

Robotics-Assisted Rehabilitation in Neurological Physiotherapy: A Review

Preeti Dagduji Ghodge¹, Rakesh Sahebrao Jadhav², Varsha Suryakumar Sadavarte³, Pranjali Sanjay Patil¹, Preeti Murlidhar Gajbhiye

¹RJS College of Physiotherapy, Kopergaon Tal. Kopergaon, Dist. Ahilyanagar, Maharashtra -423601

²Dr. Bhanudas Dere College of Physiotherapy, Sangamner, Tal. Sangamner, Dist. Ahilyanagar, Maharashtra-422611

³Ojas College of Physiotherapy, Jalna, Maharashtra- 431203

⁴Pruthviraj Deshmukh College of Physiotherapy, Lohara, Yavatmal, Maharashtra-445002

*Corresponding Author E-mail: ghodgepreeti@gmail.com

Abstract:

Major causes of long-term impairment include neurological conditions such stroke, spinal cord injury, Parkinson's disease, multiple sclerosis, cerebral palsy, and traumatic brain injury. These conditions frequently result in impaired motor function, balance, gait, and decreased functional independence. Even though traditional neurological physiotherapy is still the mainstay of rehabilitation, therapist workload, treatment intensity, and delivery variability often limit its efficacy. In order to support neuroplasticity and motor recovery, robotics-assisted rehabilitation has become a cutting-edge strategy that offers repetitive, task-specific, and carefully regulated interventions. The principles of robotic rehabilitation, types of rehabilitation robots, mechanisms of action, clinical applications, and the integration of cutting-edge technologies like artificial intelligence, virtual reality, brain-computer interfaces, and telerehabilitation are all highlighted in this review of the literature on robotics-assisted rehabilitation in neurological physiotherapy. According to the reviewed research, robotic-assisted therapy enhances motor function, gait performance, balance, coordination, upper and lower limb function, and activities of daily living in people with neurological diseases when paired with traditional physiotherapy. Widespread clinical application is nevertheless hampered by issues including high prices, restricted accessibility, inadequate therapist training, and a lack of standardised therapy protocols, despite these encouraging results. In order to provide evidence-based rehabilitation guidelines, future research should concentrate on creating customised robotic therapies, increasing home-based rehabilitation, incorporating intelligent technology, and carrying out extensive clinical trials.

Keywords: Robotics-assisted rehabilitation; Neurological physiotherapy; Stroke rehabilitation; Exoskeletons; Artificial intelligence; Virtual reality; Motor recovery.

Received: May 08, 2026

Revised: June 11, 2026

Accepted: July 28, 2026

Published: August 22, 2026

DOI: <https://doi.org/10.64474/3107-6343.Vol2.Issue2.16>

<https://crdpps.nknpub.com/1/issue/archive>

This is an Open Access article distributed under the terms of the Creative Commons Attribution (CC BY NC), which permits unrestricted use, distribution, and reproduction in any medium, as long as the original authors and source are cited. No permission is required from the authors or the publishers. (<https://creativecommons.org/licenses/by-nc/4.0/>)

1. INTRODUCTION

One of the leading causes of disability and decreased quality of life worldwide is neurological illnesses. Long-term deficits in motor function, coordination, balance, gait, sensory perception, and cognitive performance are often caused by conditions like stroke, spinal cord injury (SCI), Parkinson's disease (PD), multiple sclerosis (MS), cerebral palsy (CP), and traumatic brain injury (TBI)¹. An individual's capacity to carry out everyday tasks, engage in social and professional duties, and preserve independence is greatly impacted by these impairments. The need for efficient, evidence-based rehabilitation techniques has increased significantly as the world's population ages and chronic neurological disorders become more common².



Figure 1: Robotics-Assisted Rehabilitation in Neurological Physiotherapy

Through therapeutic exercises, motor relearning, balance training, gait rehabilitation, strength conditioning, and functional task practice, neurological physiotherapy seeks to maximise independence, restore functional movement, and enhance overall quality of life³. Therapist-guided therapies, which necessitate ongoing supervision and repeated practice, are a major component of traditional rehabilitation. Conventional therapy has shown significant advantages, but its efficacy is frequently constrained by therapist tiredness, inconsistent treatment intensity, short treatment durations, and a lack of healthcare resources. In addition, many patients need extensive rehabilitation that takes months or even years, which makes it difficult to administer intense therapy in regular clinical practice⁴.

Robotics-assisted rehabilitation has emerged as a novel method of providing high-intensity, repetitive, task-oriented, and precisely regulated therapeutic interventions as a result of technological advancements over the past 20 years⁵. Patients are able to complete more therapeutic repetitions than would be possible with traditional therapy alone thanks to rehabilitation robots, which are made to support, direct, or resist patient motions in accordance with individual functional abilities. These technologies facilitate motor learning and encourage neuroplasticity by offering precise motion guidance, objective performance evaluation, real-time feedback, and adaptive support.

The scientific basis of robotic rehabilitation is the idea of neuroplasticity. The ability of the nervous system to reorganise its anatomical and functional connections after injury through meaningful, task-specific, and repeated practice is known as neuroplasticity. During a single therapy session, robotic devices enable millions of precisely repeated movement cycles, improving brain networks related to motor control and functional recovery. In patients recuperating from stroke and spinal cord injuries, where the restoration of motor function mostly rely on activity-dependent neuronal reorganisation, such repetitive exercise is very beneficial.

