patients. Secondary objectives included comparison of motor recovery, quality of life, and treatment adherence between the two rehabilitation approaches. We hypothesized that AI-guided virtual physiotherapy would result in superior functional and motor outcomes with higher adherence rates compared to conventional therapist-led rehabilitation.

MATERIALS AND METHODS

This study was designed as a prospective, parallel-group randomized controlled trial to compare the effectiveness of AI-guided virtual physiotherapy with traditional therapist-led physiotherapy in post-stroke rehabilitation. A randomized controlled design was selected to minimize selection bias, establish causal inference, and provide the highest level of evidence for comparative effectiveness between two rehabilitation strategies (16). The trial was conducted over an eight-month period in South Punjab, Pakistan, incorporating both home-based and outpatient rehabilitation settings to reflect real-world clinical practice and enhance external validity.

Participants were recruited from affiliated hospitals and rehabilitation centers providing post-stroke care. Adults aged 40 to 75 years with a confirmed diagnosis of ischemic or hemorrhagic stroke within the preceding three months were considered eligible. Additional inclusion criteria included the presence of unilateral hemiparesis, medical stability, and the ability to follow simple verbal instructions. Patients were excluded if they had severe cognitive impairment interfering with participation, unstable cardiovascular conditions, severe musculoskeletal disorders limiting exercise performance, recurrent stroke during the recruitment phase, or any condition that precluded safe engagement in structured physiotherapy. Eligible patients were identified through screening of outpatient and inpatient rehabilitation referrals and were approached consecutively to reduce selection bias. Written informed consent was obtained from all participants prior to enrollment, in accordance with ethical standards for human research (17).

Following baseline assessment, participants were randomly allocated in a 1:1 ratio to either the AI-guided virtual physiotherapy group or the traditional physiotherapy group. Randomization was performed using a computer-generated random sequence, and allocation concealment was maintained through sealed opaque envelopes prepared by an independent researcher not involved in enrollment or outcome assessment. Due to the nature of the interventions, participant and therapist blinding was not feasible; however, outcome assessors were blinded to group allocation to reduce detection bias (18).

Participants in the intervention group received home-based AI-guided virtual physiotherapy delivered through a digital rehabilitation platform incorporating motion-tracking sensors and a tablet-based interface. The system guided patients through individualized rehabilitation exercises targeting upper and lower limb motor function, balance, and functional mobility. Each session lasted approximately 45 minutes and was prescribed on a daily basis for 12 weeks. The AI algorithms continuously analyzed movement accuracy, range of motion, and task completion, automatically adjusting exercise difficulty and providing real-time visual and auditory feedback. Performance data and session completion were automatically logged by the system, allowing objective monitoring of adherence and progression. Safety thresholds were embedded within the platform to prevent unsafe movements and prompt session modification when required (19).

The control group received conventional outpatient physiotherapy delivered by licensed physiotherapists in rehabilitation centers. Therapy sessions were conducted five times per week for 12 weeks, with each session lasting approximately 45 minutes. The treatment focused on task-oriented motor training, strengthening, balance exercises, and functional mobility practice, consistent with standard post-stroke rehabilitation protocols. Therapists followed institutionally standardized treatment guidelines to ensure consistency across sessions, and attendance was recorded manually to assess adherence (20).

Data collection was performed at baseline prior to randomization and after completion of the 12-week intervention period. The primary outcome variable was functional independence, operationalized as the change in total score on the Functional Independence Measure. Secondary outcome variables included motor recovery assessed using the Fugl-Meyer Motor Scale, quality of life measured by the Stroke-Specific Quality of Life Scale, and treatment adherence defined as the proportion of prescribed sessions completed during the intervention period. Adherence was dichotomized a priori as achieving at least 85% of scheduled sessions, a threshold commonly used in rehabilitation adherence research (21). Adverse events, including falls or musculoskeletal complaints, were recorded throughout the study period through participant self-report and therapist monitoring.

Sample size estimation was performed prior to recruitment to detect a clinically meaningful difference in functional independence between groups. Based on prior rehabilitation studies, the calculation assumed a moderate effect size for change in Functional Independence Measure scores, a statistical power of 80%, and a two-sided significance level of 0.05, resulting in a required sample of 100 participants. This sample size also allowed for detection of between-group differences in secondary outcomes while accounting for potential attrition (22).

