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Integrating AI into Stroke Physical Therapy: A Narrative Review of Evidence and Emerging Trends

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Abstract

Background: Artificial Intelligence (AI) has rapidly emerged as a transformative force across healthcare, offering automation, predictive analytics, and personalized interventions. Stroke remains a leading cause of adult disability worldwide, with post-stroke survivors often experiencing persistent motor deficits despite conventional physical therapy. AI applications including robotics, machine learning, computer vision, and telerehabilitation have the potential to augment traditional rehabilitation, improve assessment accuracy, optimize therapy delivery, and expand access to care. However, evidence on AI's clinical utility in stroke physical therapy is scattered across diverse domains, making it difficult for clinicians and policymakers to gain a coherent understanding of its scope, benefits, and limitations.

Objective: This scoping review aims to map and synthesize existing evidence on the applications,

effectiveness, and challenges of AI in stroke physical therapy and rehabilitation, while identifying emerging trends and gaps to inform clinical practice, research, and policy makers.
Methods: This review followed Arksey and O'Malley's five-stage framework (2005), refined by Levac et al. (2010), and was reported in accordance with PRISMA-ScR guidelines. A comprehensive search was conducted in PubMed/MEDLINE, PEDro, and Cochrane Library up to August 2025 using terms related to AI (e.g., machine learning, robotics, computer vision) and stroke rehabilitation. Eligible studies included quantitative, qualitative, mixed-methods research, and reviews involving post-stroke patients in physical therapy or rehabilitation contexts. Non-AI digital tools and purely technical studies without clinical relevance were excluded. Data were extracted for study design, AI applications (assessment, intervention, decision support), clinical outcomes, and barriers.
Results: Out of 245 records, 14 studies published between 2020–2025 met inclusion criteria. Evidence demonstrated that AI enhances *assessment and monitoring* through computer vision, wearable sensors, and predictive modeling, enabling automated gait analysis, motion tracking, and recovery forecasting. In *therapy delivery*, AI-powered robotics (e.g., Lokomat, MIT-Manus), virtual reality integration, and telerehabilitation platforms improved motor function, adherence, and patient engagement, while reducing therapist workload. *Decision support tools* applied AI algorithms for outcome prediction, patient stratification, and treatment optimization, supporting more personalized rehabilitation. Reported advantages included personalization, objectivity, scalability, efficiency, and increased patient motivation. However, barriers such as limited high-quality datasets, privacy concerns, high financial costs, insufficient infrastructure in low- and middle-income countries, algorithmic bias, and limited clinician training hinder widespread adoption. Emerging trends highlight hybrid models combining therapist-guided and AI-driven therapy, explainable AI to improve trust, integration with brain-computer interfaces, and home-based wearable systems tailored for resource-limited settings.
Conclusion: AI holds transformative potential in stroke rehabilitation by improving diagnostic accuracy, personalizing therapy, and extending access through robotics and digital platforms. While short-term studies report encouraging outcomes, large-scale clinical trials, cost-effectiveness analyses, and ethical evaluations are urgently needed. A hybrid rehabilitation model—integrating AI technologies with therapist expertise—appears most promising. Future research should prioritize patient-centered, context-specific approaches, particularly in low-resource settings, to ensure equitable, safe, and sustainable integration of AI into stroke physical therapy.

Keywords: Artificial Intelligence, Stroke, Physical Therapy, Rehabilitation, Machine Learning, Robotics, Scoping Review

Introduction

Digital technologies, Computers and modern-day application and software have revolutionized every aspect of human life. Their presence has become very important in homes, schools, and businesses. Research and development is increasingly focusing on creating advanced machines and automated systems, minimizing the need for human intervention(1). Within this context, Artificial Intelligence (AI) defined as the ability of a digital computer or computer-controlled robot to perform tasks typically associated with intelligent way, has become an irreplaceable part of our lives today. Like every field, Ai has successfully made its way into the healthcare(2). The COVID-19 pandemic has made people rely more on machines and technology in the medical field, emphasizing the need for automation to improve efficiency, accuracy,

and accessibility of care(3).Like every other medical field, AI has made its way into the field of physical therapy(4). In rehabilitation, AI is rapidly expanding its role. Machine learning algorithms, predictive analytics, and robotic-assisted systems are being developed to assist therapists in diagnosis, treatment planning, and ongoing patient monitoring (4, 5).

