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INTEGRATING ARTIFICIAL INTELLIGENCE AND AUTOMATION IN PHYSIOTHERAPY: INNOVATIONS, CLINICAL OUTCOMES, AND ETHICAL FRONTIERS: A NARRATIVE LITERATURE REVIEW

Physiotherapy

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ABSTRACT

Background: Physiotherapy is rapidly evolving through the integration of artificial intelligence (AI) and automation, leading to enhanced objectivity in clinical assessment, personalization of rehabilitation plans, and expanded access to remote care. This review critically examines recent advances in AI-driven automation in physiotherapy, its clinical impact, patient and practitioner perspectives, and ethical concerns. **Methods:** We conducted a comprehensive synthesis of recent systematic reviews, meta-analyses, experimental studies, and cross-sectional surveys published between 2023 and 2025. Sources included digitized motion-capture trials, AI-driven tele-rehabilitation platforms, and stakeholder-focused qualitative research. Global literature was accessed, with a focus on clinical validation, educational adaptation, and regional perspectives from low- and middle-income countries. **Results:** Advances span robotics, AI-powered computer vision, 3D printing, smart sensors, and tele-rehabilitation applications. AI supports objective assessment, optimizes personalized therapy, and improves patient engagement, but barriers persist, including loss of human touch, privacy concerns, technological disparities, and therapist training deficits. Quantitative and qualitative evidence confirms AI parity (and sometimes superiority) with standard care, especially in home-based or resource-limited settings. **Conclusion:** Automation and AI promise a hybrid future for physiotherapy, combining human expertise with data-driven precision. Ethical vigilance, data security, equitable access, and professional upskilling are required to ensure patient-centered, effective integration.

KEYWORDS

Artificial Intelligence, Automation, Rehabilitation, Robotics, Tele-rehabilitation, Computer Vision, Ethics.

INTRODUCTION

Physiotherapy stands at the threshold of profound transformation. The confluence of global population aging, chronic disease prevalence, and health crises such as the COVID-19 pandemic has driven rapid digitization in rehabilitation medicine. Traditional models, reliant on face-to-face manual therapies, are increasingly challenged by patient demand, workforce shortages, and the imperative for evidence-based, outcomes-focused practice.[1]

Recent advances in artificial intelligence (AI), automation, and digital technologies offer an unprecedented opportunity to reimagine rehabilitation medicine. From AI-driven motion analysis and robotic exoskeletons to intelligent tele-rehabilitation platforms and 3D-printed assistive devices, these innovations promise increased objectivity, personalized therapeutic plans, and scalable access to care. Yet such technological disruption brings new risks: erosion of the therapeutic alliance, data privacy dilemmas, algorithmic bias, and educational or infrastructural gaps.[2]

This Article Aims To:

1. Review the state-of-the-art in AI and automation for physiotherapy;
2. Synthesize evidence of clinical outcomes and user acceptability;
3. Critically discuss the ethical, educational, and practical challenges in integrating AI into rehabilitative care.

Methods

Article Title & Authors	Study Focus	Key Findings	Methodology	Contribution to Physiotherapy/AI Integration	Limitatios/ Future Directions
Knowledge and Attitude Regarding Artificial Intelligence Among Physiotherapists (Adil et al.)	Assess physiotherapists' knowledge & attitudes towards AI in rehabilitation	Positive attitude towards AI in clinical decision-making but limited detailed knowledge on AI specific applications; need for targeted AI education	Cross-sectional survey among physiotherapists in Karachi, Pakistan	Highlights gap between awareness and detailed competence; emphasizes AI literacy for facilitating adoption	Regional limitation; future work on AI training impact needed
AI-Assisted Physiotherapy for Patients with Non-Specific Low Back Pain: Systematic Review and Meta-Analysis (Kapil et al.)	Evaluate effectiveness of AI-assisted physiotherapy vs usual care in NSLBP	No statistically significant difference in outcomes like pain intensity, functional impairment, and mental health between AI-assisted and usual physiotherapy	Systematic review and meta-analysis of RCTs	Provides comprehensive synthesis; indicates AI-assisted physiotherapy is promising but currently comparable to usual care	Small number of studies, heterogeneity, requires larger longitudinal studies
A Breakthrough in Producing Personalized Solutions for Rehabilitation and Physiotherapy Thanks to AI in Additive Manufacturing (Mikoajewska et al.)	Review integration of AI with 3D printing in personalized rehabilitation devices	AI enables precise customization, rapid prototyping, and optimized functional/device designs; facilitates patient-specific orthoses, prosthetics, and supports	Bibliometric and literature review on AI and additive manufacturing	Demonstrates advanced AI-enabled customization and scalability in physiotherapy devices, improving outcomes and accessibility	Challenges include regulatory approval, data security, and dataset diversity