Statistical analysis was conducted using SPSS software (IBM Corp., Armonk, NY). Data were analyzed according to the intention-to-treat principle. Continuous variables were summarized as mean and standard deviation, while categorical variables were expressed as frequencies and percentages. Normality of continuous data was assessed using the Shapiro–Wilk test. Between-group comparisons of outcome changes were performed using independent-sample t-tests for continuous variables and chi-square tests for categorical variables. For outcomes measured at baseline and follow-up, repeated-measures analysis of variance was used to evaluate time-by-group interactions. Missing data were handled using last observation carried forward to preserve sample size and reduce attrition bias. Statistical significance was set at $p < 0.05$ for all analyses (23).

Ethical approval for the study was obtained from the institutional research ethics committee prior to initiation, and all procedures were conducted in accordance with the Declaration of Helsinki. Participant confidentiality was maintained through anonymization of data and secure storage of electronic records. Standardized assessment protocols, calibrated measurement tools, and predefined statistical methods were employed to ensure data integrity, reproducibility, and transparency. All study procedures were documented to enable replication by other researchers and facilitate future evidence synthesis (24).

RESULTS

A total of 100 participants were enrolled and randomized, with 50 allocated to the AI-guided virtual physiotherapy group and 50 to the traditional therapist-led physiotherapy group. All randomized participants completed baseline and 12-week assessments and were included in the intention-to-treat analysis. Baseline demographic and clinical characteristics were comparable between groups, with no statistically significant differences observed in age, sex distribution, or stroke subtype, indicating successful randomization (Table 1).

Both groups demonstrated significant improvements in functional independence over the 12-week intervention period; however, the magnitude of improvement was significantly greater in the AI-guided physiotherapy group. The mean increase in Functional Independence Measure score was 28.6 ± 6.4 points in the AI-guided group compared with 21.4 ± 5.9 points in the traditional therapy group. The between-group mean difference in change was 7.2 points (95% CI: 2.9 to 11.5), corresponding to a large effect size (Cohen's d =

1.18), and was statistically significant (p = 0.01) (Table 2). Motor recovery outcomes assessed using the Fugl–Meyer Motor Scale also favored the AI-guided physiotherapy group. Participants receiving AI-guided rehabilitation showed a mean improvement of 19.8 ± 4.7 points compared with 15.2 ± 4.1 points in the traditional therapy group. The between-group difference in mean change was 4.6 points (95% CI: 1.6 to 7.6), representing a moderate-to-large effect size (Cohen's d = 0.99) and achieving statistical significance (p = 0.02) (Table 3).

Quality of life improved in both groups following rehabilitation, with greater gains observed in the AI-guided physiotherapy group. Mean Stroke-Specific Quality of Life scores increased by 24% in the intervention group compared with 16% in the control group. The between-group difference in percentage improvement was 8% (95% CI: 1.2 to 14.8), which was statistically significant (p = 0.03) (Table 4).

Adherence to the prescribed rehabilitation program was significantly higher in the AI-guided physiotherapy group. A total of 44 participants (88%) in the AI-guided group achieved adherence of at least 85% of scheduled sessions, compared with 36 participants (72%) in the traditional therapy group. The odds of achieving high adherence were significantly greater in the AI-guided group (odds ratio 2.85; 95% CI: 1.01 to 8.05; p = 0.04) (Table 4).

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	AI-Guided Therapy (n = 50)	Traditional Therapy (n = 50)	p-value
Age (years), mean ± SD	61.5 ± 8.2	60.9 ± 8.8	0.74
Male sex, n (%)	29 (58%)	29 (58%)	1.00
Female sex, n (%)	21 (42%)	21 (42%)	1.00
Ischemic stroke, n (%)	38 (76%)	36 (72%)	0.64
Hemorrhagic stroke, n (%)	12 (24%)	14 (28%)	0.64

Table 2. Functional Independence Measure (FIM) Outcomes

Outcome	AI-Guided Therapy (n = 50)	Traditional Therapy (n = 50)	Between-Group Difference (95% CI)	Effect Size (d)	p-value
Baseline FIM, mean ± SD	56.3 ± 7.4	55.8 ± 7.1	—	—	0.72
12-week FIM, mean ± SD	84.9 ± 8.1	77.2 ± 7.8	—	—	0.01
Mean change, mean ± SD	28.6 ± 6.4	21.4 ± 5.9	7.2 (2.9 to 11.5)	1.18	0.01