On the other hand stroke is a leading cause of adult disability worldwide, with millions of individuals affected annually(6). The sudden decrease in cerebral blood flow due to ischemic or hemorrhagic stroke often results in motor disabilities and impairments, particularly hemiparesis, which badly limits a the activities of daily living of a patient and restrict the individual to live independently(7, 8) Even though conservative and traditional rehabilitation concepts such as physical therapy and occupational therapy play a vital role in the rehabilitation of post-stroke patients(9) Majority of the post stroke patients experience persistent motor deficits, especially in the upper extremities(10) This highlights the urgent need to discover adjunctive and novel therapeutic interventions aimed at enhancing neuroplasticity and functional recovery in stroke patients.(11)AI leverages diverse sources such as medical literature, evidence-based guidelines, and patient data to support clinical decision-making and reduce human errors. Moreover, AI systems can generate clinical predictions based on patient input data, enabling more precise, personalized interventions.(12).The applications of AI in physiotherapy ranges from administrative tasks such as recordkeeping, billing, and appointment management to clinical processes including outcome prediction, diagnostic support, and individualized treatment planning (1, 4). In physiotherapy, AI systems can synthesize patient information—such as symptoms, medical history, diagnostic test results, and functional assessments—to support clinical decision-making (13). Ai learns in two ways i.e. supervised learning, where structured and labeled datasets guide predictive models, or unsupervised learning, where the system autonomously identifies hidden patterns in large volumes of unstructured data. These capabilities help physiotherapists to explore clinical questions, such as understanding why conditions like low back pain or early osteoarthritis etc. may have higher prevalence in specific populations(1, 5, 14). One of key strengths of AI is its predictive analysis, where large datasets are utilized by machines to forecast patient trajectories, estimate treatment responses, and identify risk factors for poor outcomes. It helps Physical therapists to personalize rehabilitation planning and early intervention of the patient ultimately improving care quality(12). Evidence of AI's utility in physiotherapy is growing. For example, a research conducted on healthy participants combining machine learning with a smartwatch to monitor them performing at-home rotator cuff exercises, showing that AI can simplify tracking of home exercise plans(3, 5).Similarly, a study compared an AI-powered digital sessions with conventional home-based rehabilitation in patients with knee osteoarthritis following total knee replacement (TKR) surgery (15) The AI intervention proved feasible and resulted in improved short- and medium-term functional outcomes The study concluded that AI intervention proved feasible, maximizing patient's outcome and reducing physical therapist workload.(1, 5, 12). Falling is a serious public health concern among older adults, especially those suffering from Alzheimer's disease. In 2020, research was conducted using convolutional neural network CNN, which is a useful AI technology to predict the falling time among Alzheimer's patients(16) It was found to be an ideal method in determining falling events in these patients and can be used in designing a customized approach based on the predicted time of fall(12, 17). AI also exhibits strong potential for predicting rehabilitation outcomes. A study was conducted demonstrating that Machine learning platforms have accurately predicted functional recovery in stroke patients (AUC = 0.94) and accurate prediction of long-term outcomes after

rehabilitation. All these findings highlight the use of AI in ongoing patient monitoring, individualized treatment optimization, and the provision of real-time decision support to physical therapists(12, 18).

Furthermore, AI applications in rehabilitation include robotic-assisted therapy, AI-powered gait analysis, virtual reality interventions, and predictive algorithms for patient progress specially in in patient with stroke(1). Despite all these opportunities, adoption of Artificial Intelligence in post stroke physical therapy and rehabilitation remains limited, especially in low- and middle-income countries. Due to barriers like insufficient clinician training, lack of institutional support, ethical concerns, and financial constraints(1). Evidence on AI in rehabilitation is dispersed across domains such as neuro physical therapy (NPT), musculoskeletal (MSK) conditions, cardiopulmonary rehabilitation, and geriatrics(19). making it difficult for clinicians and policymakers to form a coherent understanding of current applications and gaps.

This scoping review therefore aims to map the scope of evidence on AI in stroke physical therapy and rehabilitation, synthesize applications and outcomes, and highlight barriers and knowledge gaps. Unlike systematic reviews that answer narrow questions, a scoping review offers a broad overview of existing literature, guiding future systematic reviews, policy development, and clinical translation.

Methods

Framework

This scooping review is conducted as per Arksey & O'Malley's (2005) five-stage framework (20) refined by Levac et al. in 2010, and reported all the findings in line with PRISMA-ScR guidelines.