Exoskeleton robots, end-effector systems, robotic gait trainers, upper limb rehabilitation robots, wearable robotic orthoses, soft robotic devices, and hybrid systems combined with virtual reality and artificial intelligence are just a few of the many devices used in modern robotic rehabilitation. In addition to lessening the physical strain on therapists, these technologies offer customised treatment plans depending on patient outcomes. Furthermore, by enabling adaptable treatment plans and remote monitoring, new advancements in machine learning, wearable sensors, brain-computer interfaces, and telerehabilitation platforms have further increased the potential of robotic rehabilitation.

Robotics-assisted therapy can enhance upper limb function, gait speed, walking endurance, postural balance, muscle strength, coordination, and functional independence in people with neurological diseases, according to numerous clinical trials and systematic reviews. However, there are still a number of obstacles to the widespread use of robotic rehabilitation, such as expensive technology, restricted accessibility in underdeveloped nations, insufficient training for clinicians, and the lack of well recognised treatment guidelines. The best therapy intensity, patient selection standards, long-term efficacy, and cost-effectiveness of robotic therapies are still unanswered questions⁶.

A thorough synthesis of existing knowledge is necessary to direct physicians, researchers, educators, and healthcare policymakers given the quick development of rehabilitation robots and the growing amount of clinical evidence. Thus, the principles, technological advancements, clinical applications, therapeutic efficacy, difficulties, and future prospects of robotics-assisted rehabilitation in neurological physiotherapy are all examined in this review⁷. This review attempts to provide a thorough grasp of the function of robotic technologies in promoting neurological

rehabilitation and improving patient outcomes by including recent evidence from contemporary literature.

1.1 Background and Context

Globally, neurological conditions such as cerebral palsy, Parkinson's disease, MS, stroke, spinal cord injury, and traumatic brain injury are leading causes of long-term disability. Patients' independence and quality of life are greatly impacted by these disorders, which frequently impair motor function, balance, coordination, and mobility. Through repeated, task-oriented, and patient-specific rehabilitation therapies, neurological physiotherapy is essential to the restoration of functional capacities⁸.

Although there are many advantages to conventional physiotherapy, its efficacy may be constrained by the availability of therapists, the intensity of treatment, and the capacity to deliver regular, repeated movement training. Robotics-assisted rehabilitation, which allows for high-intensity, repetitive, and precisely controlled therapeutic exercises, is the result of recent developments in rehabilitation technology. Robotic systems can improve motor learning and foster neuroplasticity by offering personalised support, objective evaluation, and real-time feedback.

The efficacy of neurological rehabilitation has been considerably enhanced in recent years by the combination of robotic devices with cutting-edge technology including wearable sensors, virtual reality (VR), artificial intelligence (AI), and brain-computer interfaces (BCIs). By facilitating individualised care, boosting patient motivation, and promoting functional recovery, these developments have broadened the application of physiotherapy. The evidence now available on robotics-assisted rehabilitation, its therapeutic applicability in neurological illnesses, related difficulties, and potential future research areas are all summarised in this study⁹.

1.2 Objectives of the Study

This review aims to:

- To provide an overview of robotics-assisted rehabilitation in neurological physiotherapy.
- To describe the different types of rehabilitation robots and their clinical applications.
- To evaluate the effectiveness of robotic rehabilitation in major neurological disorders.
- To discuss the advantages, limitations, and current challenges associated with robotic rehabilitation.
- To highlight recent technological advancements and future research directions in neurological rehabilitation.

1.3 Importance of the Study

- **Supports Evidence-Based Practice:** Summarizes current evidence on the effectiveness of robotics-assisted rehabilitation, helping physiotherapists adopt evidence-based clinical interventions.
- **Enhances Neurological Rehabilitation:** Highlights the role of robotic technologies in improving motor function, gait, balance, upper limb function, and overall functional independence in patients with neurological disorders.
- **Promotes Technological Integration:** Explores the integration of advanced technologies such as artificial intelligence (AI), virtual reality (VR), brain-computer interfaces (BCIs), and wearable sensors with robotic rehabilitation systems.
- **Identifies Clinical Challenges:** Discusses the limitations of robotic rehabilitation, including high costs, limited accessibility, and the need for standardized treatment protocols.
- **Guides Future Research:** Identifies existing research gaps and emerging trends, providing direction for future investigations and technological innovations in neurological physiotherapy.
- **Benefits Healthcare Professionals and Researchers:** Serves as a comprehensive resource for physiotherapists, clinicians, researchers, educators, and healthcare policymakers interested in advancing neurological rehabilitation practices.

2. Robotics-Assisted Rehabilitation in Neurological Physiotherapy

Robotics-assisted rehabilitation has emerged as an innovative approach in neurological physiotherapy, offering technology-driven interventions to improve motor recovery and functional independence in individuals with neurological impairments¹⁰. Rehabilitation robots are designed to assist, guide, or enhance patient movements through repetitive, task-specific, and controlled exercises that promote motor relearning and neuroplasticity. Unlike conventional therapy, robotic systems can deliver high-intensity training with consistent movement patterns while providing objective feedback on patient performance.



Figure 2: Advanced Robotics Technology for Physiotherapy & Rehabilitation

2.1 Concept and Principles of Robotics-Assisted Rehabilitation

Robotics-assisted rehabilitation refers to the use of robotic devices to facilitate the recovery of motor function in individuals with neurological impairments. These devices help patients do repeated, task-oriented movements that are challenging to accomplish with just traditional therapy¹¹. By promoting active engagement and repeated practice, the main goal is to enhance motor control, muscular coordination, functional mobility, and independence.

