MAK HILL Publications Research Journal of Medical Sciences

Review Article
doi: 10.36478/makrjms.2024.12.399.412

Role and Scope of Artificial Intelligence in Physiotherapy: A Literature Review

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ABSTRACT

The Industrial Revolution, around 200 years ago, marked a significant shift in human social and economic development. It introduced technological advancements, increased energy production and machine power, enhancing human and animal labor. This transformation improved quality of life and societal levels. Today, artificial intelligence is transforming human cognition, leading to profound social and economic changes similar to the Industrial Revolution. Unlike previous technologies that largely automated manual tasks, AI introduces the ability to learn, adapt and make predictive decisions based on large data set, making it a fundamentally different force in healthcare. Traditional tools and machines operate through predefined instructions, while AI systems, particularly those utilizing machine learning and deep learning, can improve their performance over time through experience. This self-learning capability allows AI to identify patterns, make inferences and even suggest personalized interventions tailored to individual patient data. For example, in radiology, AI-powered imaging analysis can detect minute anomalies in scans that may be overlooked by the human eye, thus aiding in early diagnosis and potentially improving patient outcomes. In oncology, AI assists in identifying effective treatment combinations for cancer patients by analyzing data from thousands of clinical cases and scientific publications. Additionally, predictive AI models are being used in preventive healthcare to identify patients at high risk of chronic conditions, enabling early intervention strategies. These advancements are mirrored in physiotherapy, where AI has started to support patient rehabilitation through personalized exercise recommendations, real-time movement analysis and even virtual assistance for at-home therapy. By bridging data analysis and patient care, AI represents a new frontier in healthcare, offering precision, scalability and accessibility that were previously unattainable with conventional technologies. This review seeks to highlight the principal discoveries and consequences associated with the application of artificial intelligence (AI) in the field of physiotherapy. This review analyzed 26 articles on AI's use in physiotherapy, focusing on machine learning, rehabilitation, patient care and physiotherapy education, using search strategies from PubMed, Cochrane, PEDro and Goggle Scholar. Twenty-six articles were identified using the mentioned search strategy and methodology across various databases. These articles were thoroughly screened to evaluate the use of AI in physiotherapy for different conditions. This study concludes that innovations in the health system are being significantly driven by artificial intelligence. AI should be employed as a complementary tool to support physiotherapists rather than replace them. The future of physiotherapy practice and education involves embracing and utilizing AI. To enhance patient care and maintain professional integrity, it is crucial to understand the complexities of AI, including its strengths, limitations and practical applications.

OPEN ACCESS

Key Words
Artificial intelligence, physiotherapy, rehabilitation, patient care

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Received: 20 August 2024
Accepted: 26 November 2024
Published: 29 November 2024

Citation: Jigisha Vaniya, Nensi Vaibhav Gandhi, Kinjal Priyesh Patel, Chaitali Bhatt and Komal Preet Kaur, 2024. Role and Scope of Artificial Intelligence in Physiotherapy: A Literature Review. Res. J. Med. Sci., 18: 399-412, doi: 10.36478/makrjms.2024.12.399.412

INTRODUCTION

The Industrial Revolution, 200 years ago, revolutionized human social and economic development with technological advancements and machine power. In the 21st century, artificial intelligence (AI) is a pivotal moment, transforming social and economic aspects. AI, a multidisciplinary field, enhances system training and prediction capabilities and modern technologies like sensors and GPS enable system perception and location[1-3]. AI has improved clinical decision-making, but ethical considerations are crucial for low- and middle-income countries. Designing systems that provide insights, support decision-making, minimize risks and protect personal data is essential[4,5]. AI-driven technologies are revolutionizing clinical practice and physiotherapy education, equipping professionals for a healthcare system suited to the 21st century. Machine learning, supervised learning and deep learning are key tools in physiotherapy, with predictive modeling and catboat systems guiding patients through rehabilitation. However, concerns about privacy and confidentiality raise ethical issues. Integrating AI into physiotherapy practice and education is a next-generation movement, requiring clinicians to develop skills beyond machine learning algorithms, such as empathy, teamwork, creativity and ethics[6-8]. AI is revolutionizing healthcare by analyzing data, predicting outcomes and personalizing treatments. However, ethical concerns must be addressed, patient data protected and human elements like empathy and creativity maintained. This prepares a new generation of healthcare professionals[9,10].

MATERIALS AND METHODS

This review aims to explore the integration of Artificial Intelligence (AI) in physiotherapy, rehabilitation and patient care. The review focuses on machine learning applications within the context of physiotherapy education and rehabilitation processes, assessing their impact on clinical practices and patient outcomes.

Search Strategy: The search strategy employed in this review includes the retrieval of relevant literature from multiple scientific sources. Eligible studies were identified through meta-analyses, systematic reviews, randomized controlled trials (RCTs), cross-sectional studies, pilot studies, feasibility studies and narrative syntheses. Key sources were sourced from the following databases: PubMed, Cochrane Library, Pedro, Science Direct and Google Scholar. Keywords used for the search include “artificial intelligence,” “machine learning,” “physiotherapy,” “rehabilitation,” “patient care” and “physiotherapy education.”

Inclusion Criteria:

- Articles must focus on the application of artificial intelligence in physiotherapy or rehabilitation.
- Studies must be published in peer-reviewed, English-language scientific journals.
- Full-text articles must be accessible for review.
- Only studies published after the year 2000 were considered.
- Studies must investigate AI-based interventions, systems, or tools within the context of physiotherapy.
- practice, education, or patient outcomes.

Exclusion Criteria:

- Articles not published in the English language.
- Studies without full-text availability.
- Articles published before 2000.
- Articles that do not focus on AI applications within physiotherapy or rehabilitation settings.