Eligibility Criteria

Population: Post stroke patients receiving physical therapy treatment or going through rehabilitation. Concept: Application of Artificial Intelligence (AI), including gait training, harness technologies, machine learning, deep learning, computer vision, robotics exoskeletons, and natural language processing. Context: stroke Physical therapy or Rehabilitation settings (hospital, outpatient, home-based, telehealth). Sources: Quantitative, qualitative, mixed-methods studies, and reviews; published in English language. Exclusions: Non-AI digital tools (e.g., standard telehealth without AI), purely technical studies without clinical relevance.

Search Strategy

Databases searched: PubMed/MEDLINE, PEDro and Cochrane Library (up to August 2025). Search terms combined:("artificial intelligence" OR "machine learning" OR "deep learning" OR "computer vision" OR "robotics") AND ("stroke physical therapy" OR "stroke physiotherapy" OR "stroke rehabilitation").A total of 245 studies were found through initial search by searching the above query string in PubMed database the results included 141 studies, PEDro 85 studies and Cochrane library 19.

Records identified through database searching (n = 245)

• PubMed (n=141)

• PEDro (n=85)

• Cochrane (n=19)

↓

Records after duplicates removed (n = 105)

↓

Records screened (title/abstract) (n =140)

↓

Full-text articles assessed for eligibility (n = 72)

↓

Studies included (n =14
After duplicates removal in the first step through online tool (n=245), titles and abstracts of 140 studies were screened, 68 were removed due to irrelevancy in different areas, followed by full texts screening of 72 studies, out of 72 studies this narrative review finally includes of 14 studies conducted between 2020 to 2025. Data were extracted and recorded for study design, AI in Assessment and Monitoring, AI in Intervention and Therapy Delivery, AI in Clinical Decision Support clinical domain, role in rehabilitation, and reported barriers. No risk-of-bias appraisal was performed, consistent with scoping review methodology.

Applications of AI from the included studies in Stroke Physical Therapy and rehabilitation

AI in Assessment and Monitoring: For effective and specific treatment it is needed that the assessment must be "Accurate assessment" which is essential for productive and effective stroke rehabilitation. Previously following Traditional methods like Fugl-Meyer Assessment, Berg Balance Scale are yet reliable but time consuming and require highly skilled therapists. In modern day AI offers automated, objective, and scalable solutions to all the issues in rehabilitation.

Computer vision–based analysis: Biomechanical activities or Motion tracking through digital cameras or smartphones can analyze gait, posture, and range of motion with minimal efforts and minimal equipment in very less time. On the other hand, Wearable sensors operated with AI is also Inertial measurement units (IMUs) integrated with ML algorithms which detect compensatory strategies, asymmetry in steps, and balance impairments. Predictive modeling: AI can provide prediction recovery routes, helping p rehab: clinicians personalize and make specific therapy goals. For example, ML models using clinical and imaging data predict motor recovery at 3–6 months post-stroke.

AI in Intervention and Therapy Delivery: AI just like a guide can enhance the process of rehabilitation by directing and making the therapy intensity, feedback, and personalization. Robot-assisted gait training (RAGT): Exoskeletons such as Lokomat, combined with AI systems, optimize gait training, manage the intensity and adaptability. Upper limb rehabilitation robots: AI Devices like MIT-Manus provide task-specific training, where AI monitors progress and adapts resistance levels. Virtual reality (VR) combined with AI is another task-oriented Computer vision and ML integrate into VR-based rehabilitation, providing immersive and adaptive exercises. Furthermore, Telerehabilitation platforms through AI chatbots and virtual assistants to guide patients remotely, ensuring adherence and tracking performances during rehabilitation process. AI is also very useful in Clinical Decision-making during assessment; AI tools assist therapists in making data extracted decisions during patient assessment. Rehabilitation outcome prediction (e.g., identifying who benefits most from which type of therapy. On the other hand Treatment optimization by analyzing large datasets to recommend exercise protocols is also the role of AI in rehabilitation of stroke. Stroke Patient stratification is also reported, based on severity and responsiveness to interventions in rehabilitation programs for stroke survivors.

