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Historical Overview of the Emergence of Artificial Intelligence in Healthcare Rehabilitation

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Abstract
The aim of this review article is to provide a historical overview of the emergence of Artificial Intelligence (AI) within the field of physical rehabilitation. Over the past decades, AI has evolved from a theoretical concept into a practical tool applied in various medical fields. While its initial adoption in healthcare focused on diagnostics and data analysis, recent years have seen growing interest in rehabilitation medicine. Despite the growing body of work on AI in healthcare, few studies trace its historical trajectory into rehabilitation with a specific focus on regulatory and regional contexts. This article explores the historical milestones of AI development, its integration into rehabilitation practices, current applications in the European Union and Hungary, regulatory and ethical issues, and the potential directions for future advancement.

keywords: Artificial Intelligence, Rehabilitation, Healthcare Technology, Innovation, Historical Overview

Introduction
Artificial Intelligence (AI) has become one of the most transformative technologies in modern healthcare. From machine learning algorithms that assist in diagnostics to predictive analytics and intelligent robotic systems, AI has demonstrated its capacity to improve efficiency, accuracy, and patient outcomes. Among the many domains of healthcare, rehabilitation occupies a unique position. Rehabilitation is a long-term, patient-centered process aimed at restoring functional independence and improving quality of life after injury, illness, or disability.[1] Given its complexity, the integration of AI into rehabilitation represents both a challenge and an opportunity. To understand the current state of AI in physical rehabilitation, it is necessary to examine its historical roots, early applications, and future potential.

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Historical Overview of AI and Its Entry into Healthcare

The development of artificial intelligence is the result of a long evolutionary process built on the foundations of multiple scientific disciplines, including logic, statistics, cognitive psychology, decision theory, neuroscience, linguistics, cybernetics, and computer engineering.[2]

AI includes various techniques:

- AI (Artificial Intelligence): The study and implementation of intelligent behavior in machines, enabling problem-solving, decision-making, and learning.
- NLP (Natural Language Processing): A branch of AI that allows machines to understand, interpret, and generate human language.
- ML (Machine Learning): A part of AI where systems learn and improve autonomously from data without being explicitly programmed for every step.
- DL (Deep Learning): A subset of machine learning that uses deep neural networks to recognize complex patterns with minimal human intervention.
- LLM (Large Language Models): AI algorithms that use deep learning techniques and massive datasets to understand, summarize, generate, and predict new text-based content.[3]

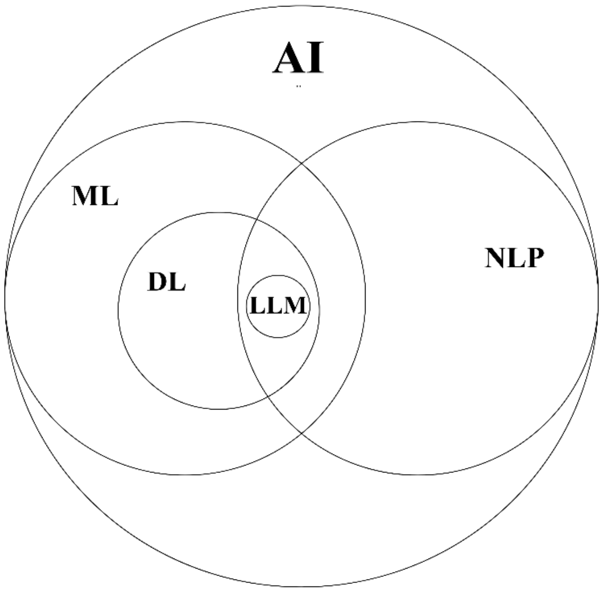

Figure 1. Artificial intelligence techniques.
Source: Authors' own compilation based on Alowais et al.[3]

The idea that a machine could think on a level equivalent to human intelligence emerged as early as the mid-19th century with Charles Babbage's invention of the mechanical computer, and later with Alan Turing's famous 1950 question: "Can machines think?". The term "artificial intelligence" was first introduced in 1956 at a research workshop held at Dartmouth College, where the AI problem was defined as creating a machine that behaves in a way considered intelligent if a human behaved similarly. This event signaled the start of the modern era of AI. The Turing Test, which serves as a benchmark for machine intelligence, examines whether a computer can produce responses indistinguishable from those of a human. To pass the full Turing Test, a machine needs capabilities such as natural language processing, knowledge representation, automated reasoning, machine learning, computer vision, and physical interaction.[2]