Study Selection and Quality Assessment: Each study identified through the search strategy was assessed for relevance based on the inclusion and exclusion criteria. Studies that met these criteria were further evaluated for methodological rigor, including the design, sample size, outcome measures and AI-related methodologies. The quality of the studies was assessed using standardized tools, including the Cochrane Risk of Bias Tool for RCTs and the ROBINS-I tool for non -randomized studies. Only studies deemed to have moderate to high quality were included in the final review.

Data Synthesis: A narrative synthesis approach was employed to summarize the findings of the selected studies, providing an overview of AI applications, their effectiveness in rehabilitation and implications for physiotherapy education. Where applicable, data from randomized controlled trials were quantitatively synthesized to assess the impact of AI on clinical outcomes in rehabilitation.

Related Work and Analysis: A total of twenty-six articles were located through a strategic search term approach across multiple databases. The researchers conducted a thorough screening of these articles to investigate the application of Artificial Intelligence in the field of physiotherapy. The reviewed articles explore various applications of Artificial Intelligence (AI) and Machine Learning (ML) in physiotherapy and related healthcare practices. Collectively, they highlight the potential of AI to transform clinical and rehabilitation outcomes, particularly through enhanced diagnostics, personalized treatment and data-driven

Table 1: Synthesis of Reviewed Articles

Sr. No.	Article	Type	Objective	Result	Conclusion
1	Role and Scope of Artificial Intelligence in Physiotherapy: A Literature Review	Scientific Literature Review	To examine the influence of AI technologies on physiotherapy and the educational adjustments needed for professionals.	Integrating AI literacy into core curricula fosters creativity and adaptability, enabling future therapists to effectively collaborate with AI and strengthen their unique skills.	Educators must provide disciplinary expertise, personalized learning and emotional connections to support students in an AI-driven healthcare environment.
2	Physical Therapists' Knowledge and Attitudes on AI in Healthcare and Rehabilitation	Cross-sectional Study	To investigate PTs' knowledge and attitudes on AI applications in rehabilitation.	PTs have lower awareness of AI in rehabilitation, with factors like gender, experience and education influencing knowledge levels.	AI can enhance physical therapy, but knowledge gaps among PTs highlight the need for further education and training in AI applications.
3	Facilitators and Barriers of AI Applications in Rehabilitation	Mixed-Methods Approach	To explore factors that impact AI adoption in rehabilitation.	Limited AI knowledge among PTs, with cost and resources as major barriers., nonacademic status, seniority and education level are significant predictors of AI knowledge.	AI adoption is hindered by costs and limited experience among PTs, suggesting a need for improved access to resources and training.
4	Medical Students' Attitudes Towards AI: A Multicenter Survey	Multicenter Survey	To assess attitudes of medical students towards AI in radiology and medicine.	52% of 263 students were aware of AI in radiology, 83% believed it could detect pathologies and most thought AI would transform radiology, though not replace humans.	Students recognize AI's role in medicine but doubt full automation., radiology should lead in educating about AI'sapplications.
5	Knowledge and Attitudes of Physical Therapists on AI in Healthcare and Rehabilitation	Cross-sectional Study	To examine PTs' knowledge and perceptions of AI in healthcare.	Findings mirrored those in other studies, highlighting limited knowledge of AI applications among PTs.	Increased AI knowledge is necessary for PTs to effectively integrate AI technologies into their practices.
6	AI in Pediatric Physiotherapy Practice: Past, Present and Future	Systematic Review	To assess AI's impact on pediatric physiotherapy outcomes and potential educational improvements.	Advocates for professional growth frameworks to equip practitioners with skills and adaptability for a rapidly evolving workplace.	AI can optimize pediatric physiotherapy highlighting the need for updated training and education frame works for professionals.
7	AI and ML in Clinical Practice and Physiotherapy	Literature Overview	To discuss AI and ML's potential impacts on clinical and physiotherapy practices.	Emphasizes human connection and innovative solutions in tasks AI cannot replicate, asserting that research regulation is crucial for AI integration.	Adapting education and practice to AI-enhanced systems will improve healthcare delivery and professional competency.
8	Implications of AI for Physiotherapy Education	Conceptual Discussion	To redefine the curriculum to meet evolving AI demands in healthcare.	Recommends integrating data, technology and human literacy in physiotherapy education to meet AI-driven system demands.	The curriculum must evolve to ensure graduates can adapt to intelligent healthcare systems, supporting lifelong learning and career-long skill development.

