International Journal of Research in Medical Sciences
Bajaj G et al. Int J Res Med Sci. 2025 Dec;13(12):5260-5266
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20253947

Original Research Article

Integration of artificial intelligence and robotics in rehabilitation therapy: enhancing motor recovery after injury or stroke

Gaurav Bajaj[1]*, Gayathri Davu[1], B. Viswanathan[2]

[1]Department of Neuroscience, Neuravantex Medical Innovation & Wellness Centre, India
[2]KPPC Group of Institutions, Theni, Tamil Nadu, India

Received: 06 June 2025
Revised: 03 September 2025
Accepted: 16 October 2025

***Correspondence:**
Dr. Gaurav Bajaj,
E-mail: gaurav_54bajaj@yahoo.com

ABSTRACT

Background: Artificial intelligence (AI) and robots are revolutionizing healthcare by delivering intelligent, adaptable, and patient-centric solutions. These technologies restore motor function, improve therapeutic precision, and adapt patient treatment regimens, making them vital for rehabilitation therapy. Recent advances in neuroscience, motor control, robotics, and AI-based algorithms have opened new doors in brain and motor rehabilitation. Invasive and non-invasive human-machine interfaces can reduce the long-term effects of strokes and spinal cord injuries. This research examines how AI and robotics can improve motor recovery after injury or stroke in rehabilitation therapy.
Methods: This study utilizes the quantitative research methodology. Data were gathered from different clinical trials and studies that specifically examined AI-assisted robotic rehabilitation therapy. Important indicators consist of the enhancement in motor function, rates of patient adherence, and the overall efficacy of therapy. A total of 19 participants were selected for this investigation. The standard of care group had ten participants and the robotic therapy group nine.
Results: The study showed that robotic therapy improved all evaluations more than the control group, proving that AI and robotic technology work in rehabilitation therapy.
Conclusions: The findings demonstrate that AI-integrated robotic therapy outperforms normal care in rehabilitation. Subsequent research endeavours may delve deeper into the enduring advantages and enhance the treatment regimens to optimize patient recuperation.

Keywords: AI, Robotics, Rehabilitation therapy, Motor recovery, Injury, Stroke

INTRODUCTION

Stroke, which refers to the sudden interruption of blood supply to the brain, impacts over twelve million individuals globally each year.[1] It is worth noting that up to one in every five strokes occur in young adults between the ages of 18 and 50.[2,3] In addition, up to 50% of stroke survivors may experience long-term difficulties and disabilities.[4] These individuals may live with the effects of stroke for over twenty years, becoming chronic stroke sufferers.[5] Given the prolonged length of chronic stroke, which can last for years or even decades, it is crucial to tailor rehabilitation and reintegration programs to optimize stroke recovery. This includes providing personalized care to help patients adjust to their limitations and successfully reintegrate into their daily lives.[1] However, the customization of rehabilitation and reintegration programs, which involve physical and cognitive exercises, tasks, and activities, depends not only on the severity of post-stroke complications but also on the specific clinical needs of patients and their recovery goals.[6] These complications can occur due to physical and cognitive impairments, as well as emotional and sensory disruptions, which are worsened by other existing medical problems, the patient's living and/or working conditions, and, most significantly, the age and post-stroke state of the person.

The incorporation of AI and robots in rehabilitation therapy is based on a long-standing tradition of progress in “medical technology and neuro-rehabilitation’’. Historically, process of restoring motor function following injury or stroke mainly relied on therapists administering physical, repetitive exercises.[1] Nevertheless, the constraints of therapy delivered by humans, such as inconsistencies in performance and difficulties in scaling, have emphasized the necessity for more reliable and flexible options. The initial investigations into robotic aid throughout the 1990s laid the foundation for the creation of devices such as exoskeletons and robotic arms, which were specifically developed to support and enhance human mobility. Simultaneously, progress in AI, namely in machine learning and data analytics, has created opportunities for the development of real-time monitoring and adaptive feedback systems. These technologies facilitate the development of customized rehabilitation programs that may adapt in real-time according to the patient's progress and requirements.