During this time, innovations used in the healthcare sector also appeared. In 1955, General Motors developed the first robotic arm. This was followed in 1964 by Eliza, the first chatbot, created by Joseph Weizenbaum at the MIT AI Laboratory. Eliza identified keywords in the input text and generated responses based on reassembly rules, allowing it to simulate a conversation with a human therapist. During the 1960s, AI research advanced rapidly, with one of its most notable achievements being Shakey - the first robot capable of understanding human instructions and performing actions accordingly.

Medical applications of AI began gaining traction in the 1970s with the creation of INTERNIST-1 in 1971, the first artificial medical consultant designed to generate clinical diagnoses from patient symptoms. This marked a major milestone, as it offered decision support for clinicians and enabled cross-checking of differential diagnoses. Recognizing AI's potential in medicine, the first AI in Medicine conference was held at Rutgers University, supported by the National Institutes of Health. Interdisciplinary collaboration further accelerated progress, leading to systems like MYCIN, which helped physicians select appropriate antibiotics for infectious diseases. In the 1980s, DXplain emerged at the University of Massachusetts, offering broader diagnostic capabilities than INTERNIST-1 and serving as an early medical information resource for clinicians.[4]

In the 1980s and 1990s, artificial intelligence research shifted to machine learning and neural networks, enabling machines to learn from data and improve their performance. During this period, systems such as IBM’s Deep Blue were developed, which defeated world chess champion Garry Kasparov in 1997. In the 2000s, AI research continued to advance, particularly in natural language processing and computer vision, leading to the development of virtual assistants like Apple’s Siri and Amazon’s Alexa, which could understand human language and fulfill user requests.[3] The modern era of AI began in the early 2000s, bringing significant advancements in healthcare and everyday life. In 2007, IBM introduced Watson, a question-answering system that outperformed top contestants on Jeopardy! by using DeepQA technology, which applied language processing to analyze diverse data sources and generate accurate answers. This innovation expanded AI’s role in healthcare beyond symptom-based diagnosis to more complex tasks; for instance, in 2017, Watson identified RNA-binding proteins linked to amyotrophic lateral sclerosis. New systems also emerged to enhance patient care, such as Pharmbot, developed in 2015 to educate patients and families about medications and treatment processes.[4]

ChatGPT, a conversational AI from OpenAI, was released in November 2022. Using deep learning and large language models (LLMs), it generates human-like text for tasks like customer service, content creation, translation, and coding. Its user base grew rapidly, reaching 100 million within two months.

In healthcare, ChatGPT’s user-friendly QA interface has attracted interest for medical education, consultation, diagnosis support, and clinical scenario simulations. Many studies

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have explored its use across specialties, noting both potential and ethical concerns, particularly around AI-based treatment decisions. However, these applications have only been tested in controlled, laboratory-like settings using exam questions, CSD alerts from Epic EHR, or clinical vignettes from Merck Sharpe & Dohme (MSD), with no real-world clinical deployment reported.

Overall, ChatGPT's out-of-the-box performance in healthcare is moderate and does not meet high clinical standards. While it can provide accurate information in areas like cancer, this cannot be generalized. Its use in research remains experimental due to ethical issues and inability to generate novel topics. Specialization, standardized evaluation, and objective, automated metrics are needed for clinical integration. A professional, specialty-focused version shows promise but requires further development and validation.[5]

Today, AI research focuses on two main branches: narrow AI, which is specialized for specific tasks, and artificial general intelligence (AGI), which aims to fully replicate human thinking-though the latter is still decades away. For now, the rapid advancement of narrow AI is delivering intelligent systems and applications that are transforming daily life and industry.[2] AI is increasingly transforming sectors like healthcare, finance, and transportation. In education, it powers intelligent tutoring systems that adapt to individual students, improving learning outcomes in subjects such as math and science. In research, AI analyzes large datasets to uncover patterns, driving advances in genomics and drug discovery. In healthcare, it supports diagnostic tools and personalized treatments. As AI develops, responsible use for the benefit of all is essential.[3]

However, the previously mentioned early tools were confined to research settings and lacked widespread clinical adoption due to technological limitations and skepticism among healthcare professionals.

