JK-Practitioner, Volume 31, Number 1, January-March 2026

Review

Effectiveness of AI-Driven Robotic Therapy for Post-Stroke Spasticity: A Systematic Review

Saliha Rafat, Adarsh Kumar Srivastav

Introduction: Post-stroke spasticity (PSS) is a common and debilitating complication that impairs motor function and quality of life in stroke survivors. AI-Driven Robotic therapy has gained significant attention in rehabilitation for stroke survivors, particularly for reducing spasticity and improving motor functions.

Aim: To review and synthesize existing evidence on the efficacy of Robotic therapy for reducing spasticity in stroke survivors.

Materials and methods: A comprehensive literature search was conducted across major databases up to January 2025, focusing on randomized controlled trials (RCTs) involving robotic therapy for PSS. Methodological quality was assessed using the PEDro scale and Downs and Black Checklist, and risk of bias was evaluated per Cochrane guidelines.

Results: Six RCTs met the inclusion criteria, with intervention durations ranging from 2 to 12 weeks. Robotic therapy demonstrated significant improvements in muscle tone, motor function, and activity limitation compared to conventional rehabilitation. However, the included studies exhibited moderate to high risk of bias, particularly in blinding and allocation concealment.

Conclusion: Robotic therapy is effective in reducing spasticity and enhancing motor recovery in stroke survivors. Nevertheless, further high-quality RCTs are needed to confirm these findings and optimize clinical protocols.

JK-Practitioner2026;31(1):1-6.

Author Affiliations:
Saliha Rafat: PhD Scholar, **Adarsh Kumar Srivastav**: Assistant Professor; Department of Physiotherapy, School of Health Sciences, Chhatrapati Shahu Ji Maharaj University, Kanpur -208024. Uttar-Pradesh. India.
Correspondence: Dr. Adarsh Kumar Srivastav, Email: adarshsrivastava13@gmail.com (M): +91-8618889003

Indexed: EMBASE ,SCOPUS , IndMED, ESBCO ,Google Scholar besides other national and international databases
Cite this article as: Rafat S, Srivastav AK. Effectiveness of AI-Driven Robotic Therapy for Post-Stroke Spasticity: A Systematic Review JK Pract2026;31(1):1-6.
Full length article available at **jkpractitioner.com** one month after publication
Keywords: Stroke, Muscle spasticity, Upper Extremity, Robotics.

Introduction

Stroke, a debilitating cerebrovascular event, affects millions worldwide, often leading to long-term disabilities, including spasticity.[1] Spasticity, characterized by velocity-dependent increases in tonic stretch reflexes, significantly impairs motor control, functional abilities, and overall quality of life in stroke survivors.[2] Conventional rehabilitation strategies, including physiotherapy, occupational therapy, and pharmacological management, play a key role in addressing spasticity but often yield limited results, particularly in individuals with severe motor impairments.[3]

Recent advances in neurorehabilitation have explored the use of robotic therapy as a means to deliver high-intensity, repetitive, and task-specific training, which is critical for promoting neuroplasticity and motor recovery.[4] Robotic devices equipped with artificial intelligence (AI) offer additional advantages by providing adaptive, personalized therapy based on real-time patient performance, enhancing engagement and optimizing therapeutic outcomes. [5] Furthermore, AI-driven robotic systems can reduce therapist workload and ensure consistency in intervention delivery, making them particularly valuable for patients with significant functional limitations.[6]

Despite these promising attributes, the effectiveness of AI-driven robotic therapy for post-stroke spasticity remains an area of active investigation, with mixed results reported in the literature. Some studies have demonstrated improvements in spasticity, motor control, and functional independence, while others have found only modest or no significant benefit.[7] This variability underscores the need for a comprehensive synthesis of current evidence. Therefore, this study aims to systematically review and critically evaluate the existing literature on the effectiveness of AI-driven robotic therapy in managing post-stroke spasticity.