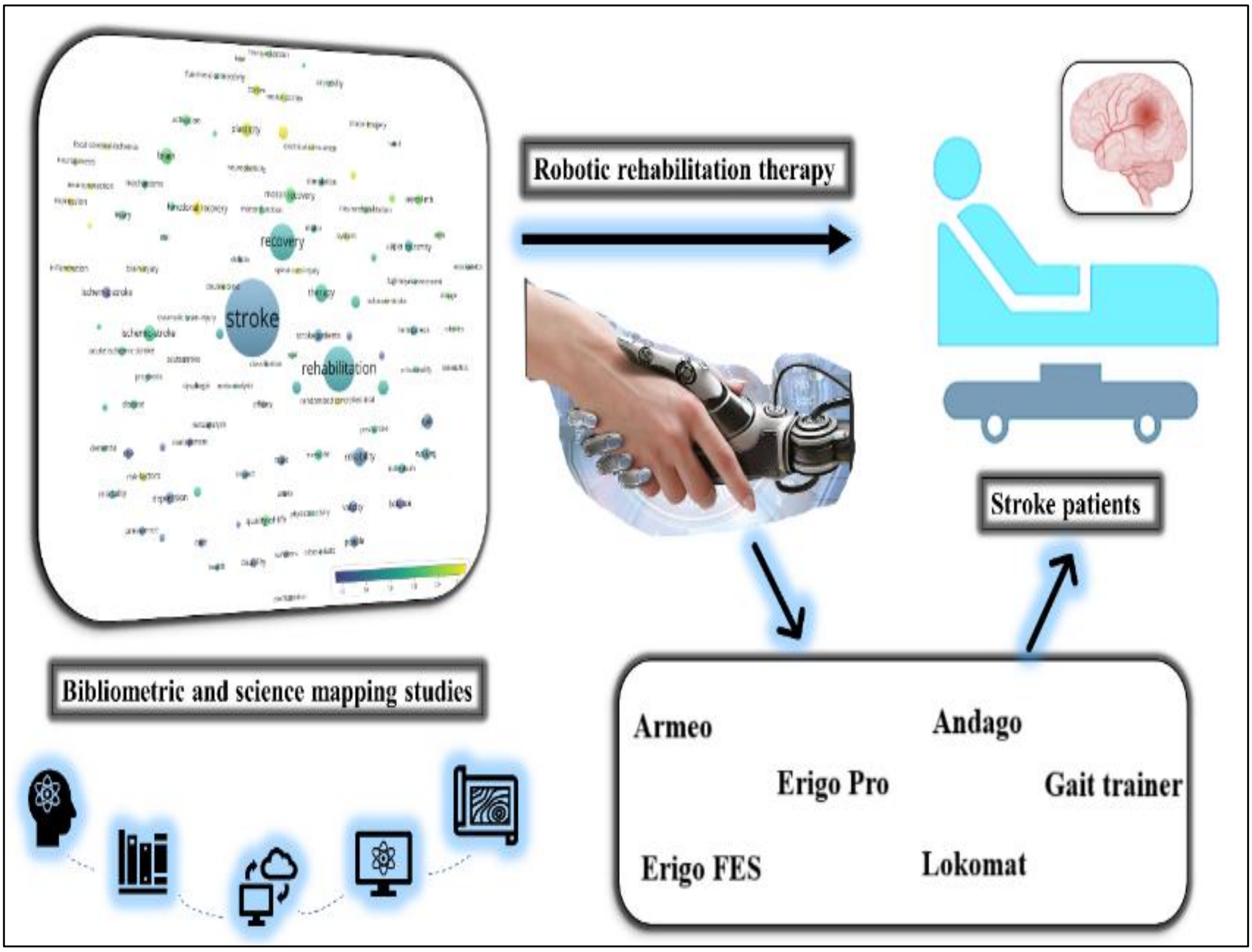

Figure 1: Application of robotic recovery techniques.[7]

The merging of the AI and robotics in rehabilitation therapy has resulted in a revolutionary method which improved accuracy, consistency, and the possibility of ongoing enhancement in patient results. So, the main goal of this research initiative is to undertake a comprehensive investigation on the integration of AI and robotics in rehabilitation therapy, specifically focusing on how it can enhance motor recovery after injury or stroke.

Although there have been notable progressions, there is still a deficiency in the lasting effectiveness and durability of AI and robotic-assisted rehabilitation therapy. The lack of extensive clinical trials and longitudinal studies raises concerns over the long-term sustainability of motor recovery improvements. Furthermore, it is necessary to do further research to verify that the integration of these technologies into various healthcare settings and their availability to a larger number of patients is fair and has a wide range of advantages. The main purpose of this study is to investigate the integration of AI and robotics in rehabilitation therapy, with the aim of improving motor recovery following injury or stroke.