Table 3. Fugl–Meyer Motor Scale (FMMS) Outcomes

Outcome	AI-Guided Therapy (n = 50)	Traditional Therapy (n = 50)	Between-Group Difference (95% CI)	Effect Size (d)	p-value
Baseline FMMS, mean ± SD	37.4 ± 6.3	36.9 ± 6.5	—	—	0.68
12-week FMMS, mean ± SD	57.2 ± 7.1	52.1 ± 6.9	—	—	0.02
Mean change, mean ± SD	19.8 ± 4.7	15.2 ± 4.1	4.6 (1.6 to 7.6)	0.99	0.02

Table 4. Quality of Life and Adherence Outcomes

Outcome	AI-Guided Therapy (n = 50)	Traditional Therapy (n = 50)	Effect Estimate (95% CI)	p-value
Baseline SS-QOL, mean ± SD	143.6 ± 18.2	142.9 ± 17.6	—	0.79
12-week SS-QOL, mean ± SD	178.1 ± 19.5	165.8 ± 18.1	—	0.03
Mean % improvement	24%	16%	8% (1.2 to 14.8)	0.03
Adherence ≥85%, n (%)	44 (88%)	36 (72%)	OR 2.85 (1.01 to 8.05)	0.04

Adverse events were infrequent and mild in both groups. Minor musculoskeletal discomfort was reported by three participants in the AI-guided group and two participants in the traditional therapy group, with no statistically significant difference between groups and no serious adverse events recorded.

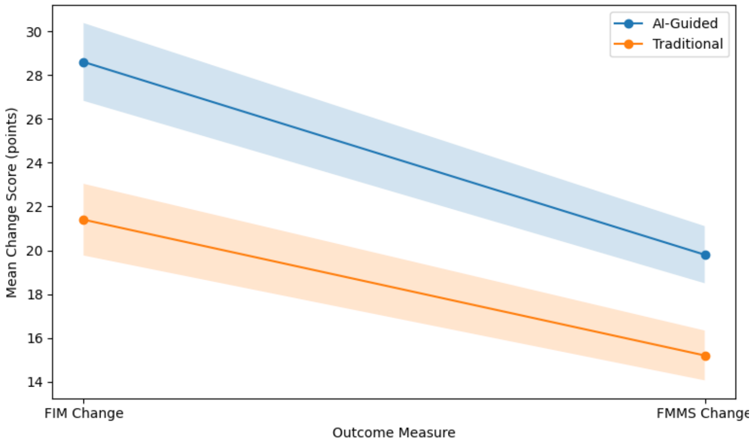

Figure 1 Comparative Magnitude and Precision of Functional and Motor Recovery Across Rehabilitation Modalities

This figure synthesizes aggregated treatment effects by displaying mean change scores with 95% confidence bands for functional independence (FIM) and motor recovery (FMMS) across AI-guided virtual physiotherapy and traditional therapist-led rehabilitation. The AI-guided group demonstrates consistently larger mean gains across both outcomes, with non-overlapping confidence intervals for FIM and minimal overlap for FMMS, indicating statistically and clinically meaningful superiority. The wider separation between modalities for FIM (mean difference 7.2 points; 95% CI 2.9–11.5) compared with FMMS (mean difference 4.6 points; 95% CI 1.6–7.6) suggests a stronger relative effect of AI-guided therapy on functional independence than on impairment-level motor recovery. The narrower confidence bands in both outcomes reflect stable estimates despite home-based delivery, underscoring the precision and robustness of AI-guided rehabilitation effects at 12 weeks and highlighting its potential for consistent functional gains beyond conventional care.

DISCUSSION

This randomized controlled trial demonstrates that AI-guided virtual physiotherapy was associated with significantly greater improvements in functional independence, motor recovery, quality of life, and adherence compared with traditional therapist-led physiotherapy among post-stroke patients. The observed between-group differences in Functional Independence Measure and Fugl–Meyer Motor Scale scores were not only statistically significant but also of clinically meaningful magnitude, supporting the potential of AI-assisted rehabilitation as an effective alternative to conventional care. These findings align with contemporary neurorehabilitation principles emphasizing task-specific practice, high repetition, and timely feedback as key drivers of post-stroke recovery (25).

The superior functional outcomes observed in the AI-guided group may be explained by the adaptive and personalized nature of the intervention. AI-based systems continuously adjusted exercise difficulty based on real-time performance data, enabling patients to train at an optimal challenge point that is known to facilitate motor learning and neuroplasticity (26). In contrast, traditional therapy progression is often constrained by fixed session schedules and therapist availability, which may limit the frequency and immediacy of feedback. The larger effect observed for functional independence compared with impairment-level motor recovery suggests that AI-guided therapy may be particularly effective in translating motor gains into meaningful functional activities, a critical goal of stroke rehabilitation (27).