Material and methods

Registration

This review protocol was registered in the PROSPERO under registration number CRD420250656076 and was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses PRISMA guidelines.[8]

Table 1:

	Inclusion criteria	Exclusion criteria
Population	Both men and women aged (≥18 years) diagnosed with stroke and with PSS	Patients <18 years or those with non-stroke-related spasticity
Intervention	AI-driven Robotic Therapy	Studies using non-AI robotic therapy, virtual reality, exergaming, or wearable devices
Comparator	Conventional therapy	Studies using standard rehabilitation protocols or other interventions
Outcomes	Spasticity (MAS) and Motor function (FMA-UE) measured before and after intervention	Studies with single time-point assessments or non-standard outcome measures
Study Design	Randomized Controlled Trial	Non-randomized studies, descriptive studies, systematic reviews, and grey literature
Publication	Peer-reviewed, English-language studies from the last 10 years	Non-peer-reviewed, non-English studies

Study selection criteria

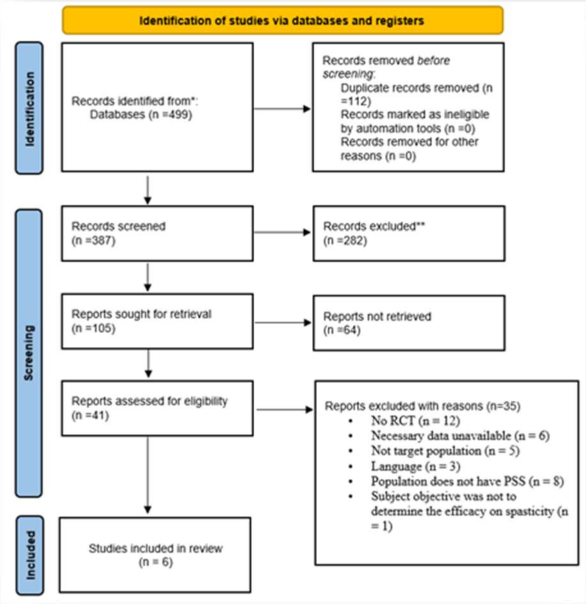
The included and excluded studies were selected according to the PICOS (Participants, Intervention, Comparator, Outcomes, Study Design) framework, which is detailed in Table 1

Search Strategy and data resourceA comprehensive literature search was conducted across the PubMed, Cochrane, MEDLINE, Embase, Scopus, Web of Science, and PEDro databases, covering all records up to December 2024. To enhance the search process, AI tools such as Litmaps, Research Rabbit, and Consensus were utilized. The search strategy involved manually applying the following MeSH terms: ("Stroke" OR "Cerebrovascular Accident" OR "Brain Ischemia" OR "Brain Hemorrhage") AND ("Spasticity" OR "Muscle Hypertonia" OR "Hypertonicity" OR "Muscle Spasm") AND ("Robotics" OR "Robot-Assisted Therapy" OR "Robotic Rehabilitation" OR "Robotic Exoskeletons"). These terms were combined using the Boolean operators OR, AND, and NOT to refine the search results effectively.

Study selection

After conducting a search in electronic databases, all related articles and studies were preselected, and the titles and abstracts of all studies found during the primary search were reviewed by both authors (SR and AKS). The ultimate choice to include or exclude them from this study was reached following a full-text review of articles to determine their relevance to this investigation. Both authors independently screened titles and abstracts, retrieving full texts for further evaluation. Disagreements were resolved through discussion. Record management and duplicate removal were done using manual and automated method by using EndNote™ software.

Figure 1:



Data Extraction and management

Both authors (SR, AKS) independently extracted the following data from every study that were included in this review. The following data were extracted from the included studies:

1. Methods: study design, randomisation method, allocation concealment method, and blinding methods.
2. Trial characteristics: sample size, author name, year of publication, trial type and country.
3. Participants: diagnosis (type and severity of stroke) number in each group, age, gender, time from onset.
4. Objective of the study.
5. Intervention: details of Robotic therapy (intensity, frequency, duration, treatment session, type of robotic therapy).
6. Outcomes: types of outcomes (included spasticity, motor function and activity limitation), assessment time points.
7. Other: setting, publication year, funding source, intention-to-treat analysis.
8. Results.

Table 2: Main characteristics of the participants included in the systematic review.