AI's transformative impact on healthcare is highlighted across several domains. In diagnostics, AI enhances early disease detection by analyzing medical images and electronic health records, identifying subtle patterns that may elude human clinicians. In clinical decision support, AI systems assist healthcare professionals by providing evidence-based recommendations, improving decision-making processes and patient outcomes. For population health management, AI analyzes large datasets to identify health trends and predict disease outbreaks, enabling proactive interventions. Regarding personalized treatment plans, AI tailors therapies to individual patients by considering genetic, environmental, and lifestyle factors, leading to more effective and targeted treatments. These applications underscore AI's potential to enhance efficiency, accuracy, and personalization in healthcare delivery.[3 6]

Period	**Milestone**	**Significance for Healthcare**
1960s	ELIZA chatbot	Early natural language interaction; precursor to therapeutic dialogue
1970s	INTERNIST-1, MYCIN	First medical expert systems for diagnosis and antibiotic selection
1980s	DXplain system	Expanded AI-based clinical decision support

Period	Milestone	Significance for Healthcare
1990s	Early rehabilitation robotics	Robotic exoskeletons introduced for motor recovery
2000s	Virtual assistants (Siri, Alexa)	NLP progress enabling conversational healthcare tools
2007	IBM Watson	AI for medical knowledge processing and clinical decision-making
2012	Deep learning breakthrough (AlexNet, ImageNet win)	Revolutionized image analysis; basis for modern medical imaging AI
2010s	AI in imaging, early telerehabilitation prototypes	Widespread use in diagnostics; foundation for remote rehabilitation
2015	Pharmbot introduced	AI system educating patients about medications
2018	First FDA-cleared AI systems for healthcare	Marked regulatory acceptance for AI in clinical practice
2020	COVID-19 pandemic	Accelerated telehealth and AI-driven telerehabilitation adoption
2020s	AI-powered rehab apps, wearables, robotics	Personalized, data-driven rehabilitation with remote monitoring
2022	ChatGPT	Assists in diagnostics, education, and research
2024	EU AI Act adopted	First binding regulatory framework for AI in healthcare

Table 1. Milestones of AI development in healthcare.
Source: Authors' own compilation.

AI in Rehabilitation: Past, Present, and Future

Past:

1. Early Innovative Applications in Rehabilitation

AI entered the field of rehabilitation relatively late compared to other areas of medicine. Early efforts primarily focused on assistive technologies for individuals with disabilities, as well as the development of expert systems to support therapy planning. At the same time, simple robotic devices were introduced, aimed at improving motor function recovery.

In the 1990s, the first generation of rehabilitation robotics emerged, driven by advances in mechatronics and computer control. Early devices, including robotic exoskeletons, were mainly developed for motor rehabilitation in stroke patients. While promising, their clinical adoption was limited by high costs and a lack of strong evidence demonstrating superior outcomes compared to conventional therapy.

Traditional rehabilitation relied heavily on the expertise of therapists, and their assessments were often subjective and not quantitatively tracked, which significantly reduced the ability to objectively evaluate intervention effectiveness.

2. Technological Advances and Digital Rehabilitation

Over the following two decades, technological advances, such as telerehabilitation and digital monitoring tools, gradually overcame barriers related to accessibility and adherence to home exercise programs. Robotic exoskeletons showed encouraging results in upper-

limb and motor rehabilitation; however, many designs remained at the prototype stage, and the lack of full clinical trials limited their routine clinical use.[7 8]
These early developments laid the foundation for integrating AI into rehabilitation robotics, enabling more precise assessment, personalized therapy, and improved usability, while inspiring the design of lighter, more portable, and ergonomically optimized systems.[9]
Despite these advancements, AI adoption in physical rehabilitation remains limited due to challenges related to usability, perceived usefulness, and cost. Most evidence still comes from retrospective "proof of concept" studies, with relatively few prospective clinical evaluations.[7 8]