METHODS

A quantitative study evaluated stroke patient robotic training feasibility and efficacy. Functional improvements and therapy tolerance were measured using validated clinical evaluations. The study explored whether AI-assisted robotic rehabilitation may increase patient compliance, safety, and early motor recovery alongside hospital therapy. From screening and recruiting to treatment group allocation, intervention delivery, and outcome monitoring, an organized approach was used. Our methodology ensured repeatability, transparency, and high-quality data collection to assess stroke patients' robotic rehabilitation feasibility and scalability.

Study type

The quantitative study measured patient outcomes and therapeutic feasibility. Quantitative analysis allowed researchers to summarize participant characteristics, measure motor recovery gains with the Fugl-Meyer assessment (FMA), and assess functional impairment with the modified Rankin scale (mRS). The researchers compared AI-assisted robotic rehabilitation to standard physiotherapy for compliance, tolerance, and patient satisfaction. The study used quantitative methods to extrapolate its findings to a larger stroke population and prepare for controlled clinical trials.

Study place

The study was held at Neuravantex Medical Innovation & Wellness Centre, which uses robotic exoskeletons. This facility had a diverse stroke patient population and certified physiotherapists in conventional and technology-assisted rehabilitation. Researchers followed standardized protocols to recruit and intervene with subacute stroke patients from October 2023to April 2024. Replicating hospital clinical practices and scheduling problems improved the study's external validity.

Selection criteria of the patients

To ensure uniformity and safety, patients were selected using defined inclusion and exclusion criteria.

Participants aged 18+ with their first ischemic or hemorrhagic stroke were eligible. For instruction comprehension, patients need medical records demonstrating weakness or sensory loss, two-step verbal competency, corrected visual acuity ≥20/50, and basic English comprehension. Participants also agreed to a 2-week intervention with pre- and post-assessments.

Patients with neurological disorders, orthopedic difficulties, or a pre-stroke mRS score >2 were excluded to reduce confounding factors and safety risks.

Before recruiting volunteers, research personnel educated them about the study's goals, methodology, risks, and benefits once stroke rehabilitation unit specialists recognized them. All participants or their lawyers supplied written informed consent.

Procedure

A feasibility and preliminary data sample of 19 appropriate participants was selected. Participants were randomly divided into two groups:

Standard care group (n=10)

Balance, strength, and task-specific motor practice were offered.

The robotic therapy group (n=9)

Received AI-assisted robotic therapy and standard care for upper and lower limb motor rehabilitation utilizing a robotic exoskeleton.

For 10 days, certified physiotherapists supervised all participants in one-hour rehabilitation sessions. The robotic system tracked each patient's development and adjusted support and resistance for repetitive, task-oriented activities using AI algorithms. Pre-intervention demographics and clinical data included age, gender, stroke type, afflicted side, and motor scores. The FMA and mRS measured functional outcomes before and after the 10-day intervention.

Compliance, therapy tolerance, and adverse events were recorded daily. Everyone completed robotic therapy sessions, and most were satisfied. While weariness was the most common side effect, no significant adverse events were identified, even in participants who started robotic therapy eight days post-stroke. Nobody departed either group during the experiment. Regular robotic therapy was hardest due to medical appointment conflicts.

This study picked a smaller sample. A larger sample size may not improve data presentation here. This feasibility research assessed robotic therapy's practicality, safety, and early acceptability rather than statistical significance. A small, carefully selected sample is usually enough for pilot or feasibility studies to provide substantial insights and potential difficulties, making a larger sample unnecessary.

Ethical approval and statistical analysis

The Neuravantex Medical Innovation & Wellness Centre ethics committee approved the study protocol. Before giving signed informed consent, participants were told of the study's goals, methods, risks, benefits, and confidentiality rules. The voluntary nature of participation was stressed, and individuals might withdraw at any time without affecting their care. Anonymized participant data were encrypted and only accessible to the study staff. Adverse occurrences were clinically addressed and reported to the ethics committee following institutional protocols throughout the experiment.

Microsoft excels data analysis was used for data analysis. Means, standard deviations, frequencies, and percentages were calculated to describe baseline and post-intervention variables. This allowed clear comparisons between conventional care and robotic therapy cohorts for motor recovery, functional impairment, and feasibility.