S. No	Author/Year/ Study design	Intervention EG vs CG	Participants	Age (Years) Mean ± SD
1.	Chang et al. 2024, RCT[12]	UL robotic training with Rebless® vs. conventional therapy with Motomed ergometer.	EG: 15 CG: 15	EG: 65.2 ± 5.4 CG: 67.2 ± 5.4
2.	El-Kafy et al. 2022, RCT[13]	Armeo Spring training vs. traditional functional UL exercises in conventional therapy.	EG: 18 CG: 18	EG:54.13± 5.46 CG: 53.42 ± 4.33
3.	Hung et al. 2022, Pilot RCT[14]	Robot-assisted vs. task-oriented upper limb training with BoNT-A injection.	EG: 12 CG: 12	EG: 47.68 ± 12.79 CG: 49.71 ± 10.86
4.	Gandolfi et al. 2019, RCT[15]	BoNT injection + Armotion-assisted training vs. BoNT injection + passive mobilization, stretching, and UL exercises.	EG: 16 CG: 16	EG: 59.31 ± 14.40 CG: 59.13 ± 14.97
5.	Lee et al. 2016, RCT[16]	Neuro-X robotic rehabilitation vs. stretching, strengthening, and assisted ROM exercises.	EG: 22 CG: 22	EG: 50.27 ± 11.11 CG: 52.32 ± 8.66
6.	Sale et al. 2014, RCT[17]	Intensive Goal-directed robotic UL therapy vs intensive traditional UL therapy.	EG: 26 CG: 27	EG: 67.7 ± 14.2 CG: 67.7 ± 14.2

Quality of Study

Methodological quality of included studies

The methodological quality of RCTs was assessed using the Physiotherapy Evidence Database (PEDro) scale, which evaluates internal validity and study interpretability. The scale includes 11 items scored as "yes" (1) or "no" (0), with total scores ranging from 0 to 10: 0–3 (poor), 4–5 (fair), 6–8 (good), and 9–10 (excellent). Scores were retrieved from the official PEDro website (https://www.pedro.org.au/).[9] Additionally, a modified Downs and Black (D&B) Checklist was used to appraise both randomized and non-randomized studies. It contains 27 items across five domains: study quality, external validity, internal validity (bias and confounding), and study power. Scores classify studies as excellent (26–28), good (20–25), fair (15–19), or poor (≤14).[10]

Assessment of risk of bias in included studies

The risk of bias of all the included studies was assessed by two reviewers (SR, AKS) using the criteria outlined in the Cochrane Hand-book for systematic Reviews of Interventions.[11] We assessed risk of bias according to their domains: sequence generation, allocation concealment, blinding, incomplete outcome data and selective reporting. For each outcome in the included studies, two reviewers applied the tool independently and recorded information to support judgements of risk of bias at the domain level (low, high, and unclear). An overall level of risk across the outcomes evaluated was then judged based on the highest perceived rating of risk across any of the five domains. Disagreements about risk of bias judgements were resolved by consensus or by arbitration with a third reviewer.

Results

From 499 records, 112 duplicates were removed. After screening 387 records, 282 were excluded. Of 105 reports retrieved, 41 were assessed, with 35 excluded for reasons like non-RCT design or missing data. Six studies were included in final analysis.

Study characteristics

Table 1 and 2 summarizes the characteristics of included participants. This review included six randomized controlled trials (RCTs) involving post-stroke patients, comparing various robotic-assisted upper limb (UL) therapies with conventional or task-oriented rehabilitation. Sample sizes ranged from 24 to 53 participants, with mean ages between 47.68 and 67.7 years. Intervention durations varied from 2 to 12 weeks, with session lengths from 30 to 75 minutes.

Risk of Bias

Figure 2 and Figure 3 represents a summary of the risk of bias of the included RCTs. Most studies showed low risk of bias in randomization, outcome data, reporting, and other biases. Allocation concealment and blinding of outcome assessment were partly unclear, while blinding of participants and personnel had the highest risk of bias across studies.