3. Data-Driven and Personalized Rehabilitation

With the rise of digital medicine and portable technology, vastly more data became available, enabling a better understanding of the time course of disease and recovery across diverse patient cases. AI tools are increasingly capable of learning from large and complex datasets, allowing clinicians and researchers to extract new insights from the vast amounts of patient data collected daily.
In rehabilitation medicine, AI can identify patterns within these extensive datasets, which can then be applied at the individual level to design personalized care strategies and interventions. This approach allows rehabilitation programs to be tailored to each patient's specific needs and progress, optimizing treatment outcomes.[10]

Present:

AI-Based Systems in Physical Rehabilitation

AI technologies are increasingly used in physical rehabilitation, enabling personalized treatments, remote monitoring, and improved therapy efficiency.

- **App-Based Systems, Monitoring**
  App-based interventions offer accessibility, ease of use for tech-literate users, and personalized exercise programs. Studies report that app instructions are easier to follow than verbal guidance, and integration with existing messaging apps can enhance usability. Apps reduce manpower needs as they can operate autonomously, and data privacy concerns can be mitigated by storing data locally on patients' devices. Barriers include low technological literacy, especially among older adults, inability to verify exercise completion, device battery demands, and contextual limitations of tailored recommendations. [7, 11, 12, 13,]
  Hybrid rehab apps fuse IMU (Inertial Measurement Unit), PPG (Photoplethysmography), and camera streams with FHIR-compliant data layers, while reinforcement learning adapts exercise intensity and feedback to fatigue and adherence signals. Privacy-preserving federated learning sustains model performance across heterogeneous clinics without centralizing patient data, enabling scalable tele-rehabilitation. Recent studies recommend applying DECIDE-AI for early real-world evaluations and reporting predictive modules with TRIPOD+AI to support calibration, drift monitoring, and external validity. [14,15]

- **Robotics for Function Replacement**
  Prosthetic and limb-replacement robotics support functional training, gradually increasing degrees of freedom to transition from direct control to AI-driven systems.

Barriers include prosthesis fit, material choice affecting electrode contact and durability, technical limitations, lack of portability, need for calibration, and fatigue from overuse. [7 11 12 13] Deep models for myoelectric control (CNN/RNN and hybrids) lower intent-recognition latency and improve robustness for multi-DOF prosthetic manipulation. Edge inference reduces cloud dependency and network jitter, improving portability and reliability in community settings. Self-calibrating controllers that update electrode mapping and torque policies help counter electrode drift and muscle fatigue during long-term use.[16]

- **Robotics for Function Restoration**
  Adaptive robotic orthoses and intelligent treadmills improve usability and patient preference compared to fixed-pattern systems. EMG-based systems receive high usability ratings for clarity, comfort, and effectiveness, with no significant implementation barriers reported. [7, 11, 12, 13,]
  Studies recommend visual encodings that expose assistance-as-needed curves, gait-phase timing, and stride-level torque as synchronized overlays with uncertainty bands and stride heatmaps for rapid interpretation. Research describes 3D digital twins that replay EMG and IMU streams with controller actions to enable what-if simulations and safe parameter tuning without interrupting therapy. Evaluation work recommends logging SUS, NASA-TLX, and task-completion delta together with calibration and drift traces to relate controller behavior to workload and safety. For deployment, studies recommend FHIR-compatible data flows and cohort-benchmarked dashboards that quantify benefit versus assistance burden over time.[17]

- **Gaming Systems**
  Game-based rehabilitation is low-cost, highly usable, and flexible, leveraging commercial hardware like Kinect. Systems allow remote monitoring and objective progress assessment, while patients find exercises engaging and appropriately challenging through gamification and virtual reality. Barriers include latency-related motion sickness, fatigue, unclear visuals, and desire for greater personalization.
  Studies recommend latency-aware interfaces that surface frame pacing, motion-prediction windows, and clear progress overlays to reduce visual load during VR and exergames. Research describes adaptive difficulty controllers that tune task complexity and repetition counts from real-time kinematics and fatigue proxies, while dashboards show adherence and motor performance with uncertainty bands and weekly trendlines. Reviews also report cohort-benchmarked goals, session heatmaps, and configurable rendering parameters that personalize challenge and mitigate cybersickness. Prototype toolchains add 3D replays of key segments for remote review and rapid iteration of game rules and sensor thresholds. [13, 18,]