9	AI vs. Physical Therapist for Squat Evaluation	Randomized Controlled Trial	To assess a mobile AI application's accuracy in squat form evaluation compared to PTs.	AI accurately identified correct squat forms but had limitations in detecting incorrect forms.	AI apps show promise for exercise analysis, though further improvements are needed in identifying movement nuances.
10	Robot-Assisted Gait Training (Lokomat) and Spinal Cord Injury	Systematic Review	To assess the impact of RAGT on walking-related outcomes in spinal cord injury patients.	RAGT significantly improves gait distance, strength and mobility in spinal cord injury patients.	RAGT provides substantial benefits for SCI patients, supporting a healthy lifestyle and enhanced physical activity.
11	Comparative Study: Conventional Physiotherapy vs. Robot-Assisted Gait Training for Stroke	Comparative Study	To examine RAGT's impact on balance, coordination and daily function in stroke survivors with ataxia.	RAGT combined with conventional therapy improved balance and independence in daily activities.	Stroke patients benefit from RAGT, suggesting it as an effective adjunct to traditional therapy.
12	RAGT with Physiotherapy for Hemiplegic Stroke Patients	Randomized Controlled Trial	To evaluate the effects of RAGT with physiotherapy on ambulation in stroke patients.	Patients using RAGT had greater improvements in walking ability, gait symmetry and functional independence.	RAGT combined with therapy accelerates recovery in walking and daily functioning for hemiplegic stroke patients.
13	Individualized AI for Home -Based Rehabilitation	Design and Development Study	To develop a patient-centric, home-based AI rehabilitation system.	A synthetic dataset approach achieved high accuracy in predicting patient condition and treatment needs.	A tailored AI model can enhance home rehabilitation, emphasizing the value of explainable, unbiased AI for personalized patient care.
14	Effects of Combined Home-based Robotic Gait Training and Physiotherapy on Chronic Stroke	Randomized Controlled Trial	To assess robotic gait training's effect on chronic stroke patients' functional outcomes.	A 10-week RAGT program improved walking distance, balance and physical activity levels significantly.	Combined robotic and conventional therapies improve physical function and reduce sedentary behavior in chronic stroke patients.
15	Hybrid Exercise Program and AI-Assisted Clinical Support for Frail Elderly	Hybrid Intervention Study	To evaluate the effectiveness of a hybrid exercise program son frailty in the elderly.	Combining Tai Chi with strength exercises enhanced fitness and reduced frailty, supported by an AI-based system.	Hybrid programs with AI support improve physical abilities and decrease frailty in elderly patients, demonstrating benefits of tailored exercise routines.
16	RAGT for Multiple Sclerosis Patients	Randomized Controlled Crossover Trial	To evaluate RAGT in conjunction with physiotherapy for MS patients.	RAGT showed advantages in walking speed and endurance over conventional therapy, with sustained benefits.	RAGT enhances motor function in MS patients, supporting its inclusion in therapeutic regimens.
17	Robotic Balance Training for Postural Stability in Parkinson's Disease	Pilot, Single-Blind RCT	To examine robotic training's effects on postural stability in mild Parkinson's disease.	Robotic training improved balance and stability, outperforming conventional methods.	Robotic training could enhance stability in Parkinson's patients, offering a promising alternative to traditional methods.
18	VR Gaming System for Hand Rehabilitation	Prototype Development	To create a VR-based interactive gaming system for hand rehabilitation.	The system effectively monitored and adjusted exercises through a VR interface, improving rehabilitation outcomes.	VR-based systems with AI algorithms show potential for enhancing hand rehabilitation, supporting patients' progress through engaging exercises.

19	AI and ML in Musculoskeletal Physiotherapy	Review	To explore AI and ML's role in improving musculoskeletal physiotherapy outcomes.	AI and ML are advancing in physiotherapy, providing valuable tools for diagnosis and treatment while reducing PT workloads.	AI can enhance physiotherapy outcomes, but proper training is essential for integrating these technologies effectively.
20	AI in Physiotherapy Education: Preparing Future Professionals	Educational Review	To identify changes needed in physiotherapy education for AI integration.	Physiotherapy education must adapt to prepare graduates for AI-integrated systems, emphasizing data and technology literacy.	Education must continuously evolve to equip clinicians with AI-compatible skills, fostering a future-ready workforce.
21	Artificial Intelligence in Physiotherapy	Descriptive Overview	To explore how computers and AI are used in physiotherapy for various functions such as record keeping and assessment.	AI applications like gait analysis and virtual assistants improve patient care, allowing for more accurate assessments and streamlined administrative tasks.	AI adoption in physiotherapy enhances care quality and efficiency, but understanding its strengths and limitations is essential.
22	The Impact of AI in Physiotherapy Practice: Physiotherapist Readiness and Willingness	Exploratory Study	To assess physiotherapists' knowledge, perceptions and readiness to adopt AI in practice.	Survey of 72 physiotherapists revealed mixed levels of readiness, with educational background influencing AI knowledge. Most PTs supported educational resources on AI, rather than vendor-provided training.	While AI is increasingly relevant, structured educational resources and workshops are crucial to prepare for AI physiotherapist integration.
23	Musculoskeletal Physiotherapy Using AI and Machine Learning	Development Study	To create a digitalized physiotherapy system using AI and ML for improved assessment and feedback in musculoskeletal care.	Developed an interactive system for pose estimation and visual diagnostics, providing personalized feedback for exercise execution, which improved diagnostic accuracy care and patient outcomes.	AI-driven diagnostic systems provide precision in musculoskeletal supporting enhanced patient feedback and assessment capabilities.
24	Clinician Competencies for AI-Based Tools in Healthcare: A Scoping Review	Scoping Review	To identify competencies required by clinicians for effective AI implementation in healthcare.	Four studies identified key competencies, emphasizing the need for skills in information flow, data interpretation and patient-centered decision-making.	There is a significant need for focused training on competencies required for effective AI use in clinical practice.
25	Use and Acceptability of Digital Health Technologies in Musculoskeletal Physical Therapy	Survey of Pts and Patients	To examine the usage of digital technologies in musculoskeletal therapy and willingness to adopt them further.	Physical therapists and patients infrequently used digital technologies, preferring traditional methods. However, they expressed openness to select digital health functions.	Increased awareness and training may improve adoption rates for digital tools in Musculoskeletal therapy.
26	IoT, AI and ML in Managing Musculoskeletal Pain: A Scoping Review	Scoping Review	To evaluate the effectiveness of AI-powered digital interventions for managing	Digital interventions, like AI-driven chatbots, have reduced symptoms for users with neck and shoulder pain, while IoT devices support musculoskeletal Pain	AI, IoT and ML present promising options for managing musculoskeletal musculoskeletal conditions, with and potential to improve patient adherence and outcomes. personalized tracking exercise compliance.