Discussion

This comprehensive review supports the effectiveness of AI-driven robotic therapy in reducing post-stroke spasticity (PSS) and enhancing motor function and activity levels compared to conventional rehabilitation. The findings align with previous research highlighting the advantages of robotic-assisted neurorehabilitation.

Several studies have shown AI-driven robot-assisted training improves upper limb motor function and muscle tone. For example, Gassert et al. (2018) emphasized that repetitive, task-specific robotic

Table 3: Main characteristics of the participants included in the systematic review.

S. No	Author/Year/ Study design	Intervention time setting	Outcome Measure	Result
1.	Chang et al. 2024, RCT	30 min- session, 10 sessions within 4 weeks.	FMA-UE, MAS, MBI, MI_Upper, ROM	The EG enhanced upper limb function, reduced spasticity, and lowered unaffected hemisphere activity. Rebless® may aid stroke recovery by restoring motor function and contralateral activation.
2.	El-Kafy et al. 2022, RCT	2 hour- session, 3 times/ week for 12 weeks.	ARAT, WMFT, WFMT-Time, MAS, AROM, Hand Grip Strength.	Robot-assisted gaming effectively reduced spasticity and improved upper limb motor function in chronic stroke patients.
3.	Hung et al. 2022, Pilot RCT	75 min-session, 3 times/week, for 8 weeks.	FMA, MAS, MAL, AOU, QOM, Arm Activity Level.	BoNT-A injections with robotic or active control training reduced spasticity and improved motor and daily function in stroke patients.
4.	Gandolfi et al. 2019, RCT	45 min/session, 2 sessions/week for 5 weeks.	MAS, FMA-UE, MRC, EMGs.	Robot-assisted training with botulinum toxin may enhance upper limb strength and muscle activation in chronic stroke patients with spasticity.
5.	Lee et al. 2016, RCT	20 sessions (30 minutes/ session, 2 sessions / day, 5 days a week, for 2 weeks.	MAS, MMT, MFT, Brunnstrom stage, K-MBI.	RT provided similar spasticity relief as CT and may offer a reliable, repeatable method for ROM exercises in stroke patients.
6.	Sale et al. 2014, RCT	30 sessions (5 days/week for 6 weeks)	Motricity index, FMA, MAS, PROM.	Robot-assisted therapy enhances motor recovery in subacute stroke, with early intervention offering significant clinical benefits.

Table 4: Quality assessment using the Physiotherapy evidence database scale (PEDro).

Study	**Eligibility criteria**		**Random allocation**	**Concealed allocation**	**Baseline comparability**	**Blind subjects**	**Blind therapists**	**Blind assessors**	**Adequate follow-up**	**Intention-to-treat analysis**	**Between-group comparisons**	**Point estimates and variability**	**Total Score**
Chang et al.	+		+	-	+	-	-	-	+	-	+	+	5, Good
El-Kafy et al.	+		+	-	+	-	-	+	+	-	+	+	6, Good
Hung et al.	+		+	-	+	-	-	+	+	-	+	+	6, Good
Gandolfi et al.	+		+	-	+	-	-	+	+	+	+	+	7, Good
Lee et al.	+		+	-	+	-	-	-	-	-	+	+	4, Fair
Sale et al.	+		+	+	+	-	-	+	+	+	+	+	8, Good

Table 5: Quality assessment using Down and Black Checklist (DBC).

Study	Reporting (10)	External Validity (3 item)	Internal Validity (Bias) (7 item)	Internal Validity (Confounding) (6 items)	Power (1 item)	Total Score (28)
Chang et al.	10	3	4	5	2	24, Good
El-Kafy et al.	9	3	6	6	2	26, Excellent
Hung et al.	9	1	6	5	0	21, Good
Gandolfi et al.	9	3	6	6	2	26, Excellent
Lee et al.	10	3	5	5	0	23, Good
Sale et al.	10	3	6	6	1	26, Excellent