- **Wearable Activity Monitoring**
  Wearables such as smartwatches, IMUs, and accelerometers provide portability, comfort, low cost, and complex data analysis. When integrated with telerehabilitation, they improve patient satisfaction and reduce consultation times. Limitations include sensor type and number, discomfort, battery life, connectivity issues, poor compliance, and inability to verify exercise accuracy.[7 11 12 13]

Self-supervised pretraining on large unlabeled wearable datasets improves generalization and enables patient-level personalization without heavy manual labeling. Active learning pipelines prompt brief in-app confirmations only when uncertainty is high, reducing annotation effort and improving recognition around clinically relevant transitions. Validated non-wear detection that fuses acceleration with skin temperature marks off-wrist intervals on the timeline so clinicians can interpret gaps and avoid bias in outcome metrics.[19]

- **Clinical Tool – supporting decision-making**
  Large language models are increasingly being explored in rehabilitation medicine as tools to address the complexity of treatment planning, outcome assessment, and data integration. According to Bonnechère, rehabilitation is often described as a "black box," due to its reliance on patient-specific characteristics, varied interventions, and subjective outcome measures. LLMs can help open this "black box" by analyzing large and diverse datasets, improving the standardization of clinical language, and supporting evidence-based decision making. Their applications range from predicting outcomes such as length of stay or readmission, to assisting in treatment personalization, automating documentation, improving patient-provider communication, and even generating rehabilitation prescriptions. They also support translational research by enhancing reproducibility, enabling more nuanced evaluations, and facilitating the integration of rehabilomics data. While they hold promise for making rehabilitation more precise, cost-effective, and patient-centered, LLMs remain supplementary tools: challenges such as bias, contextual limitations, ethical concerns, and the need for validation underscore the necessity of close collaboration between clinicians, researchers, and AI specialists.[20]

  From a visualization and AI-engineering stance, RAG-powered evidence panels that show sentence-level citations and guideline snippets next to each recommendation, enabling rapid provenance checks before any EHR write-back. Research reports uncertainty-first dashboards that combine reliability diagrams, prediction intervals, and adjustable thresholds with disaggregated subgroup performance to surface bias and dataset shift at the point of use. Visual analytics frameworks add interaction logs, case-based retrieval galleries, and counterfactual probes so teams can test how different inputs or references would change an LLM suggestion and keep a reproducible audit trail. Evaluations also note that concise, task-anchored explanations improve clinician trust compared with raw model internals, so interfaces favor short rationales and context cues over dense attributions.[21] [22] [23]

- **Medical Education**
  Artificial intelligence is becoming an important tool in medical education and mentoring within rehabilitation medicine, offering new ways to address challenges such as limited mentor availability, geographic barriers, and time constraints. Silver and their colleagues describe how AI can support teaching, feedback, and professional development through three main models: expert systems, conversational agents, and hybrid approaches. Expert systems provide specialized, field-specific guidance; conversational agents enable interactive, natural language–based learning and feedback; and hybrid models combine AI efficiency with human empathy and

contextual understanding. In rehabilitation, these applications include teaching clinical procedures, creating personalized rehabilitation plans, enhancing anatomy training, and supporting stroke rehabilitation through AI-driven assessments. AI mentoring platforms also broaden access to guidance, improve mentor–mentee matching, and allow for continuous, adaptive feedback. While ethical challenges such as bias, data privacy, and academic integrity remain, integrating AI into medical education and mentoring offers scalable, personalized, and flexible support for trainees. Crucially, AI is not positioned to replace human mentors but to complement them, enhancing accessibility and enriching the learning experience in physical medicine and rehabilitation.[24]