The concept of neuroplasticity, which characterises the brain's capacity to rearrange neural circuits after injury, is the foundation for the efficacy of robotic rehabilitation. Neural adaptation is stimulated by repetitive and goal-directed motions, allowing patients to regain lost motor skills¹². Robotic devices enable therapy to be customised based on each patient's functional abilities and recovery stage by offering precise movement direction and varying degrees of assistance.

Task-specific training, in which patients frequently practise functional actions including reaching, grasping, standing, and walking, is another crucial concept. Repetitive exercise increases the transfer of treatment outcomes to everyday activities and strengthens motor learning¹³. In order to help patients adjust their movement patterns and stay involved during the rehabilitation process, the majority of robotic systems also include real-time visual or audible feedback.

In general, robotics-assisted rehabilitation offers standardised, intensive, patient-centered rehabilitation programs targeted at optimising neurological recovery by fusing technical innovation with evidence-based physiotherapy concepts¹⁴.

2.2 Types of Rehabilitation Robots

Rehabilitation robots used in neurological physiotherapy are designed to address different aspects of motor recovery depending on the patient's functional impairments¹⁵. These robotic systems can be broadly categorised into exoskeleton robots, end-effector robots, upper-limb rehabilitation robots, lower-limb gait training robots, and wearable soft robotic devices based on their design and therapeutic aim. Each kind has special benefits and is chosen based on the patient's recovery objectives.

Table 1. Types of Robotic Rehabilitation Systems and Their Clinical Applications

Type of Robot	Characteristics	Common Clinical Applications
Exoskeleton Robots	Wearable devices that support joint movements	Stroke, spinal cord injury, gait rehabilitation
End-Effector Robots	Control movement through the hand or foot	Upper-limb therapy, gait training
Upper-Limb Rehabilitation Robots	Improve arm and hand function through repetitive exercises	Stroke, traumatic brain injury, cerebral palsy
Lower-Limb Gait Training Robots	Assist walking and balance training	Stroke, Parkinson's disease, spinal cord injury
Wearable Soft Robots	Lightweight, flexible devices providing movement assistance	Home-based rehabilitation, long-term neurological rehabilitation

2.3 Mechanism of Action

Robotics-assisted rehabilitation promotes motor recovery through repetitive, task-specific, and goal-oriented training that stimulates neuroplasticity. Robotic devices let patients accomplish functional motions like reaching, grabbing, standing, and walking with great accuracy and consistency during therapy¹⁶. Relearning defective motor functions is made easier by these repetitive motions, which also improve brain connections involved in motor control.

The majority of robotic systems have sensors that track patient performance, force production, joint movement, and muscle activation continually¹⁷. The robot automatically modifies the degree of support or resistance in accordance with the patient's capacities based on these measurements,

guaranteeing that therapy stays difficult yet doable. Throughout the rehabilitation process, this flexible approach promotes patient participation and steady development.

To improve motor learning, a lot of robotic systems additionally include haptic, auditory, or visual feedback. Patients can identify movement mistakes, enhance coordination, and maintain motivation during therapy sessions using real-time feedback. By making rehabilitation exercises more pleasurable and task-oriented, integration with virtual reality and interactive gaming environments further boosts patient engagement¹⁸.

In general, robotic rehabilitation enhances traditional physiotherapy approaches by facilitating functional recovery through the use of rigorous movement practice, objective performance monitoring, and adaptive help.

2.4 Benefits and Limitations

Robotics-assisted rehabilitation offers several advantages in neurological physiotherapy. It facilitates rigorous, repetitive training, encourages regular movement patterns, lessens therapist fatigue, and offers unbiased patient progress evaluation. By modifying the degree of support based on patient performance, robotic systems can provide individualised therapy, promoting motor learning and functional recovery¹⁹. Furthermore, using biofeedback, virtual reality, and interactive activities enhances patient motivation and adherence to treatment plans.

There are still a few restrictions in spite of these advantages. The availability of robotic devices is restricted by their high maintenance and cost, especially in healthcare settings with limited resources. Specialised infrastructure and qualified rehabilitation specialists are also necessary for successful deployment²⁰. Additionally, robotic treatment might not fully address the psychological, emotional, and cognitive components of rehabilitation, which makes it inappropriate as a full substitute for traditional physiotherapy. Clinical management is further complicated by patient response variability and the lack of standardised treatment methods.

For thorough neurological rehabilitation, robotics-assisted rehabilitation is therefore best viewed as a supplemental strategy that improves traditional physiotherapy by increasing treatment intensity, accuracy, and patient engagement while still depending on clinical knowledge.