Literature based Evidence: AI-based imaging technologies, like deep learning when combined and applied to CT and MRI scans, may bring improvement in early detection and timely diagnosis and identify ischemic shadow, enabling the clinicians in timely, personalized treatment. AI-based decision support systems can optimize acute stroke treatment, including thrombolysis and endovascular therapies.(21) In

motor rehabilitation, AI-powered robots and exoskeletons provide precise, adaptive assistance, while AI-augmented Virtual and Augmented Reality environments offer immersive, tailored recovery experiences.(22) Brain-Computer Interfaces use AI for neurological rehabilitation through processing of neural signal, which support recovery in motor rehabilitation.(23) Robotics & AI in Gait Training is also having Multiple RCTs which report improvement in walking speed, increase strength and endurance, and symmetry when AI-driven robotic training is integrated with conventional therapy(21) However, one recent systematic review suggested that outcomes are most significant when combined with therapist-supervised interventions.(24) in the Upper Limb Rehabilitation Studies indicated that AI-assisted robotic arms improve motor control with balance and coordination, particularly in chronic stroke survivors.(25) AI also have crucial role as assessment Tools, a study concluded that when an interpreted dataset is unavailable initially, the rule-based (RB) model can be used to assess post-the quality of movements in stroke patients which identify samples with low confidence scores to support effective interpretations for training machine learning (ML) models. As that system requires 22 - 33% of explanations from therapists to give input to an ML model. (26) one study validated that AI-powered smartphone motion capturing is equivalent to physical therapist-administered assessments for upper limb motions.(27) another aspect of integration AI in stroke rehabilitation is Telerehabilitation AI-based telerehabilitation platforms established improved adherence and satisfaction among stroke patients, as it reduce barriers to accessibility.(28) AI is also used as Predictive Models Several ML models in modern day technology accurately predicted functional recovery and rehabilitation with more than 80% accuracy, which highlights potentials for personalized rehabilitation program.(29)

Advantages of AI in Stroke Rehabilitation

Personalization, Tailors therapy intensity and goals to individual patients. Scalability, Extends rehabilitation access with the help of telerehabilitation and home-based AI tools. AI also play role in Objectivity, which Provides accurate, precise, real-time quantitative assessments. One advantage of AI integration in stroke rehabilitation is Efficiency, Reducing the therapist workload and administrative tasks in a rehabilitation program, Motivation is another main advantage of AI integrated VR and gamification, which improve patient engagement in rehabilitation protocols

Challenges and Barriers to AI: Despite the promising benefits, the reviewed studies also highlighted several barriers that hinder the effective integration of AI into physical therapy practice. Data-related challenges were among the most frequently reported, including limited availability of large, high-quality datasets and concerns regarding data privacy and security. Technical limitations such as algorithmic bias, lack of transparency in AI decision-making, and insufficient interoperability with existing clinical systems further reduced clinician trust and adoption. Financial constraints were another major barrier, as high costs associated with acquiring, maintaining, and updating AI and robotic systems remain prohibitive, particularly in resource-limited settings. In addition, contextual barriers such as inadequate infrastructure, poor internet connectivity, and disparities in access widened the digital divide, especially in low- and middle-income countries. Finally, human factors—including resistance from clinicians due to fear of reduced human touch, limited training in digital tools, and ethical concerns over patient autonomy emerged as critical obstacles. Collectively, these barriers emphasize that while AI has the potential to transform physical therapy, its implementation requires careful attention

to technical, economic, ethical, and contextual considerations. Data privacy and ethics, clinical validation and patient acceptance were also some of the reported barriers.

Emerging Trends and Future Directions: Hybrid rehabilitation models, Integration of AI with traditional therapist-guided therapy are highly needed and is the emerging trend in stroke rehabilitation. AI-driven neuroimaging analysis, Using MRI and EEG with ML to guide rehabilitation planning for stroke survivors is also emerging in rehabilitation of stroke. In under developed countries like Pakistan due to limited resources Home-based smart rehabilitation like Wearable AI systems that deliver therapy outside the clinical setups is recommended and is having promising benefits in previous researches, physical Therapy researchers are encouraged to dive deep into this area. Explainable AI (XAI) are Ensuring transparency in decision-making to improve clinician trust in stroke rehabilitation. Integration with Brain-Computer Interfaces (BCI) Using AI to decode the brain signals and support motor recovery among post stroke patients.

Conclusion: AI holds transformative potential in stroke physical therapy by improving assessment accuracy, personalizing interventions, and expanding access to rehabilitation through robotics and telerehabilitation. While evidence supports its effectiveness, barriers such as high cost, limited large-scale validation, and ethical concerns must be addressed. A hybrid approach, combining the expertise of physical therapists with AI-driven tools, represents the most promising future direction. Multidisciplinary collaboration, patient-centered design, and robust clinical trials will be essential for integrating AI into routine stroke rehabilitation practice.

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