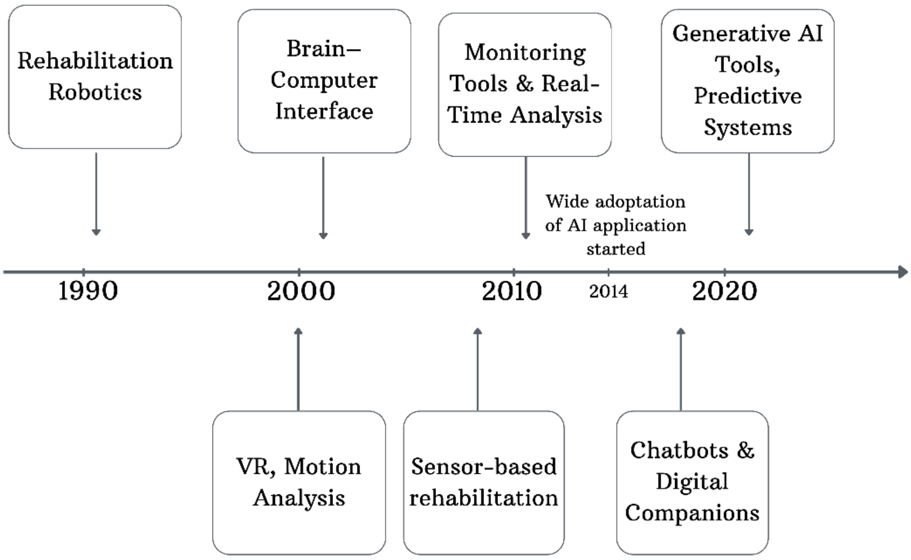

Figure 2. Milestones of AI development in healthcare rehabilitation.
Source: Authors' own compilation based on Senadheera et al.[12]

AI-supported physical rehabilitation increasingly relies on data-driven approaches to enhance patient care. Wearable sensors, robotic devices, and app-based systems generate large volumes of data on movement patterns, physiological signals, and patient engagement. By applying data science and machine learning techniques to these datasets, clinicians can identify subtle trends, personalize exercise programs, and predict functional recovery more accurately. Data analytics also enable objective monitoring of progress over time, optimizing interventions and supporting remote rehabilitation. However, challenges such as data quality, integration from multiple sources, and ensuring interpretability for clinicians and patients remain critical for the successful implementation of AI-driven, data-informed rehabilitation strategies.[7 11 12 13]

Extending these models, visualization-centric training pipelines pair XR scenes with live performance overlays, session replays, and compact progress indicators so mentors and trainees can review skills in context. Uncertainty-aware dashboards add reliability diagrams, confidence intervals, and subgroup drilldowns to track mastery and surface bias during formative assessment. Digital-twin scenarios enable safe rehearsal with telemetry playback

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and counterfactual tweaks, while acceptance studies emphasize clear UI cues and structured feedback to sustain engagement and transfer. [25] [26] [27]

Regulatory and Ethical Considerations

The integration of AI into rehabilitation does not only involve technical innovation; it also requires robust regulatory and ethical frameworks. In the European Union, the proposed AI Act seeks to classify medical AI systems according to risk, imposing strict requirements for transparency, accountability, and human oversight. Rehabilitation technologies often fall under the category of high-risk medical devices, necessitating compliance with the Medical Device Regulation (MDR). Ethical concerns include data privacy, algorithmic bias, and the potential for reduced human contact in therapy. Addressing these issues is essential for building trust and ensuring patient safety.

Since April 2021, EU legislators have worked on establishing a binding legal framework for AI systems, culminating in the Artificial Intelligence Act, published in July 2024 and entering into force in August 2024. Full applicability is expected by August 2027, with initial compliance requirements starting in February 2025. The AI Act represents the world's first comprehensive legal framework for AI, aiming to promote human-centred, trustworthy AI while protecting health, safety, and fundamental rights. It sets harmonised rules for the development, marketing, deployment, and use of AI systems and applies broadly – including extraterritorially to providers whose AI outputs are used in the EU.

For healthcare, the Act addresses a regulatory gap not covered by the Medical Device Regulation or In Vitro Diagnostic Medical Device Regulation (IVDR), which govern medical devices but do not explicitly cover AI applications or general-purpose models like large language models. Its provisions affect developers, providers, healthcare professionals, and patients, outlining obligations and safeguards to ensure safe and responsible AI implementation. While its horizontal approach limits its ability to address healthcare-specific needs fully, the Act sets a global benchmark through the "Brussels Effect," influencing AI developers worldwide. As AI adoption in healthcare grows, clear standards for development and use become increasingly urgent to prevent harm, support innovation, and improve patient care.[28] [29]