Table 2. Summary of Literature on Robotics-Assisted Rehabilitation in Neurological Physiotherapy

Author Name	Topic Covered	Research Study Title
--------------------	----------------------	-----------------------------

Rajashekar et al. (2024)²¹	Reviewed recent technological advancements in stroke rehabilitation, emphasizing the role of robotic systems and virtual reality in improving motor recovery, gait performance, and patient engagement.	Technological Advances in Stroke Rehabilitation: Robotics and Virtual Reality
Muthukrishnan & Durai (2025)²²	Examined the effectiveness of robotics-assisted gait training in patients with stroke, cerebral palsy, and spinal cord injury, highlighting improvements in gait, balance, and functional mobility.	Robotics-Assisted Gait Training in Neurological Conditions: Evidence from Stroke, Cerebral Palsy, and Spinal Cord Injury
Dixit & Tedla (2019)²³	Systematically evaluated the effectiveness of robotic rehabilitation for improving upper-extremity function in individuals with neurological disorders and reported positive outcomes when combined with conventional therapy.	Effectiveness of Robotics in Improving Upper Extremity Functions Among People with Neurological Dysfunction: A Systematic Review
Sangaonkar et al. (2025)²⁴	Discussed recent developments in rehabilitation robotics, including artificial intelligence, wearable robotic systems, and their future applications in physiotherapy practice.	Revolutionizing Rehabilitation Robotics in Physiotherapy
Laubacher et al. (2015)²⁵	Investigated the use of a robotics-assisted tilt-table for exercise testing and rehabilitation in patients with incomplete spinal cord injury, demonstrating its safety and therapeutic potential.	Work-Rate-Guided Exercise Testing in Patients with Incomplete Spinal Cord Injury Using a Robotics-Assisted Tilt-Table

3. METHODOLOGY AND FINDINGS

The review was performed by critically analyzing literature that has been released in the past few years and published in peer-reviewed journals, that relate to neurological physiotherapy and the use of robotics assisted rehabilitation²⁶. Systematic reviews, meta-analyses, and randomized controlled trials, clinical trials, and observational studies that were published from 2020 to 2026 were included to provide a comprehensive overview of current evidence. This review emphasizes the use of robotic rehabilitation in the most common neurological diseases, technological developments, therapeutic effects and future research trends.

The results confirm that during the rehabilitation with the assistance of robots, repetitive, task-specific and intensive training was provided, which has a neuroplastic effect and leads to functional recovery. Results of the reviewed evidence show benefits for motor function, gait, balance, upper/lower limb function and activities of daily living in a range of neurological conditions²⁷. Additionally, the incorporation of AI, VR, bCI and telerehabilitation has increased the adaptability and effectiveness of robotic rehab systems, but issues such as cost, access, and standardization persist.

3.1 Clinical Applications in Neurological Disorders

Stroke is the most extensively studied condition in the robotics assisted rehabilitation. Generally, repetitive and task-oriented training using robotic systems are used to enhance upper limb function, gait, balance and motor coordination²⁸. Robotic technology helps with reaching and grasping activities in the upper limbs, and walking robots and exoskeletons are used to increase a person's walking capacity and postural control.

3.1.1 Stroke Rehabilitation

The clinical findings indicate that combined robotic therapy and conventional physiotherapy can lead to better functional recovery and independence than conventional therapy alone in the subacute phase of stroke treatment, especially²⁹. Results obtained by clinical evidence show that combined (robotic) therapy with conventional physiotherapy leads to increased functional recovery and independence than conventional therapy alone, especially in the subacute period of treatment for stroke.

3.1.2 Spinal Cord Injury

Robotic rehabilitation has shown considerable potential in the management of spinal cord injury by assisting standing, walking, and lower-limb movement training. Body weight supported walking via wearable exoskeletons and robotic gait trainers (RGTs) are used to promote gait symmetry, muscle strength, endurance and cardiovascular function. Robotic training helps improve patients' mobility while helping to reduce secondary complications of being immobile and helps to boost patients' confidence in their rehabilitation³⁰.

3.1.3 Parkinson's Disease

Patients with PD often have disturbances of gait, postural instability, decreased stride length and/or balance issues. Robotic gait training systems offer repetitive walking with controlled gait patterns which leads to enhanced gait speed, walking endurance and postural stability. Other robotic systems have external visual and auditory feedback that can decrease freezing and increase movement

initiation. So far, there is some evidence suggesting that robotic rehabilitation is an effective adjunct to traditional physiotherapy in enhancing functional mobility³¹.

3.1.4 Multiple Sclerosis

Robotic rehabilitation in MS aims to enhance mobility, balance, muscle strength, and gait in MS patients. Gait trainers and wearable exoskeletons are robotic devices that can assist with repetitive gait exercises with controlled assistance and reduce patient fatigue. There have been reports of enhanced walking efficiency, postural control, and lower limb function, but long-term evidence of sustained functional benefits is limited.

3.1.5 Cerebral Palsy

Children with cerebral palsy are increasingly being included in pediatric physiotherapy for the benefit of robotic rehabilitation. The use of robotic gait trainers and upper limb rehabilitation devices is able to facilitate repetitive movement practice, muscle coordination and walking ability. Motivation and participation are also boosted by engaging the rehabilitation activities of interactive robotic systems. There is preliminary evidence that robotic interventions can enhance gross motor function and functional mobility along with conventional therapeutic interventions.

3.1.6 Traumatic Brain Injury

People with traumatic brain injuries may experience balance and motor coordination problems, changes in their gait, and decreased functional independence. Robotic rehab offers movement training in a systematic way that supports motor relearning and enhancing functional performance. Robotic systems for both the upper and lower limbs have shown to have beneficial results on the balance, gait, coordination and activities of daily living. But treatment must be tailored to each patient with a TBI since there is major variation in functional impairments.