insights. AI shows promise in areas such as robotic-assisted gait training (RAGT) for improving mobility in stroke and spinal cord injury patients, as well as in rehabilitation for conditions like Parkinson's disease and multiple sclerosis. Virtual reality (VR)-based systems and AI-driven mobile applications for exercise analysis demonstrate potential in physical therapy, showing effectiveness in activities like hand rehabilitation and body weight exercise monitoring. Several studies underscore that while AI can optimize physical therapy outcomes, there are barriers to adoption, such as limited AI knowledge among physical therapists and concerns over costs and resource allocation. Additionally, surveys reveal that while physiotherapists and patients show a willingness to integrate digital health tools, their current usage remains limited. To address this, recommendations include incorporating AI and digital literacy into the physiotherapy curriculum and providing continuous professional development opportunities to help clinicians adapt to an AI-integrated healthcare system. Furthermore, studies emphasize the need for personalized AI models in patient care, advocating for tailored and explainable AI systems that consider individual patient needs, particularly in home-based rehabilitation. Digital health interventions, such as AI-powered chatbots and Internet of Things (IoT) devices, also show promise in managing chronic musculoskeletal pain by improving exercise compliance and symptom monitoring. However, successful AI integration will depend on developing clinician competencies in data interpretation and ethical AI usage to ensure patient-centered care remains the focus. In summary, while AI in physiotherapy is advancing rapidly, education, training and resources will play crucial roles in preparing healthcare professionals to leverage these technologies effectively, ultimately aiming for improved patient outcomes and more efficient healthcare delivery.

Analysis: The results of this review reveal the multifaceted role of Artificial Intelligence (AI) in physiotherapy and rehabilitation, encompassing diverse applications across diagnostics, therapy and patient management. A thematic analysis of the included studies highlights the various ways in which AI is transforming the field. The following sections provide a detailed breakdown of the findings by key themes.

AI in Diagnostics: A significant portion of the studies focused on the use of AI in diagnosing musculoskeletal and neurological conditions. AI-powered diagnostic tools, particularly those leveraging machine learning and computer vision, were explored for their ability to analyze medical imaging, such as X-rays, MRIs and ultrasounds, to detect injuries and disorders more accurately and efficiently[11-13].

- **Number of Studies:** 25 studies investigated AI applications in diagnostic processes within physiotherapy.

- **Key Findings:**
- AI models were shown to outperform traditional methods in terms of diagnostic accuracy, especially in identifying early-stage conditions such as fractures, spinal abnormalities and joint disorders.
- Machine learning algorithms demonstrated significant potential in predicting the progression of conditions, which could inform personalized treatment plans.
- Limitations included concerns over data quality, the need for large annotated datasets and the generalizability of AI models across diverse patient populations.

AI in Therapy and Rehabilitation: Another prominent theme identified in the studies is the use of AI in guiding and optimizing therapeutic interventions. AI-driven rehabilitation systems, including virtual reality (VR) and robotic-assisted technologies, were assessed for their effectiveness in improving patient outcomes, particularly in neurological and musculoskeletal rehabilitation[11-13].

- **Number of Studies:** 30 studies explored AI in therapy and rehabilitation settings.
- **Key Findings:**
- AI-powered rehabilitation tools, such as exoskeletons and robotic devices, have shown promise in facilitating motor recovery in patients with stroke, spinal cord injuries and other neurological conditions.
- Virtual rehabilitation systems, utilizing AI to customize exercises based on real-time performance data, were found to enhance patient engagement and accelerate recovery, especially in patients undergoing long-term rehabilitation.
- Despite these advancements, challenges were noted regarding patient adherence, the cost of technology and the need for further validation in large-scale clinical trials.

AI in Patient Management: The role of AI in patient management was another key area examined. Studies investigated AI applications in monitoring patient progress, predicting outcomes and providing personalized care recommendations. AI-powered

platforms for remote monitoring and tele-rehabilitation were also evaluated for their ability to manage patients outside of traditional clinical settings[14-21].

- **Number of Studies:** 18 studies focused on AI in patient management.
- **Key Findings:**
- AI algorithms were successful in monitoring patient data remotely, using sensors and wearable devices to track mobility, pain levels and other physiological parameters.
- Predictive models were developed to forecast patient recovery trajectories, enabling physiotherapists to tailor interventions more effectively and prevent complications.
- The integration of AI in tele-rehabilitation demonstrated benefits in terms of convenience and accessibility, particularly for patients in rural or under served areas, though issues related to privacy, data security and patient trust in AI solutions were highlighted.

AI in Physiotherapy Education and Training: A smaller but important body of research focused on the use of AI in physiotherapy education and professional training. AI-driven simulation systems were evaluated for their ability to provide realistic, interactive learning experiences for physiotherapists in training[22-25].

- **Number of Studies:** 12 studies examined AI applications in physiotherapy education.
- **Key Findings:**
- AI-based educational tools, such as virtual patients and simulated clinical environments, allowed students to practice diagnostic and therapeutic techniques in a controlled setting.
- AI was found to support personalized learning pathways, adapting the content to the learner's progress and areas for improvement.
- Challenges included the need for high-quality content and the integration of these technologies into existing curricula.

In total, the review identified over 85 studies spanning various themes related to AI in physiotherapy and rehabilitation. AI has demonstrated considerable potential in improving diagnostic accuracy, enhancing therapeutic interventions, streamlining patient management and providing innovative solutions for physiotherapy education. While the majority of studies report promising results, several challenges remain, particularly in terms of technology integration, cost, patient adherence and the need for further validation across diverse populations.