A major barrier to clinical adoption of AI-based rehabilitation tools is the lack of standardized benchmarks and evaluation frameworks, but also the limited readiness for compliance with the EU AI Act, highlighting the urgent need for strategic planning, awareness, and alignment with emerging regulatory and benchmarking initiatives. Most AI rehabilitation solutions are validated in isolated or small-scale research contexts, making cross-comparison and broader implementation difficult. Efforts like the ITU-WHO Focus Group on AI for Health have begun establishing international benchmarking protocols to assess healthcare AI systems accurately, which is a critical step toward regulatory acceptance and widespread deployment. [30] [31] [32]

Explainable AI (XAI) is vital in rehabilitation to foster clinical trust and accountability. Advanced AI models often function as "black boxes," making it hard for clinicians to understand the rationale behind recommendations. XAI frameworks address this by providing interpretable explanations - such as visual or textual rationales - thereby enabling clinicians to evaluate and trust AI outputs. Research confirms that explainability enhances willingness to use AI in clinical settings and supports safer, more informed decision-making.[33]

Beyond transparency, data privacy and the digital divide pose significant ethical challenges in AI-enhanced rehabilitation. These systems often depend on sensitive personal data collected via wearables, sensors, or telehealth platforms, raising concerns about breaches and misuse. Moreover, unequal access to stable internet and digital literacy risks marginalizing rural, low-income, or elderly populations. Studies have documented that such disparities limit the readiness for telerehabilitation among these groups.[34]

Current State in the EU

Artificial intelligence is increasingly transforming rehabilitation practices across Europe, enhancing patient care, personalising treatments, and improving accessibility. The European Union emphasizes safety, ethical use, and sustainability in the application of AI in healthcare, while aiming to establish a leading role on the global stage. AI is already present in practice across numerous areas: it supports imaging and diagnostics, enables personalized medicine based on patients' genetic and clinical data, accelerates drug development, and optimizes healthcare data management through the European Health Data Space (EHDS). EU legislation and initiatives - such as the AI Act, the European AI Board, the EHDS, the Product Liability Directive, and the AICare@EU program - ensure reliable, transparent, and internationally coordinated AI development, while supporting clinical integration, automation of administration, resource optimization, and innovation. The EU strengthens its competitiveness and international cooperation at the WHO, OECD, G7, and G20 levels through significant investments of €200 billion.

Current State in Hungary

In Hungary, several rehabilitation centers have begun incorporating robotic devices for motor recovery and telerehabilitation platforms, although full-scale integration remains limited due to cost and infrastructure challenges. In Hungary, robot-assisted therapeutic devices are the most widespread tools used in rehabilitation. They are commonly implemented across clinics and rehabilitation centers to support motor function recovery, improve gait and balance, and complement conventional therapy. While not all of these systems incorporate artificial intelligence, their use is the predominant method for delivering advanced, technology-assisted rehabilitation. However, explicit AI-based technologies in rehabilitation are still in their infancy in Hungary. Several factors contribute to this, including limited funding specifically for AI research in healthcare, regulatory and data privacy challenges, the need for large, high-quality datasets to train AI models, and a general cautious approach among clinicians toward adopting fully autonomous AI systems in patient care. As a result, while AI shows great potential for personalized therapy and home-based rehabilitation, its practical deployment remains limited compared to robot-assisted tools.

For example, at Széchenyi István University in Győr, researchers have developed an AI-powered system that allows patients to perform rehabilitation exercises at home. The system evaluates the accuracy of movements and provides detailed progress reports to the treating physician. This development, part of the project, is a collaboration between Széchenyi István University and Semmelweis University, highlighting the integration of AI into clinical rehabilitation practices.

In terms of domestic legislation, Hungary plans to allow access to health data for AI developers starting from January 2026, including data from the EESZT platform. This step aligns with the EU's European Health Data Space initiative, which aims to enable the secure and structured sharing of health data for research, innovation, and clinical applications. The access is based on the amendment of Act XLVII of 1997 on Health Data Processing, as amended by Act XXIX of 2024.