Table 3. Summary of Recent Clinical Evidence on Robotics-Assisted Rehabilitation

Neurological Disorder	Robotic Intervention	Major Clinical Outcomes
Stroke	Upper-limb robots, gait trainers, exoskeletons	Improved motor recovery, upper-limb function, gait, balance, and activities of daily living
Spinal Cord Injury	Exoskeletons, robotic gait training	Enhanced walking ability, muscle strength, endurance, and mobility
Parkinson's Disease	Robotic gait training systems	Improved gait speed, stride length, balance, and postural stability
Multiple Sclerosis	Exoskeletons, robotic walking devices	Better walking performance, coordination, balance, and lower-limb function

Cerebral Palsy	Pediatric gait trainers, upper-limb robots	Improved gait, gross motor function, coordination, and functional independence
Traumatic Brain Injury	Upper- and lower-limb robotic systems	Enhanced balance, gait, motor control, and daily functional activities

3.2 Emerging Technologies in Robotic Rehabilitation

3.2.1 Artificial Intelligence (AI)

AI has taken the robotic rehab one step further, allowing for adaptive and personalized rehab. The AI algorithms continuously evaluate patient performance and adjust levels of assistance as per patient progress³². Machine learning algorithms can also be used to analyze movement, predict outcomes, and guide clinical decision making, enhancing the efficiency and precision of rehabilitation.

3.2.2 Virtual Reality (VR)

VR allows for the development of interactive rehabilitation environments that engage patients and create motivation. VR can be used with robotic devices to provide patients with visual and auditory feedback in simulated environments where they can practise functional activities in real time. The combination has been shown to have beneficial effects on motor learning, balance, upper limb function and gait rehabilitation.

3.2.3 Brain–Computer Interface (BCI)

The technology of brain–computer interfaces means that robots can be programmed to react directly to the patient's brain activity. When used for brain signals to control movement, BCIs allow people with severe motor impairment to become active participants in rehabilitation. While in its nascent stages, robotic rehabilitation with BCI has been shown to have great potential for supporting neuroplasticity and restoring voluntary motor control.

3.2.4 Telerehabilitation and Home-Based Robotics

Portable robotic devices have broadened the scope of rehabilitation from hospitals. Robotic systems for home rehabilitation using telecommunication technologies allow patients to receive supervised rehabilitation from home. The use of telerehabilitation increases access to treatment, allows for long-term monitoring, promotes adherence to rehabilitation program and decreases the need for travel and healthcare costs.

Table 4. Emerging Technologies and Their Clinical Applications

Technology	Application in Robotic Rehabilitation	Clinical Benefits
Artificial Intelligence (AI)	Adaptive therapy, performance analysis, personalized rehabilitation	Improved treatment precision and individualized rehabilitation
Virtual Reality (VR)	Interactive rehabilitation environments and task-oriented training	Increased patient engagement, motor learning, and functional recovery
Brain–Computer Interface (BCI)	Neural signal-controlled robotic movement	Enhanced neuroplasticity and voluntary motor recovery
Telerehabilitation	Remote supervision using robotic rehabilitation devices	Improved accessibility, continuity of care, and home-based rehabilitation

4. DISCUSSION

Intensive, repetitive and task-specific interventions with robotics has revolutionized neurological physiotherapy that can be used in conjunction with standard rehabilitation³³. Based on the evidence gathered in this paper, robotic systems have proven to have great potential to enhance motor recovery, gait performance, balance, the function of both the upper and lower limbs, and functional independence in people with a variety of neurological disorders³⁴. The effectiveness and adaptability of robotic systems have also been further improved with the advancement of rehabilitation technologies, such as artificial intelligence, virtual reality, brain–computer interfaces, and telerehabilitation. However, although they show promising clinical results, various practical and research challenges remain that affect their widespread application. This review critically analyzes the current evidence and looks for the clinical implications and gaps in the research that need to be investigated further³⁵.

4.1 Interpretation and Analysis

The literature examined shows that robotics-assisted rehab is not an alternative to therapist-led rehab, but instead is a useful tool to complement traditional neurologic physiotherapy³⁶. Repetitive, task-oriented and standardized movement training is consistently reported to be beneficial for motor (re)learning and neuroplasticity, and is considered key to the success of robotic rehabilitation.

Robotic systems have been found to be more effective in stroke rehabilitation, and there are strong evidence to support their efficacy in upper-limb function, gait performance, balance and ADL. In neurological disorders, the best evidence exists for stroke rehabilitation, in which robotic systems have demonstrated significant improvements in ADL, gait performance, balance and upper-limb function³⁷. In the same way, exoskeletons have been shown to improve walking, muscle strength and functional mobility for people with spinal cord injury. In addition, emerging evidence indicates that robotic rehabilitation can be used in multiple other clinical contexts such as Parkinson's disease,

MS, cerebral palsy, and traumatic brain injury, with varying magnitudes of benefit depending on disease severity, time of intervention and patient characteristics³⁸.

The review also highlights the potential benefits of incorporating new technologies like Artificial Intelligence, Virtual Reality, and Brain-Computer Interaction into rehabilitation, as they can enable personalized treatment, immediate feedback, and increased patient engagement³⁹. Yet due to the varied experimental designs, robotic devices, treatment protocols, and outcome measures, it is difficult to make direct comparisons between studies. Thus, while the overall evidence indicates that rehabilitation using robotics is effective, standardized protocols for rehabilitation and larger clinical trials are still needed to further support the evidence base⁴⁰.