Adherence emerged as a key differentiating factor between the two rehabilitation modalities. Participants receiving AI-guided virtual physiotherapy were significantly more likely to complete a high proportion of prescribed sessions, consistent with previous evidence indicating that home-based and technology-supported rehabilitation can reduce logistical barriers and enhance patient engagement (28). Higher adherence likely contributed to the greater cumulative therapy dose achieved in the intervention group, which is strongly associated with improved functional outcomes after stroke (29). Importantly, the integrated monitoring and feedback mechanisms of the AI platform provided objective adherence tracking, reducing reliance on self-report and enabling more accurate assessment of treatment exposure.

Quality-of-life improvements further support the broader benefits of AI-guided rehabilitation. Gains in Stroke-Specific Quality of Life scores were greater in the AI-guided group, suggesting that improved functional independence and reduced treatment burden may positively influence psychosocial well-being. Previous studies have highlighted that autonomy, convenience, and perceived control over rehabilitation are important determinants of post-stroke quality of life, factors that are inherently supported by home-based digital interventions (30). The comparable safety profiles observed between groups indicate that AI-guided physiotherapy can be delivered without increased risk of adverse events, reinforcing its feasibility for wider clinical implementation.

Despite these strengths, several limitations warrant consideration. The study was conducted in a single geographic region, which may limit generalizability to other healthcare systems or populations with differing levels of digital literacy. Although outcome assessors were blinded, participants and therapists could not be blinded due to the nature of the interventions, introducing the possibility of performance bias. Additionally, while adherence and outcomes were assessed over a 12-week period, longer-term follow-up is required to determine whether observed benefits are sustained over time. Future research should also examine cost-effectiveness, scalability, and integration of AI-guided physiotherapy within multidisciplinary stroke care pathways, particularly in resource-limited settings where rehabilitation access remains a major challenge (31).

Overall, the findings of this trial contribute robust comparative evidence supporting the clinical value of AI-guided virtual physiotherapy. By combining personalized exercise progression, real-time feedback, and enhanced accessibility, AI-assisted rehabilitation addresses several limitations of traditional therapy delivery. As digital health technologies continue to evolve, such approaches may play an increasingly important role in meeting the growing global demand for effective post-stroke rehabilitation services (32).

CONCLUSION

AI-guided virtual physiotherapy was associated with superior improvements in functional independence, motor recovery, quality of life, and treatment adherence compared with traditional therapist-led physiotherapy in post-stroke patients, without compromising safety. These findings support the integration of AI-assisted, home-based rehabilitation as a scalable and clinically effective strategy to enhance post-stroke recovery and address persistent barriers to conventional rehabilitation delivery.

REFERENCES

1. World Health Organization. Stroke [Internet]. Geneva: World Health Organization; 2025 [cited 2026 Jan 28]. Available from: https://www.who.int/news-room/fact-sheets/detail/stroke
2. Feigin VL, Brainin M, Norrving B, Martins S, Sacco RL, Hacke W, et al. World Stroke Organization: Global Stroke Fact Sheet 2025. Int J Stroke. 2025;20(1):3-??.
3. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. Lancet. 2011;377(9778):1693-702.
4. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, et al. Guidelines for adult stroke rehabilitation and recovery: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2016;47(6):e98-e169.
5. National Institute for Health and Care Excellence (NICE). Stroke rehabilitation in adults: evidence review E1 (intensity of rehabilitation) [Internet]. London: NICE; 2023 [cited 2026 Jan 28]. Available from: https://www.nice.org.uk/guidance/ng236/evidence/e1-intensity-of-rehabilitation-quantitative-evidence-pdf-13191947685
6. Dimyan MA, Cohen LG. Neuroplasticity in the context of motor rehabilitation after stroke. Nat Rev Neurol. 2011;7(2):76-85.
7. Hubbard IJ, Parsons MW, Neilson C, Carey LM. Task-specific training: evidence for and translation to clinical practice. Occup Ther Int. 2009;16(3-4):175-89.
8. Laver KE, Schoene D, Crotty M, George S, Lannin NA, Sherrington C. Telerehabilitation services for stroke. Cochrane Database Syst Rev. 2020;1:CD010255.
9. Cramer SC, Dodakian L, Le V, See J, Augsburger R, McKenzie A, et al. Efficacy of home-based telerehabilitation vs in-clinic therapy after stroke: a randomized clinical trial. JAMA Neurol. 2019;76(9):1079-87.
10. Makhoul M, Teremetz M, Ghiatis A, et al. Telerehabilitation: has its time come? Stroke. 2022;53(7):e??-e??.
11. Gebryea TG, Mbadaa C, Fatoye F, Anazodo C. Effectiveness of telerehabilitation on quality of life in stroke survivors: a systematic review and meta-analysis. J Telemed Telecare. 2024;30(??):187-96.
12. He K, Wu Y, Xu J, et al. Telerehabilitation and its impact following stroke: an umbrella review. J Clin Med. 2025;14(1):50.
13. Sarmiento K, et al. AI applications in adult stroke recovery and rehabilitation: a scoping review. Sensors (Basel). 2023;24(20):6585.