RESULTS

The incorporation of AI and robots in rehabilitation therapy represents a notable progress in improving motor recovery for individuals who have experienced accidents or strokes. This section presents a quantitative assessment of the efficacy of these technologies, drawing on current studies. Figure 2 compares the demographics and baseline characteristics of standard care and robotic therapy group members. Both groups exhibit similar age, gender, stroke type, affected side, and baseline FMA scores, indicating similar starting conditions. Variations in results can be attributed to the intervention rather than pre-existing inequalities with this equilibrium.

The following Table 1 provides a concise overview of the data analysis conducted for the study on robotic therapy for subacute stroke patients. The study "evaluates and contrasts the robotic therapy group and the control group using a range of clinical and robotic evaluations".

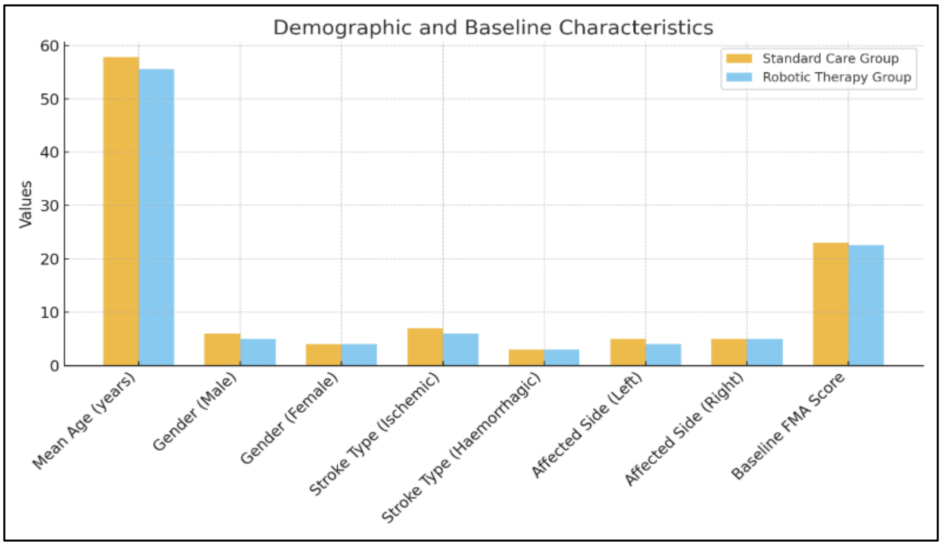

Figure 2: Demographic and baseline characteristics details.

Table 1: Data analysis.

Assessment	Metric	Robotic therapy	Control group
FMA of upper extremity (FMA UE)	Pre-intervention mean (SD)	22.5 (5.0)	23.0 (5.2)
	Post-intervention mean (SD)	30.0 (5.5)	26.0 (5.3)
	Improvement (Mean)	7.5	3.0
Action research arm test (ARAT)	Pre-intervention mean (SD)	25.0 (6.0)	24.5(5.8)
	Post-intervention mean (SD)	32.0 (6.2)	27.5(6.0)
	Improvement (Mean)	7.0	3.0
Functional independence measure (FIM)	Pre-intervention mean (SD)	80.0 (10.0)	78.0 (9.5)
	Post-intervention mean (SD)	90.0 (10.5)	82.0 (10)
	Improvement (Mean)	26.0 (4.5)	20.0 (4.3)
Visually guided reaching task	Pre-intervention mean (SD)	8.0 (4.0)	17.5 (4.2)
	Post-intervention mean (SD)	26.0 (4.5)	20.0 (4.3)
	Improvement (Mean)	8.0	2.5
Arm position matching task	Pre-intervention mean (SD)	15.0 (3.5)	14.5 (3.6)
	Post-intervention mean (SD)	23.0 (4.0)	17.0 (3.8)
	Improvement (Mean)	8.0	2.5

The data unambiguously demonstrates that the group undergoing robotic therapy exhibited superior enhancements in all evaluations in comparison to the control group, hence underscoring the efficacy of integrating artificial intelligence and robotic systems in rehabilitation therapy.

FMA UE and ARAT improvements

The group undergoing robotic therapy showed significantly greater increases in motor function, as assessed by the FMA UE and ARAT, indicating better recovery of upper extremity function.