Figure 2: Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

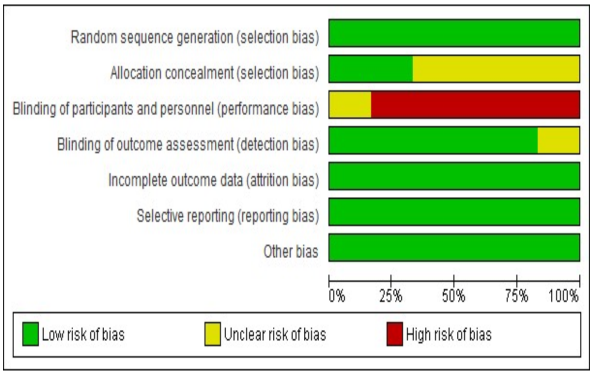
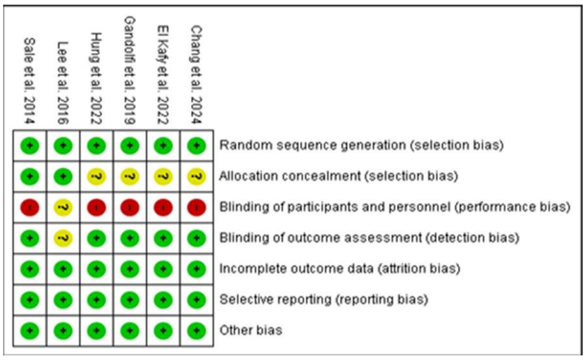


Figure 3: Risk of bias summary: review authors' judgements about each risk of bias item for each included study.



therapy enhances spasticity and motor outcomes, particularly in severely impaired patients, by promoting neuroplasticity through controlled, high-dose movement. [18] Trials consistently reported significant improvements in muscle tone (MAS) and motor function (FMA-UE).[19] Chang et al. (2024) demonstrated Rebless®'s benefits in regulating hemispheric activity, while Demers M et. al, (2022) linked task-specific, repetitive therapy to cortical reorganization.[20] AI-based robotic therapy also offers real-time, adaptive adjustments in intensity and complexity. Studies by Lee et al. (2018), and El-Kafy et al. (2022) highlighted its role in delivering high-dose, personalized therapy, improving outcomes and reducing therapist workload.[13, 16] Ortega-Martorell S (2024) further noted AI's potential to refine rehabilitation through data-driven insights.[21]

However, these promising results warrant cautious interpretation due to methodological limitations, including moderate-to-high risk of bias and variations in intervention protocols and adjunct therapies. affirms the growing potential of AI-driven robotic therapy for PSS. Future research should prioritize large, multicenter RCTs with standardized protocols and integrate neurophysiological assessments (EEG, EMG, fMRI) as recommended by Chaudhary U (2025) to better elucidate underlying mechanisms.[22]

Conclusion

AI- Driven Robotic therapy represents a promising advancement in the rehabilitation of post-stroke spasticity, offering significant improvements in muscle tone, motor function, and activity limitation compared to conventional approaches. However, the current evidence base is limited by methodological weaknesses and moderate to high risk of bias in existing studies. High-quality, large-scale randomized controlled trials are needed to validate these findings, refine intervention protocols, and facilitate the integration of robotic therapy into standard clinical practice for stroke rehabilitation.

Conflict of interest

None.

Acknowledgement

The authors received no specific funding for this work.

References

1. **Jambi LK, Hamad A, Salah H, et al.** Stroke and Disability: Incidence, Risk Factors, Management, and Impact. Journal of Disability Research 2024; 3: 20240094.

2. **Chen B, Yang T, Liao Z, et al.** Pathophysiology and Management Strategies for Post-Stroke Spasticity: An Update Review. International Journal of Molecular Sciences 2025, Vol 26, Page 406 2025; 26: 406.

3. **Shahid J, Kashif A, Shahid MK**. A Comprehensive

Review of Physical Therapy Interventions for Stroke Rehabilitation: Impairment-Based Approaches and Functional Goals. Brain Sciences 2023, Vol 13, Page 717 2023; 13: 717.

4. **Braun RG, Wittenberg GF.** Motor Recovery: How Rehabilitation Techniques and Technologies Can Enhance Recovery and Neuroplasticity. Semin Neurol 2021; 41: 167–176.