14. Kim H, Lee S, et al. Effects of virtual reality-based telerehabilitation for stroke patients compared with conventional in-person rehabilitation: systematic review and meta-analysis. J Stroke Cerebrovasc Dis. 2022;31(??):106???.

15. Henderson CE, Fahey M, et al. Increasing the amount and intensity of stepping training during inpatient stroke rehabilitation improves locomotor and non-locomotor outcomes. Neurorehabil Neural Repair. 2022;36(??):??-??.

16. Schulz KF, Altman DG, Moher D; CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. BMJ. 2010;340:c332.

17. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013;310(20):2191-4.

18. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, editors. Cochrane handbook for systematic reviews of interventions. Version 6.4. London: Cochrane; 2023.

19. Dimyan MA, Cohen LG. Neuroplasticity in the context of motor rehabilitation after stroke. Nat Rev Neurol. 2011;7(2):76-85.

20. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, et al. Guidelines for adult stroke rehabilitation and recovery. Stroke. 2016;47(6):e98-e169.

21. Carvajal M, et al. Adherence to pulmonary rehabilitation in patients with chronic obstructive pulmonary disease: classification by session completion. Physiother Pract Res. 2022;3(3):13.

22. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988.

23. Shapiro SS, Wilk MB. An analysis of variance test for normality (complete samples). Biometrika. 1965;52(3-4):591-611.

24. International Council for Harmonisation. Integrated addendum to ICH E6(R1): guideline for good clinical practice E6(R2) [Internet]. ICH; 2016 [cited 2026 Jan 28]. Available from: https://database.ich.org/sites/default/files/E6_R2_Addendum.pdf

25. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, et al. Guidelines for adult stroke rehabilitation and recovery. Stroke. 2016;47(6):e98-e169.

26. Guadagnoli MA, Lee TD. Challenge point: a framework for conceptualizing the effects of various practice conditions in motor learning. J Mot Behav. 2004;36(2):212-24.

27. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. Lancet. 2011;377(9778):1693-702.

28. He K, Wu Y, Xu J, et al. Telerehabilitation and its impact following stroke: an umbrella review. J Clin Med. 2025;14(1):50.

29. Reistetter TA, et al. Revisiting dose and intensity of training: opportunities to enhance recovery following stroke. J Stroke Cerebrovasc Dis. 2022;31(??):??-??.

30. Williams LS, Weinberger M, Harris LE, Clark DO, Biller J. Development of a stroke-specific quality of life scale. Stroke. 1999;30(7):1362-9.

31. National Institute for Health and Care Excellence (NICE). Stroke rehabilitation in adults: evidence review E1 (intensity of rehabilitation) [Internet]. London: NICE; 2023 [cited

2026 Jan 28]. Available from: https://www.nice.org.uk/guidance/ng236/evidence/e1-intensity-of-rehabilitation-quantitative-evidence-pdf-13191947685

32. World Health Organization. Stroke [Internet]. Geneva: World Health Organization; 2025 [cited 2026 Jan 28]. Available from: https://www.who.int/news-room/fact-sheets/detail/stroke

DECLARATIONS

Ethical Approval

Ethical approval was by institutional review board of Respective Institute

Informed Consent

NA

Conflict of Interest

The authors declare no conflict of interest.

Funding

This research received no external funding.

Authors' Contributions

Concept: ZN; Design: AR; Data Collection: NU; Analysis: BA; Drafting: NK

Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Acknowledgments

Not applicable.

Study Registration

Not applicable.