FIM score increases

The greater increase in FIM ratings observed in the group receiving robotic therapy suggests superior advancements in overall functional independence, a critical factor for post-stroke quality of life.

Robotic assessments

The robotic therapy group demonstrated significantly larger improvements in the visually guided reaching and arm position matching tasks, highlighting the advantages of precision and feedback-oriented robotic therapies in promoting sensorimotor repair.

The findings of this study suggest that rehabilitation can be effectively employed in the treatment of subacute stroke, with minimal occurrence of adverse events. None of these incidents were sufficiently severe to impede participants from proceeding with the intervention. Throughout the 10-day intervention, it was seen that patients in the robotic therapy group consistently demonstrated improvement in their rehabilitation tasks. The intervention led to a considerable improvement in performance on nearly all robotic rehabilitation activities compared to the initial baseline. At the conclusion of the pilot trial, the group receiving robotic intervention demonstrated notably greater scores in FMA UE, ARAT, and FIM compared to their initial baseline scores. The intervention group showed a notable enhancement in Visually Guided Reaching, potentially due to the resemblance between the evaluation and robotic rehabilitation activities.

DISCUSSION

The subsequent Table 2 provides an in-depth analysis of previous material about the integration of AI and robotics in rehabilitation therapy, specifically focusing on how it improves motor recovery following injury or stroke.

Table 2: Related works.

Authors	Methodology	Findings
Hobbs et al[8]	This extensive review study examined such perspectives through three lenses: interaction objective and kind, physical implementation, and robotic device sensorimotor pathways. Researchers arrange their approaches to recovering gait function intuitively.	In conclusion, using the approaches that work and integrating them in organized ways to create new methods that may improve outcomes may solve the overwhelming number of gait therapy methods.
Nizamis et al[9]	In order to replace or restore functions and increase natural neuronal output, this narrative review looked at current and developing brain rehabilitation technology, and recruiting dormant neuroplasticity. This study concluded with thoughts on neurological rehabilitation research, diagnosis, and treatment based on the technologies and their main obstacles.	Ultimately, the discipline needs to overcome clinical translational difficulties that are keeping many solutions from having a significant patient impact, even in the face of technology advancements, creative uses, synergies, feasibility demonstrations, and an expanding clinical base.
Xiong et al[10]	In order to provide a novel approach to stroke rehabilitation, this study examined the most recent updates to rehabilitation therapy for limb motor recovery in stroke patients.	Neutral research shows that intervention and control groups restore movement similarly. To improve stroke rehabilitation research design and implementation, this cited study expanded inclusion criteria to increase inclusion rate, universality of outcomes, allocation concealing, and timely characterization of leading indications of follow-up measures.
Cisek et al[1]	A methodological search yielded approximately 14,000 publications from the past 20 years in the Web of Science and Scopus databases. The study conducted a filtering process on the materials, resulting in a selection of 1062 documents. This process involved the use of keywords and a qualitative review.	created a 3-, 4-, and 5-topic model and interpreted the topics as four literature thematic: “robotics, software, functional, and cognitive”. This study examined the incidence and uniqueness of each thematic and find field-neglected areas.
Berger et al[11]	This study suggested that improving visual feedback in VR can improve motor performance, engage patients in learning, and help restore functional muscle patterns.	“An EMG-controlled virtual reality interface can aid rehabilitation by targeting changes in muscle synergies and activations after a stroke, enabling personalized therapy to address individual deficiencies.”

This study found that AI-integrated robotic therapy improved motor recovery and functional independence more than usual care, as measured by FMA UE, ARAT, and FIM scores. Hobbs et al found that robotic-assisted rehabilitation improves gait and motor outcomes.[8] The studied literature shows how technology is changing rehabilitation, with different perspectives. Hobbs et al stressed organized integration of robotic gait therapy, while Nizamis et al addressed translational hurdles to neuroplasticity-driven technology.[8,9] Xiong et al found equal recoveries in intervention and control groups, highlighting the need for better trial design and inclusion.[10] A broader theme study by Cisek et al identified robotics and cognitive rehabilitation underexplored areas.[1] Finally, Berger et al shown how electromyography (EMG) - controlled VR might improve individualized therapy.[11] These studies indicate that long-term efficacy and clinical translation remain major problems despite advances.