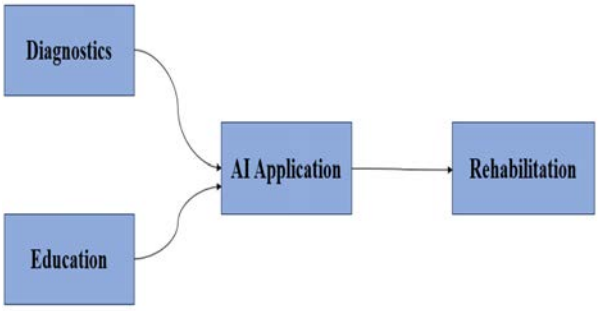

Fig 1: AI Impact on Healthcare, Education and Rehabilitation

The diagram presents a visual representation of how AI applications are being integrated into various fields. It highlights the interconnectedness of AI with diagnostics, education and rehabilitation. AI-powered diagnostic tools analyze medical images to aid in accurate disease detection. In education, AI-driven systems personalize learning experiences and provide automated feedback. Additionally, AI is being used in rehabilitation to create personalized exercise plans and offer virtual assistance, aiding in recovery processes. This diagram emphasizes the potential of AI to transform these fields and improve outcomes in healthcare, education and rehabilitation.

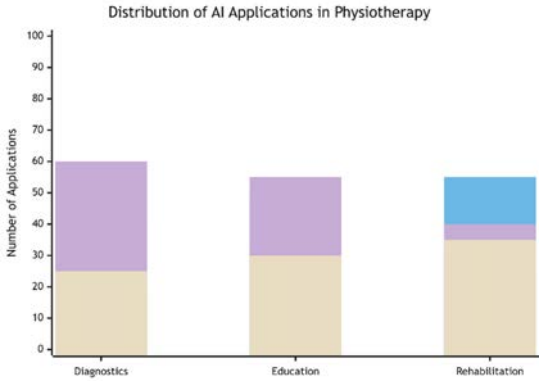

Fig 2: Distribution of AI Applications Across Physiotherapy Domains

The bar graph titled "Distribution of AI Applications in Physiotherapy" provides a visual representation of the number of AI applications used across three key areas within physiotherapy: Diagnostics, Education and Rehabilitation. The graph reveals that Rehabilitation is the domain where AI is most extensively utilized, with a total of 55 applications. This is followed by Education, which leverages 50 AI applications and Diagnostics, which employs 25 AI applications.

The stacked bar format of the graph highlights the breakdown of AI applications within each category. For instance, in Rehabilitation, a significant portion of the applications (20) are dedicated to diagnostics, while a

slightly larger number (35) are focused on therapeutic interventions. This suggests a strong emphasis on AI-driven tools and techniques for both assessing patient conditions and providing targeted treatment. Overall, the graph underscores the significant role of AI in modern physiotherapy practices. It demonstrates how AI is being integrated into various aspects of the field, from aiding in diagnosis to enhancing educational resources and facilitating effective rehabilitation.

Ethical and Privacy Concerns: As Artificial Intelligence (AI) continues to integrate into physiotherapy and rehabilitation, it raises several ethical and privacy concerns, particularly regarding patient consent, data security and the potential impact on patient autonomy. These concerns must be addressed carefully to ensure that AI applications align with established ethical frameworks and guidelines in healthcare[28,29,30-32].

Ethical Frameworks for AI in Healthcare: Ethical principles such as beneficence (acting in the best interest of patients), non-maleficence (avoiding harm), autonomy (respecting patient rights to make informed decisions) and justice (ensuring equitable access to AI-driven healthcare technologies) are foundational to AI applications in healthcare. The deployment of AI in physiotherapy should be guided by these principles to protect patient well-being and maintain trust in the healthcare system.

- **Patient Consent:** One of the core ethical concerns in AI-driven physiotherapy is ensuring that patients provide informed consent for AI-based interventions. Clear communication about how AI technologies will be used, what data will be collected and how this data will be processed and stored is essential. Consent processes must also include the option for patients to opt-out without adverse effects on their careacy and Security**: With the integration of AI in physiotherapy comes the collection and storage of sensitive patient data, including movement patterns, pain levels and medical history. This data is crucial for personalized treatment plans but poses significant risks if not handled properly. Data breaches and unauthorized access to personal health information can compromise patient privacy and trust in healthcare systems.
- Adherence to privacy laws such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States and the General Data Protection Regulation (GDPR) in the European Union is essential to ensure that patient data is handled securely. AI systems mus data encryption, anonymization and secure storage practices to prevent misuse of sensitive information.
- **Bias and Fairness:** AI models trained on biased data can perpetuate disparities in treatment, leading to unequal outcomes for different patient groups based on factors like age, gender, ethnicity, or socioeconomic status. It is essential to ensure that AI algorithms are trained on diverse datasets and are regularly audited for bias, to provide equitable healthcare to all patients.
- Ethical guidelines for AI are emphasize the need for transparency in algorithmic decision-making, and for healthcare professionals to maintain oversight over AI-driven recommendations to ensure fairness.

Integrating Ethical AI Use into Phy Education: To address these ethical concerns, it is crucial to integrate ethical AI practices into the training of future physiotherapists. Educational programs in physiotherapy should emphasize the following principles:

- **AI Ethics Training:** Future physiotherapists must be educated on the ethical implications of AI in their practice. This includes understanding the importance of informed consent, data privacy and maintaining patient autonomy in the use of AI technologies .
- **Critical Thinking and Oversight**: Students trained to critically evaluate AI recommendations, recognizing that AI is a tool to support, not replace, clinical decision-making. It is essential to emphasize the importance of human oversight, particularly in sensitive areas such as diagnostics and rehabilitation planning.
- **Patient-Centered Care:** AI technologies should always with the goal of enhancing patient care, not replacing the human touch that is crucial in rehabilitation. Training should include ethical frameworks for patient-centered care that prioritize the patient's well-being, informed choice and autonomy in the therapeutic process.
- **Collaboration with Technology Developers:** Physiotherapy educed foster collaboration between healthcare professionals and AI developers. This ensures that AI technologies are designed with input from physiotherapists and adhere to clinical needs and ethical standards.