While the articles provide an extensive overview of various AI prototypes and experimental rehabilitation systems, they offer limited discussion of their clinical impact. Specifically, preliminary evidence exists, but robust, high-quality trials are scarcely presented regarding how these AI-based interventions translate into measurable improvements in patient outcomes. Key questions remain unanswered, such as whether these systems enhance functional recovery, reduce rehabilitation time, or improve quality of life compared to conventional therapy. Rigorous, controlled clinical trials are essential to validate the efficacy of these technologies and to determine which patient populations might benefit most. Without such evidence, the promise of AI in rehabilitation remains largely theoretical.

Future Perspectives:

Looking ahead, AI in rehabilitation is expected to move toward greater personalization and integration. Emerging trends include adaptive algorithms that tailor therapy intensity in real time, AI-driven prosthetics that interact with the nervous system, and advanced brain–computer interfaces for patients with severe motor impairments. Additionally, the combination of big data analytics and wearable sensors will allow continuous, home-based rehabilitation with remote clinician oversight.[7] [35] [36] However, these developments raise important questions regarding safety, accessibility, and equitable distribution across healthcare systems.

In response to the time, distance, cost, and accessibility limitations of rehabilitation services, new solutions have emerged, such as live communication channels where professionals remotely guide patients, as well as more advanced systems based on sensors and ICT technologies, complemented by artificial intelligence algorithms. AI plays a key role in shaping a decentralized rehabilitation model, supporting clinical decision-making and the monitoring of health outcomes. In recent years, numerous AI-based methods and solutions have been developed to enable assisted physical therapy and assessments with minimal supervision, even in home settings. AI-driven applications are expected to transform decentralized rehabilitation services by enabling widespread access to continuous, high-quality therapy.[37]

The future of rehabilitation lies in hybrid intelligence - a model in which clinicians and AI systems work as partners rather than competitors. While AI excels at analyzing large datasets and predicting outcomes, human expertise remains essential for nuanced decision-making, empathy, and ethical judgment. This synergy ensures that treatments remain patient-centered, trustworthy, and adaptive - even as technology scales.[38]

Future systems will pair patient-specific digital twins with foundation models for physiological time series to deliver on-device, real-time therapy adaptation, with interfaces that visualize calibrated uncertainty, drift alerts, and provenance for clinician oversight. Ambient sensing will extend beyond wrist devices through smart acoustic textiles and sensory-interactive fibers, while room-scale mmWave radar provides camera-free gait analytics; UI stacks will surface battery-aware sampling, confidence badges, and drift alerts to keep home programs reliable and private. Immersive training and telerehabilitation will move from canned 3D scenes to photoreal volumetric content powered by Gaussian splatting and neural radiance techniques, enabling precise spatial feedback and safe what-if replays of difficult maneuvers. Immersive rehab training will shift from canned scenes to photoreal volumetric content powered by Gaussian splatting, delivering real-time anatomy and "what-if" replays in XR and hybrid apps without vendor lock-in. Hybrid apps will render the same scenes in headsets or browsers, using standardized component libraries and WebXR to avoid vendor lock-in while keeping analytics consistent across devices. Neurotechnology will emphasize co-adaptive human-AI control. Noninvasive BCIs already demonstrate finger-level decoding for robotic effectors, suggesting near-term assistive channels for training and assessment when paired with transparent intent visualizations and safety interlocks. [39] [40] [41] [42]

Conclusion

The historical trajectory of artificial intelligence in rehabilitation reflects more than a technological evolution - it marks a paradigm shift in how recovery is conceived, delivered, and experienced. From the early days of rule-based systems and rudimentary robotics to today's data-driven, patient-tailored interventions, AI has transformed rehabilitation from a largely manual process into a domain of precision and adaptability. Yet, progress has not been linear; the journey has been shaped by scientific breakthroughs, regulatory debates, and the constant negotiation between human expertise and machine intelligence. The current landscape, especially within the EU and Hungary, demonstrates both the promise and the practical constraints of implementation, reminding us that innovation alone does not guarantee adoption. Looking forward, the challenge is not merely to build smarter algorithms or sleeker devices, but to ensure that these tools integrate seamlessly into clinical workflows, remain ethically grounded, and enhance - not replace - the therapeutic alliance. In this sense, the future of rehabilitation will not be defined by technology alone, but by a balanced collaboration where human empathy and artificial intelligence evolve together toward better patient outcomes.

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