5, **Deshmukh Product Manager PA**. The Integration of Artificial Intelligence and Wearable Technology in Personalized Physical Therapy Programs for Enhanced Recovery Outcomes. International Journal of Artificial Intelligence, Data Science, and Machine Learning 2023; 4: 1–9.

6. **Ness S, Xuan TR, Oguntibeju OO.** Influence of AI: Robotics in Healthcare. Asian Journal of Research in Computer Science 2024; 17: 222–237.

7. **Rasa AR.** Artificial Intelligence and Its Revolutionary Role in Physical and Mental Rehabilitation: A Review of Recent Advancements. Biomed Res Int 2024; 2024: 9554590.

8. **Moher D, Liberati A, Tetzlaff J, et al.** Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med; 6. Epub ahead of print 1 July 2009. DOI: 10.1371/JOURNAL.PMED.1000097.

9. **de Morton NA**. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. Australian Journal of Physiotherapy 2009; 55: 129–133.

10. **Downs SH, Black N.** The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health (1978) 1998; 52: 377–384.

11. **by Julian Higgins EP, Savović J, Page MJ, et al**. Revised Cochrane risk of bias tool for randomized trials (RoB 2.0).

12. **JY, Chun MH, Lee A, et al**. Effects of training with a rehabilitation device (Rebless®) on upper limb function in patients with chronic stroke: A randomized controlled trial. Medicine (United States) 2024; 103: e38753.

13. **Abd El-Kafy EM, Alshehri MA, El-Fiky AAR, et al.** The Effect of Robot-Mediated Virtual Reality Gaming on Upper Limb Spasticity Poststroke: A Randomized-Controlled Trial. Games Health J 2022; 11: 93–103.

14. **Hung JW, Yen CL, Chang KC, et al.** A Pilot Randomized Controlled Trial of Botulinum Toxin Treatment Combined with Robot-Assisted Therapy, Mirror Therapy, or Active Control Treatment in Patients with Spasticity Following Stroke. Toxins (Basel); 14. Epub ahead of print 1 June 2022. DOI: 10.3390/TOXINS14060415.

15. **Gandolfi M, Valè N, Dimitrova EK, et al**. Effectiveness of Robot-Assisted Upper Limb Training on Spasticity, Function and Muscle Activity in Chronic Stroke Patients Treated With Botulinum Toxin: A Randomized Single-Blinded Controlled Trial. Front Neurol; 10. Epub ahead of print 2019. DOI: 10.3389/FNEUR.2019.00041.

16. **Lee KW, Kim SB, Lee JH, et al**. Effect of Upper Extremity Robot-Assisted Exercise on Spasticity in Stroke Patients. Ann Rehabil Med 2016; 40: 961.

17. **Sale P, Franceschini M, Mazzoleni S, et al**. Effects of upper limb robot-assisted therapy on motor recovery in subacute stroke patients. J Neuroeng Rehabil; 11. Epub ahead of print 19 June 2014. DOI: 10.1186/1743-0003-11-104.

18. **Gassert R, Dietz V.** Rehabilitation robots for the treatment of sensorimotor deficits: a neurophysiological perspective. Journal of NeuroEngineering and Rehabilitation 2018 15:1 2018; 15: 1–15.

19. **Su T, Wang M, Chen Z, et al.** Effect of Upper Robot-Assisted Training on Upper Limb Motor, Daily Life Activities, and Muscular Tone in Patients With Stroke: A Systematic Review and Meta-Analysis. Brain Behav 2024; 14: e70117

20. **Demers M, Varghese R, Winstein C**. Retrospective Analysis of Task-Specific Effects on Brain Activity After Stroke: A Pilot Study. Front Hum Neurosci 2022; 16: 871239.

21. **Ortega-Martorell S, Olier I, Ohlsson M, et al.** Advancing personalised care in atrial fibrillation and stroke: The potential impact of AI from prevention to rehabilitation. Trends Cardiovasc Med. Epub ahead of print 7 December 2024. DOI: 10.1016/J.TCM.2024.12.003.

22. **Chaudhary U.** Neurotechnology in Stroke Rehabilitation. Expanding Senses using Neurotechnology 2025; 51–98