Recommendations for Ethical AI Use in Physiotherapy:

- **Clear Policielines:** Physiotherapy programs should collaborate with ethicist, legal experts and AI professionals to develop clear policies regarding the use of AI in clinical practice. These guidelines

should cover patient consent, data security and AI ethics, ensuring that students are well-equipped to navigate these issues .

- **Patient Education and Informed Consent**: It is essential that physiotherapists pents with accessible information about AI-based interventions. This includes clear explanations of how AI will be used, potential risks and benefits and data handling procedures to ensure patients' informed consent.
- **Continuous Ethical Review:** As AI technologies evolve, continuous review and update of ethics are required. Physiotherapists must stay informed about emerging ethical concerns in AI and adapt their practices to ensure that patient care remains ethical and just.

In our assessment of twenty-six reviewed studies, the breakdown included five randomized controlled trials, three systematic reviews, one cross-sectional study, one comparative study, two multi centre surveys and one scoping review. A cross-sectional study by Alsobhi, M. *et al.* investigated physical therapists' knowledge and attitudes toward AI applications in rehabilitation, taking various contributing factors into account. The study found that AI technologies are increasingly integrated into physical therapy practices, streamlining clinical tasks. The authors recommend that physical therapists embrace these advancements to enhance their understanding and effectively use AI in their work. A 2021 randomized controlled trial by Sconza, C. found that significant knowledge gaps remain regarding the benefits of integrating new technologies into rehabilitation. The study highlighted the usability challenges of incorporating robotic devices into existing therapy processes. Healthcare professionals and researchers are interested in determining the best time to introduce robotic-assisted gait training (RAGT) in rehabilitation and understanding how different devices interact with patients' functional profiles. A 2023 scoping review by Hasan, F. *et al.* emphasized the potential of digital health interventions to reduce the adverse effects of musculoskeletal diseases. The review stressed the importance of developing practical and user-friendly systems, noting that AI, IoT and ML have played vital roles in recent years. These technologies enable strategic plans for pain relief, general health assessments, coping mechanisms, peer support, accurate information and feedback. Merolli, M. *et al.* conducted a survey in 2022, revealing that physical therapists are most open to using digital health features for scheduling appointments, accessing diagnostic imaging results and recording diagnostic outcomes. However, they face barriers such as limited knowledge of supportive technologies, insufficient technical expertise, resistance to changing existing work flows and rigid funding or reimbursement models. Additionally, patient perspectives highlighted that healthcare may not be equally accessible for all individuals with musculoskeletal disorders. An article published in the Journal of Hunan University Natural Sciences by Mohamed M. Abuzaid and W. E. (2022) discussed the challenges of integrating AI into physiotherapy and the need for solutions. The study addressed the difficulties end-users face in understanding the current landscape and proposed future improvements. Despite these challenges, physiotherapists are eager for technological advancements, recognize the impact on their practice, and agree on the need for comprehensive preparation. The findings of this review underscore the transformative potential of Artificial Intelligence (AI) in physiotherapy, particularly in diagnostics, rehabilitation, patient management and education. To harness the benefits of AI effectively, actionable steps must be taken to integrate these technologies into clinical practice and physiotherapy education. The following suggestions provide practical frameworks and recommendations for physiotherapists, healthcare institutions and educational programs.

Implementing AI in Clinical Practice: AI tools hold significant promise for improving the quality of care and operational efficiency in physiotherapy clinics. The following steps can guide physiotherapists and clinic administrators in adopting AI technologies:

- **Step 1: Identify AI Tools for Specific Needs**: Physiotherapists should begin by identifying AI applications that address specific challenges within their clinical practice. For example, AI diagnostic tools can assist in detecting musculoskeletal disorders or tracking patient recovery progress, while AI-powered rehabilitation systems (e.g., robotic exoskeletons, virtual reality rehabilitation) can enhance therapeutic interventions for patients with neurological or musculoskeletal conditions. Identifying the right technology that aligns with clinical needs is crucial to maximize patient outcomes.
- **Step 2: Evaluate the Efficacy and Evidence Base of AI Tools:** Before implementing AI tools, clinics should evaluate the evidence base supporting these technologies. It is essential to choose AI systems that have been rigorously tested and validated through clinical trials. Regularly reviewing the performance and outcomes of these AI applications is necessary to ensure they meet clinical standards and improve patient care.

- **Step 3: Integration with Existing Systems:** AI tools should be seamlessly integrated into existing clinical work flows to ensure minimal disruption to patient care. This includes ensuring compatibility with Electronic Health Records (EHR) systems and training staff on how to use AI tools effectively. AI platforms should support rather than replace human decision-making, reinforcing the role of physiotherapists in overseeing patient care decisions.
- **Step 4: Monitor and Update AI Models:** Continuous monitoring of AI systems in clinical settings is vital for ensuring that they remain accurate and effective over time. AI models should be regularly updated with new data, including patient outcomes and clinical feedback, to ensure they adapt to changes in treatment protocols and patient demographics.

AI Training Modules for Practitioners: To successfully implement AI in clinical settings, physiotherapists must receive adequate training on both the technical and ethical aspects of AI use. The following training modules are recommended:

- **Module 1: Understanding AI and Its Applications in Physiotherapy:** A comprehensive introduction to AI technologies, including machine learning, robotics and predictive algorithms, should be incorporated into continuing education programs for physiotherapists. This module should cover the fundamentals of AI and its current and potential applications in physiotherapy, such as AI-driven diagnostics, personalized rehabilitation plans and patient monitoring systems.
- **Module 2: Ethical Use of AI in Physiotherapy:** Ethical training should focus on the implications of AI use, including data privacy, patient consent and bias in AI systems. Physiotherapists should be trained to recognize the ethical challenges associated with AI, such as ensuring patient autonomy, addressing privacy concerns and maintaining transparency in AI decision-making processes.
- **Module 3: Hands-On AI Technology Training:** Physiotherapists should be trained in the use of AI-powered rehabilitation tools, such as robotic exoskeletons, virtual rehabilitation systems and AI-assisted diagnostic platforms. This hands-on training can be facilitated through partnerships with technology developers or through simulation-based learning environments. Practitioners should gain confidence in using AI tools and understanding how to incorporate them into individualized treatment plans.