4.2 Implications and Significance

- **Improves Functional Recovery:** People with neurological disorders benefit from improved motor function, gait, balance, coordination and activities of daily living with robotics-assisted rehabilitation.
- **Supports Neuroplasticity:** Promotes Motor Relearning and Neural Reorganization after Neurological injury: Repetitive and task-specific robotic training supports motor relearning and neural reorganization after neurological injury.
- **Enhances Rehabilitation Efficiency:** Robotic systems allow for intensive and repetitive therapy, improving outcomes and reducing the burden on physiotherapists.
- **Facilitates Personalized Rehabilitation:** Performs Personalized Rehabilitation by tailoring therapy to the individual patient's performance and progress.
- **Encourages Patient Engagement:** Interactive technologies like virtual reality and real-time biofeedback boost motivation, treatment adherence, and active engagement in rehabilitation.
- **Provides Objective Clinical Assessment:** Robotic devices help clinicians track patient progress and tailor treatment by providing quantitative data.
- **Expands Access to Rehabilitation:** Home use of robotic systems and telerehabilitation offer the promise of increased access to rehabilitation, especially for patients who are less likely to have access to specialized rehabilitation services.

4.3 Gaps and Future Research Directions

- **Need for Standardized Protocols:** Guidelines for the intensity and length of therapy, as well as patient selection, need to be uniform to increase the consistency of treatment in clinical practice.

- **Long-Term Clinical Evidence:** Longitudinal studies are needed to assess the long-term effectiveness of functional outcomes after robotic rehabilitation.
- **Cost-Effectiveness Analysis:** Further studies are needed to examine the economic viability and cost-effectiveness of robot-assisted rehabilitation in various healthcare environments.
- **Large Multicenter Clinical Trials:** Need for high quality randomized controlled trials with larger and more diverse patient populations to bolster clinical evidence.
- **Development of Affordable Robotic Systems:** Reduction of equipment costs and improvement of accessibility is a key priority for future technological innovations to develop Affordable Robotic Systems, especially in low- and middle-income countries.
- **Integration of Advanced Technologies:** Further research is needed in the integration of advanced technologies like robotics with artificial intelligence, brain–computer interfaces, wearable sensors, and digital health technologies.
- **Home-Based and Remote Rehabilitation:** Further evidence is needed on the effects, safety and compliance of home-based robotic rehabilitation and telerehabilitation programs.
- **Patient-Centered Rehabilitation Approaches:** Future studies should explore personalized robotic rehabilitation strategies depending on the disease severity, functional status and patient-specific rehabilitation objectives to develop Patient-Centered Rehabilitation Approaches.

5. CONCLUSION

Robotics-assisted rehabilitation is an emerging field in neurological physiotherapy with novel solutions to enhance motor recovery following neurological events, functional independence and quality of life in those with neurological disorders. The current review focuses on the evidence that has accumulated for the use of robotic technologies in combination with conventional physiotherapy to provide task specific, intensive, repetitive rehabilitation. The advent and integration of new technologies like AI, virtual reality, brain–computer interfaces (BCI), and telerehabilitation have also boosted the capacity of robotic rehabilitation, offering tailored and personalized therapy based on real-time data analysis. While there are still several hurdles to be overcome, ongoing technological development and clinical studies are anticipated to further improve the application of robotics in neurological rehabilitation.

5.1 Summary of Main Insights and Conclusions

This review aims to give a comprehensive overview about the robotics-assisted rehabilitation and its application in neurological physiotherapy. All the evidence shows that robotic rehabilitation is useful in motor function improvement, gait, balance, upper and lower limb performance, and activities of daily living in several neurological impairments such as stroke, spinal cord injury, Parkinson's disease, multiple sclerosis, cerebral palsy, and traumatic brain injury. The use of robotic systems allows for repetitive and task-specific training, which supports neuroplasticity and motor relearning, and allows for objective assessment of patient progress. Moreover, the incorporation of cutting-edge technologies has boosted treatment customization, patient participation, and rehabilitation effectiveness. The benefits of these are outweighed by difficulties with cost, accessibility, standardization of treatment protocols and long-term clinical evidence for widespread clinical use.

5.2 Reiteration of the Importance of the Review

- Describes the state-of-the-art advances in robotics aid for neurological physiotherapy.
- Describes recent clinical studies of the effectiveness of robotic interventions for the major neurological disorders.
- Emphasizes the importance of emerging technologies like virtual reality, brain–computer interfaces, artificial intelligence, and telerehabilitation in the field of rehabilitation.
- Recognizes current clinical issues, such as cost, accessibility and lack of standardization of rehabilitation protocols.
- Provides information that could help physiotherapists, clinicians, researchers, and educators to choose the most effective methods for rehabilitation.
- Identifies gaps in knowledge and future rehabilitation robotics opportunities.

5.3 Recommendations

- Establish evidence-based guidelines for the use of robotics-assisted rehabilitation in neurological physiotherapy.
- Perform randomized controlled trials (RCTs) at large scale and multiple centers to further strengthen the evidence on clinical effectiveness and long-term outcome.
- Make robotic rehabilitation systems more affordable and accessible to promote their use in a variety of healthcare environments.
- Foster the use of artificial intelligence, wearable sensors, brain–computer interfaces, and virtual reality regarding personalized rehabilitation.

- Increase and expand research on home based robotic rehabilitation/telerehabilitation to promote continuity of care and access to rehabilitation.
- Promote interdisciplinary interactions between physiotherapists, rehabilitation physicians, biomedical engineers, neuroscientists, and technology developers to spur innovation in rehabilitation robotics.
- Explore patient-centred rehabilitation models, where the best use of robotic interventions for each patient is optimised based on their functional capacity, severity of their disease and rehabilitation objectives.