The results of this study align with the previously published scientific literature, indicating that upper-extremity robotic therapy is both safe and has the capacity to enhance clinical outcomes after a stroke. Nevertheless, it is crucial to possess a comprehensive comprehension of how the tasks employed in the present investigation compare to prior robotic rehabilitation tasks executed on the upper extremities. Several previous studies have employed out-and-back or point-to-point reaching scenarios. These projects may be beneficial, but they are simple and focus solely on achieving behavior. The current study required participants to do three different types of upper limb reaching activities. The challenges included assist/resist, proprioceptive reaching, and ball grab. the proprioceptive reaching challenge introduces a fresh aspect to robotic rehabilitation by emphasizing the use of proprioceptive feedback rather than visual feedback to guide participants' movements. The results also highlighted the potential of AI-integrated robotic therapy to deliver superior rehabilitation outcomes compared to standard care alone. Subsequent research endeavours could delve deeper into the enduring advantages and enhance the treatment regimens to optimize patient recuperation.

Limitations

The small sample size and short intervention period may limit the generalizability of this study. Participant variety was limited by the single-centered study. Long-term results and motor recovery durability were not examined, and scheduling issues sometimes compromised intervention consistency. These findings need to be confirmed and applied in large-scale, multicentre trials with extended follow-up.

CONCLUSION

When compared to standard therapy alone, the study reveals that AI-integrated robotic therapy dramatically improves motor recovery and functional independence in individuals who have suffered a subacute stroke. When it came to the FMA, the ARAT, and the FIM, the participants in the robotic therapy group demonstrated further and more significant improvements. The effectiveness of the device was further demonstrated by the fact that robotic evaluations revealed significant improvements in sensorimotor function. There is a strong possibility that these higher outcomes were influenced by increased patient engagement and feedback mechanisms. In general, the use of artificial intelligence and robotics into rehabilitation therapy is a promising method to enhancing the recovery process following a stroke.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Cisek K, Kelleher JD. Current topics in technology-enabled stroke rehabilitation and reintegration: A scoping review and content analysis. IEEE Trans Neural Syst Rehabil Eng. 2023;31:3341-52.
2. Feigin VL, Michael B, Bo N, Sheila M, Ralph LS, Werner H, et al. World stroke organization (WSO): Global Stroke Fact Sheet 2022. Int J Stroke. 2022;17(1):18-29.
3. Boot E, Ekker MS, Putaala J, Kittner S, De Leeuw F,Tuladhar AM. Ischaemic stroke in young adults: a global perspective. J Neurol Neurosurg Psychiatry. 2020;91(4):411-7.
4. Donkor ES. Stroke in the 21st century: A snapshot of the burden, epidemiology, and quality of life. Stroke Res Treat. 2018;3238165.
5. Shavelle RM, Brooks JC, Strauss DJ, Turner-Stokes L. Life expectancy after stroke based on age, sex, and Rankin grade of disability: A synthesis. J Stroke Cerebrovasc Dis. 2019;28(12):104450.
6. Zawawi NSM, Aziz NA, Fisher R, Ahmad K, Walker MF. The unmet needs of stroke survivors and stroke caregivers: A systematic narrative review. J Stroke Cerebrovasc Dis. 2020;29(8):104875.
7. Uivarosan D, Simona GB, Carmen DN-C, Paul AN, Alexa FB, Anca MS, et al. Application of robotic recovery techniques to stroke survivors-bibliometric analysis. J Pers Med. 2022;12(12):2066.
8. Hobbs B, Artemiadis P. A review of robot-assisted lower-limb stroke therapy: Unexplored paths and future directions in gait rehabilitation. Front Neurorobot. 2020;14:19.
9. Nizamis K, Athanasiou A, Almpani S, Dimitrousis C, Astaras A. Converging robotic technologies in targeted neural rehabilitation: A review of emerging solutions and challenges. Sensors (Basel). 2021;21(6):2084.
10. Xiong F, Xin L, Jie X, Xin B, Jiaqi H, Bi Z, et al. Emerging limb rehabilitation therapy after post-stroke motor recovery. Front Aging Neurosci. 2022;14:863379.

11. Berger DJ, D'Avella A. Myoelectric control and virtual reality to enhance motor rehabilitation after stroke. Front Bioeng Biotechnol. 2024;12:1376000.

Cite this article as: Bajaj G, Davu G, Viswanathan B. Integration of artificial intelligence and robotics in rehabilitation therapy: enhancing motor recovery after injury or stroke. Int J Res Med Sci 2025;13:5260-6.