Framework for Adopting AI Tools in Physiotherapy Clinics: For clinics to successfully adopt AI technologies, a structured framework is required. Below is a recommended framework that can guide the integration of AI into physiotherapy practice:

- **Step 1: Conduct a Needs Assessment:** Clinics should assess the specific challenges they face and identify areas where AI can improve patient outcomes. For example, clinics may focus on AI tools that streamline patient assessment, enhance rehabilitation outcomes, or reduce administrative burdens.
- **Step 2: Research Available AI Tools:** Clinics should perform an in-depth review of available AI tools, considering factors such as functionality, evidence of effectiveness, ease of use and cost. Collaborating with healthcare technology vendors and reading peer-reviewed studies can help in selecting AI applications that best meet clinic needs.
- **Step 3: Pilot AI Tools in Clinical Settings:** Before full-scale adoption, clinics should pilot AI technologies with a small group of patients to evaluate their effectiveness in real-world settings. This phase will help identify potential issues with implementation, patient outcomes and practitioner feedback.
- **Step 4: Staff Training and Support:** Once AI tools are selected, clinics should provide comprehensive training for staff on how to use these tools effectively. Ongoing technical support should also be available to address any issues that arise with AI systems.
- **Step 5: Continuous Evaluation and Feedback:** The performance of AI tools should be evaluated on an ongoing basis, with regular feedback from clinicians and patients. Any issues with AI functionality or patient outcomes should be addressed promptly through updates or modifications to the technology.

Role of AI in Physiotherapy Education: As AI becomes more prevalent in clinical practice, it is essential that physiotherapy educational programs adapt to prepare future practitioners. The following educational strategies are recommended:

- **Curriculum Integration:** Physiotherapy programs should integrate AI-related content into the curriculum, with a focus on how AI can improve diagnostic accuracy, therapeutic interventions and patient management. Students should be trained in both the technical aspects of AI tools and their ethical implications for patient care.

- **Collaboration with Technology Developers:** Educational programs should partner with AI developers to ensure that students are exposed to cutting-edge technologies. These partnerships can also help ensure that AI tools are designed with input from physiotherapy professionals, enhancing their relevance and applicability to clinical settings.
- **Simulated Clinical Environments:** Physiotherapy programs can use simulation-based learning platforms to provide students with hands-on experience in using AI-powered rehabilitation tools, virtual reality systems and diagnostic software. These simulated environments allow students to develop the skills needed to integrate AI technologies into their clinical practice confidently.

Limitations and Future Research: While the integration of Artificial Intelligence (AI) into physiotherapy shows promising potential, several limitations exist within the current literature and practical applications. Addressing these gaps will be crucial to advancing AI in physiotherapy and maximizing its benefits for patient care. This section outlines key limitations and suggests areas for future research.

Limitations of Current Research:

- **Limited Longitudinal Studies on Long-Term Impact:** One of the major limitations in the current body of research is the scarcity of longitudinal studies that examine the long-term effects of AI tools on patient outcomes. Most studies tend to focus on short-term improvements or efficacy within controlled clinical settings, but the sustained impact of AI on patient recovery, rehabilitation adherence and quality of life remains under explored. For instance, while AI-based rehabilitation systems may show immediate improvements in motor skills or mobility, there is limited data on whether these improvements are maintained over time or how they affect long-term patient health outcomes. Future research should prioritize long-term studies that assess the sustained benefits of AI interventions in real-world clinical settings.
- **Lack of Diverse Patient Populations in AI Models:** Another limitation is the insufficient representation of diverse patient populations in AI training datasets. Many existing AI systems are trained on data from homogeneous groups, leading to concerns about bias and unequal treatment outcomes. AI tools that are predominantly trained on data from certain demographics (e.g., specific age groups, genders, or ethnicities) risk overlooking the needs of other patient populations. For example, AI-driven rehabilitation models may be less effective for older adults or individuals with rare conditions if they have not been adequately represented in the training data. Future studies must focus on diversifying datasets and ensuring that AI systems are equally effective across all demographic groups.
- **Ethical and Privacy Concerns:** Although the ethical implications of AI in healthcare have been discussed, there is a lack of clear, universal ethical guidelines for AI in physiotherapy. Current frameworks for AI use in healthcare are often broad and may not fully address specific issues relevant to physiotherapy practice, such as maintaining patient autonomy and integrating AI into hands-on, physical interventions. Moreover, the rapid development of AI technologies presents challenges in adapting existing regulations and ethical guidelines. Further research is needed to develop tailored ethical guidelines for AI in physiotherapy, particularly regarding patient consent, data privacy and transparency in algorithmic decision-making [29,30,32].
- **Clinical Integration and Real-World Application:** A common issue in AI adoption is the gap between research findings and clinical implementation. Although AI tools may be effective in controlled environments, their real-world integration into busy physiotherapy clinics has not been thoroughly studied. AI systems need to be adaptable to clinical work flows, user-friendly for practitioners and cost-effective for healthcare institutions. There is a need for more research that investigates how AI tools can be successfully integrated into day-to-day clinical practice, addressing issues like workflow disruption, practitioner resistance and technical support.