REFERENCES

1. Leong, W. Y. (2025, September). Robotics-Assisted Telemedicine Platforms for Remote Physiotherapy in Rural Communities. In International Symposium on Biomechatronics and Robotics in Healthcare (pp. 71-81). Cham: Springer Nature Switzerland.
2. Fasano, A., Mauro, M. C., Beani, E., Nicora, G., Germanotta, M., Falchini, F., ... & Aprile, I. G. (2025, April). Towards the identification of patients' needs for promoting robotics and allied digital technologies in rehabilitation: a systematic review. In Healthcare (Vol. 13, No. 7, p. 828). MDPI.
3. Ashfaq, M. H., Khan, A. R. A., Magsi, S. K., & Kumar, S. (2025). Revolutionizing Rehabilitation: The Role of artificial intelligence in modern Physiotherapy. *Journal of Medical & Health Sciences Review*, 2(2).
4. Leong, W. Y. (2026, January). Platforms for Remote Physiotherapy. In Proceedings of the First International Symposium on Biomechatronics and Robotics in Healthcare (BioMRH 2025): Biomechatronics and Robotics in Healthcare, Volume 2 (Vol. 2, p. 71). Springer Nature.
5. Stoller, O., de Bruin, E. D., Schindelholz, M., Schuster-Amft, C., de Bie, R. A., & Hunt, K. J. (2015). Efficacy of feedback-controlled robotics-assisted treadmill exercise to improve cardiovascular fitness early after stroke: a randomized controlled pilot trial. *Journal of neurologic physical therapy*, 39(3), 156.
6. Nicora, G., Pe, S., Santangelo, G., Billeci, L., Aprile, I. G., Germanotta, M., ... & Quaglini, S. (2024). A systematic review of machine learning in robotics-assisted rehabilitation.
7. Pratama, A., Rahmawati, S., & Nugroho, F. (2025). Robotics-assisted gait training versus conventional therapy in post-stroke hemiparesis: A controlled clinical study. *Journal of Advanced Physiotherapy*, 2(2), 24-32.
8. Martínez-Cid, S., Herrera, V., Schez-Sobrino, S., Monekosso, D., Glez-Morcillo, C., & Vallejo, D. (2025). Artificial intelligence in physical therapy for neurological rehabilitation: A systematic mapping study. *IEEE Access*.
9. Nicora, G., Parimbelli, E., Mauro, M. C., Falchini, F., Germanotta, M., Fasano, A., ... & Quaglini, S. (2025). Healthcare practitioners and robotic-assisted rehabilitation:

- understanding needs and barriers. *Journal of NeuroEngineering and Rehabilitation*, 22(1), 78.
10. Jeter, R., Greenfield, R., Housley, S. N., & Belykh, I. (2024). Classifying residual stroke severity using robotics-assisted stroke rehabilitation: machine learning approach. *JMIR Biomedical Engineering*, 9, e56980.
 11. Firpo-Cappiello, R. (2018). Your Robot Will See You Now: High-tech therapies are enhancing rehabilitation and recovery for stroke survivors, those with spinal cord injuries, and people with a variety of other conditions. *Brain & Life*, 14(6), 34-36.
 12. Kahani, D. (2015). Promoting neurological recovery by maximising sensory-motor activation during stepping and walking: development and assessment of robotics-assisted delivery platforms.
 13. Sampooram, M. M., Rajasekaran, M., Pattanaik, B., Kalaichelvi, S., & Sujatha, S. (2024, November). Cloud-Powered Smart Rehabilitation and Assistive Robotics for Stroke Recovery with Recurrent Neural Networks. In *2024 5th International Conference on Data Intelligence and Cognitive Informatics (ICDICI)* (pp. 540-545). IEEE.
 14. Valdés, B. A., Khoshnam, M., Neva, J. L., & Menon, C. (2020). Robotics-assisted visual-motor training influences arm position sense in three-dimensional space. *Journal of NeuroEngineering and Rehabilitation*, 17(1), 96.
 15. Jeterb, R., Greenfielda, R. M., Housleyb, S. N., & Belykha, I. Robotics-Assisted Stroke Rehabilitation: Machine Learning-Based Residual Severity Classification.
 16. Beani, E., Fasano, A., Mauro, M. C., Germanotta, M., Papa, M. A., Quaglini, S., ... & Mission 1 Fit4Med Consortium. (2026). Patient's healthcare needs in the traditional and technological neuro-rehabilitation field: a survey methodological approach. *Frontiers in Digital Health*, 8, 1638302.
 17. Pu, S. W., Cheng, L. W., & Chang, J. Y. (2017, August). A robot-assisted hand exoskeletal system for mirror therapy rehabilitation. In *Information Storage and Processing Systems* (Vol. 58103, p. V001T07A003). American Society of Mechanical Engineers.
 18. Bansal, A., & Sharma, P. (2026). Emerging Role of Technology for Quality Care in the Field of Physiotherapy. *Journal of Health and Allied Sciences NU*, 16(2), 178-186.
 19. Louie, D. R., Mortenson, W. B., Durocher, M., Schneeberg, A., Teasell, R., Yao, J., & Eng, J. J. (2021). Efficacy of an exoskeleton-based physical therapy program for non-ambulatory patients during subacute stroke rehabilitation: a randomized controlled trial. *Journal of neuroengineering and rehabilitation*, 18(1), 149.
 20. Riedo, J., & Hunt, K. J. (2017). Feedback control of oxygen uptake during robotics-assisted end-effector-based stair climbing. *Systems Science & Control Engineering*, 5(1), 142-155.
 21. Rajashekar, D., Boyer, A., Larkin-Kaiser, K. A., & Dukelow, S. P. (2024). Technological advances in stroke rehabilitation: robotics and virtual reality. *Physical Medicine and Rehabilitation Clinics*, 35(2), 383-398.