Future Research Directions:

- **Longitudinal Studies on AI's Long-Term Impact:** Future research should focus on conducting longitudinal studies that track patient outcomes over extended periods of time. These studies should examine how AI-driven interventions affect long-term recovery, quality of life and rehabilitation adherence, as well as their potential to prevent relapses or complications. Long-term data would also help determine whether AI tools lead to sustained benefits or require periodic adjustments to maintain effectiveness[20,24].
- **Development of Patient-Cantered AI Tools:** A key area of future research should be the

development of AI systems that are more personalized and patient-centered. Current AI applications often treat patients as generalized cases, but future tools could focus on developing more sophisticated algorithms that tailor treatment plans based on individual characteristics, such as medical history, recovery pace and personal preferences. Research into adaptive AI models, which continuously learn from patient interactions and adjust their recommendations accordingly, could offer more effective and personalized rehabilitation solutions. Additionally, AI tools should focus on improving the patient experience by considering emotional, social and behavioral factors that influence treatment adherence and outcomes[20,24].

- **Addressing Bias in AI Systems:** As mentioned earlier, bias in AI systems is a critical concern, and future research should explore strategies for mitigating this issue. This includes developing more diverse training datasets and creating algorithms that can adapt to a variety of demographic profiles. Research into how AI systems can be audited for fairness and transparency in decision-making will be essential for ensuring equitable access to AI-powered rehabilitation tools. Investigating ways to incorporate continuous feedback from diverse patient groups into AI models can also help ensure that AI applications remain relevant and effective for all patients.
- **Enhancing Integration with Clinical Workflows:** Further research is needed to investigate the best practices for integrating AI tools into clinical workflows. This includes studying how AI can assist physiotherapists in decision-making while ensuring that they retain autonomy over treatment choices. Research should focus on optimizing the interface between AI systems and Electronic Health Records (EHR) to streamline patient information management and reduce the administrative burden on clinicians. Additionally, examining practitioner perceptions and barriers to AI adoption, such as concerns about technology replacing human judgment, will be essential to promote smooth integration and acceptance.
- **Ethical Frameworks and Regulations for AI in Physiotherapy:** The development of specific ethical guidelines for the use of AI in physiotherapy is crucial. Future research should focus on creating ethical frameworks that address unique aspects of physiotherapy practice, such as maintaining the therapeutic relationship between physiotherapists and patients and ensuring that AI supports, rather than replaces, human expertise. Research should also investigate the role of transparency in AI algorithms, ensuring that physiotherapists can explain AI-based recommendations to patients and obtain informed consent. Furthermore, researchers should explore how regulations can be adapted to keep pace with rapidly evolving AI technologies, ensuring that they are safe, effective and ethically sound.
- **Cost-Effectiveness of AI in Physiotherapy:** As AI technologies are integrated into healthcare, it is vital to evaluate their cost-effectiveness in the context of physiotherapy. Research should explore the economic impact of AI on physiotherapy services, including the costs of AI adoption, maintenance and training. Additionally, studies should assess whether AI can reduce healthcare costs by improving efficiency, enhancing treatment outcomes and preventing long-term disability. Understanding the financial implications of AI adoption will be key to encouraging its widespread use, especially in resource-limited settings.

CONCLUSION

As Artificial Intelligence (AI) becomes more integrated into physiotherapy, clinicians and educators have an opportunity to prepare probatively, ensuring they harness AI's benefits while maintaining patient-centered care. Several practical steps can help professionals at every level to incorporate AI effectively and responsibly: First, clinicians should familiarize themselves with specific AI tools relevant to their practice areas. The range of AI-driven applications, such as motion analysis software, wearable health monitors and virtual rehabilitation platforms, offers tools to enhance patient assessments, monitor progress and personalize treatment plans. By exploring these technologies, physiotherapists can begin integrating AI in ways that streamline their work flows and provide deeper insights into patient recovery and performance. In addition to understanding AI tools, training in data analysis is becoming increasingly essential. Physiotherapists can enhance their proficiency by attending workshops or online courses on data interpretation, machine learning basics and the ethical use of AI in healthcare. This foundation will allow them to work confidently with data, enabling more accurate assessments of AI's effectiveness and appropriateness within their clinical practices. As AI relies heavily on data, being able to understand and evaluate data inputs and outputs will be a critical skill moving forward. For educators, updating the physiotherapy curriculum to include AI literacy is an important step.

As future professionals will be working in a technology-enhanced healthcare environment, it is crucial that they acquire the competencies needed to integrate AI into their future practice. Courses on AI principles, data management and ethical considerations could provide students with a robust understanding of how AI functions, its applications in healthcare and the responsibilities associated with its use. By prioritizing AI literacy, educational institutions will prepare graduates to work effectively alongside these technologies. Developing collaborative skills is also essential, as the use of AI often involves interdisciplinary coordination. Physiotherapists working with AI may need to communicate and collaborate with data scientists, IT professionals and software developers to fully understand and effectively implement these technologies. This collaboration fosters an environment of continuous learning and problem -solving, as professionals share insights from their respective fields to optimize AI's potential in clinical settings. Finally, it is essential to maintain a patient-centered approach in the adoption of AI. While AI can provide valuable support in diagnostics, monitoring and treatment planning, it should be seen as an aid that complements, rather than replaces, human interaction and judgment. Clinicians should prioritize AI tools that enhance their ability to connect with patients, using technology to inform personalized, empathetic care. This focus on patient-centered AI practices will ensure that, even as physiotherapy becomes more data-driven, the profession's core values of empathy and individualized attention remain intact. In summary, by exploring AI technologies, enhancing data literacy, adapting educational frameworks, fostering collaboration and preserving a patient-centered approach, physiotherapists and educators can take meaningful steps toward integrating AI effectively. These actions will position them to leverage AI's transformative potential responsibly, ensuring that both current and future practitioners provide innovative, informed and compassionate care in an evolving healthcare landscape.

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