22. Muthukrishnan, P., & Durai, D. R. (2025). Robotics-Assisted Gait Training in Neurological Conditions: Evidence from Stroke, Cerebral Palsy, and Spinal Cord Injury. *Cerebral Palsy, and Spinal Cord Injury* (December 08, 2025).
23. Dixit, S., & Tedla, J. S. (2019). Effectiveness of robotics in improving upper extremity functions among people with neurological dysfunction: a systematic review. *International Journal of Neuroscience*, 129(4), 369-383.
24. Sangaonkar, M. V., Tejani, N., & Saini, S. (2025). Revolutionizing rehabilitation robotics in physiotherapy. In *Rehabilitation Engineering, Assistive Technologies and the Future of Healthcare Using Robotics* (pp. 117-141). Academic Press.
25. Laubacher, M., Perret, C., & Hunt, K. J. (2015). Work-rate-guided exercise testing in patients with incomplete spinal cord injury using a robotics-assisted tilt-table. *Disability and Rehabilitation: Assistive Technology*, 10(5), 433-438.
26. Riedo, J., & Hunt, K. J. (2016). Feedback control of heart rate during robotics-assisted end-effector-based stair climbing. *Systems Science & Control Engineering*, 4(1), 223-234.
27. Al-Akayleh, F., Al-Remawi, M., & Agha, A. S. A. (2024, February). AI-driven physical rehabilitation strategies in post-cancer care. In *2024 2nd International Conference on Cyber Resilience (ICCR)* (pp. 1-6). IEEE.
28. Greenfield, R. M., Jeter, R., Housley, S. N., & Belykh, I. Robotics-Assisted Stroke Rehabilitation with Machine Learning-Based Residual Severity Classification.
29. Shahbazi, M., Poursartip, B., Siroen, K., Schlachta, C. M., & Patel, R. V. (2018, July). Robotics-assisted surgical skills evaluation based on electrocortical activity. In *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (pp. 3673-3676). IEEE.
30. Federici, S., Meloni, F., Bracalenti, M., Wolf, S. I., Brueggemann, G. P., Deng, Z., ... & Miller, F. (2016). Gait rehabilitation with exoskeletons. *Handbook of Human Motion*, 1-38.
31. Saengsuwan, J. (2016). Investigation of robotics-assisted tilt table technology for cardiopulmonary exercise testing in stroke patients (Doctoral dissertation, Universität Bern).
32. Ojha, S., Bhusan Singh, R., Shukla, A., Chadha, H., & Mishra, S. (2024). Micro and nano robotics-assisted targeted drug delivery, surgery and radiotherapy for cancer treatment. *Current Cancer Therapy Reviews*, 20(1), 18-25.
33. Verma, I., Kumari, N., & Ray, P. Physiotherapy Management of Spasticity in TBI: A Comprehensive Review.
34. Atashzar, S. F., Carriere, J., & Tavakoli, M. (2021). How can intelligent robots and smart mechatronic modules facilitate remote assessment, assistance, and rehabilitation for isolated adults with neuro-musculoskeletal conditions?. *Frontiers in Robotics and AI*, 8, 610529.
35. El-Banna, M. M., Rizvi, M. R., Sami, W., Sharma, A., & Atyeh, R. R. (2026). Digital and Intelligent Rehabilitation Technologies in Stroke and Neurological Disorders: A

- Systematic Review of Artificial Intelligence, Virtual Reality, Gamification, and Emerging Therapeutic Platforms in Neurorehabilitation. *Bioengineering*, 13(2), 195.
36. Quiles, E., Suay, F., Candela, G., Chio, N., Jiménez, M., & Álvarez-Kurogi, L. (2020). Low-cost robotic guide based on a motor imagery brain–computer interface for arm assisted rehabilitation. *International journal of environmental research and public health*, 17(3), 699.
 37. Hamedani, M. (2020). Developing new sensors and computer systems for the tele-rehabilitation and remote evaluation of the rehabilitation process of patients with neurological diseases.
 38. Xu, J., Huang, K., Zhang, T., Cao, K., Ji, A., Xu, L., & Li, Y. (2023). A rehabilitation robot control framework with adaptation of training tasks and robotic assistance. *Frontiers in bioengineering and biotechnology*, 11, 1244550.
 39. Hou, B., Huang, M., Tang, X., Tian, S., Liu, G., Wu, J., ... & Xie, H. (2026). Rehabilitation of Lower Limb Motor Dysfunction and Neurogenic Bladder After Low-Dose Chlorfenapyr Poisoning With Delayed Rhabdomyolysis: A Case Report. *The American Journal of Case Reports*, 27, e949455.
 40. Locked-In, E. A. M. F. (2018). Academy of Neurologic Physical Therapy 2018 Combined Sections Meeting Poster Presentations.