Accurate Pose Estimation and Semantic Abstraction for Physiotherapy Assessment (Gordt et al.)	Development of computer vision pose estimation framework to aid physiotherapy	Improved pose estimation accuracy; modular system integrates biomechanical analysis with clinical scales to support objective patient assessment	Technical development with machine learning and vision-based methods	Supports clinical decision by quantifying movement, reducing subjectivity, and enabling longitudinal monitoring	Tested mainly on curated datasets; real-world clinical validation pending; future work on multi-modal sensing
Multinational Survey on Perceptions of AI in Medical and Rehabilitation Settings (Tortella et al.)	Survey of medical and physiotherapy students and professionals on AI adoption perspectives	Varied awareness and readiness; concerns about digital divide, ethical use, and need for curriculum updates	Multi-center questionnaire survey	Highlights educational and ethical considerations in AI adoption in physiotherapy	Need for inclusive AI education and addressing digital divide
Case-Based Reasoning for Non-Specific Musculoskeletal Disorders (Amar Jaiswal et al.)	Development of CBR and Clinical Decision Support Systems (CDSS) for non-specific MSDs	Novel data-driven similarity measures improve case retrieval; scalable, privacy-preserving federated architecture supports multi-institution collaboration; hybrid models maximize clinical usability	Comprehensive thesis synthesizing empirical studies, algorithm development, and clinical trials	Establishes foundational CBR framework for personalized physiotherapy decision support with scalable, explainable AI; addresses data privacy	Needs further domain expert validation; future work on real-world federated system evaluations and adaptation
Semantic Abstraction for Physiotherapy Using YOLO Pose (V. Gordt et al.)	Integration of computer vision pose estimation into physiotherapy assessment	Modified YOLOv8-pose models improve pose detection accuracy; semantic abstraction layers map kinematic data to clinical scales facilitating objective assessment	Development and evaluation of neural network models on custom physiotherapy datasets	Advances automated quantification of patient movement, reducing subjective bias and enabling precise clinical monitoring	Clinical validation in real-world settings pending; future inclusion of affective and multimodal sensing planned
Integration of Automation in Physiotherapy: Technologies and Impact (Jyothsna Devi Dontha)	Review of automation technologies in physiotherapy (robotics, AI, VR, wearables)	Automation enhances rehabilitation efficiency, patient engagement, and access; key challenges are cost, data security, and maintaining therapeutic human interaction	Narrative review of emerging technologies with case studies and future directions	Demonstrates benefits of hybrid AI-human physiotherapy models, tele-rehabilitation, and personalized treatment optimization	Calls for cost reduction, ethical frameworks, and further evaluation of psychological/social impacts
Telephysiotherapy Platforms: A Comprehensive Review (Georgios Kavallieratos & Ergina Kavallieratou)	Review of telephysiotherapy solutions with AI/ML, sensors, and user engagement	Telephysiotherapy is effective and fosters access despite limitations; integration of sensors, ML enables remote monitoring with varied usability and scalability	Systematic review and technological comparison of 19 telephysiotherapy solutions	Highlights technology evolution from video consultations to AI-powered feedback platforms, emphasizing scalability and patient compliance	Identifies challenges in data accuracy, patient diversity, connectivity, privacy, and human factors requiring balanced design
ChatGPT in Physiotherapy Research and Education: Advantages and Risks (Mohammad Sidiq & Jyoti Sharma)	Overview of AI chatbot use in physiotherapy research and education	ChatGPT supports academic writing, formulation of research hypotheses, and literature mapping; risks include academic integrity, misinformation, and digital divide	Narrative overview examining AI impacts on physiotherapy academia and clinical research	Encourages ethical AI integration to augment productivity without substituting core scientific reasoning skills	Recommends educational policies on AI literacy and broader access to mitigate inequities and misuse

This review utilizes a structured synthesis of the most current peer-reviewed literature, focusing on primary studies, systematic reviews, and high-impact experimental work from 2023–2025. Sources were selected based on the following criteria:

- Evidence on clinical efficacy, user acceptance, or real-world deployment of AI and automation in physiotherapy;
- Studies focusing on robotics, computer vision, smart sensors, digital health platforms, and tele-rehabilitation;
- Papers reporting clinical trials, meta-analyses, systematic reviews, or large-scale cross-sectional and qualitative research;
- Attention to ethical, social, or educational implications, including therapist and patient perspectives.[3]

Major databases screened included PubMed, Scopus, Web of Science, and discipline-specific repositories. Reference lists of recent reviews were examined for additional studies. Region-specific challenges and experiences, especially in South Asia and low- to middle-income contexts, were considered.[4]

RESULTS

Robotics and Automation in Rehabilitation

Robotic-Assisted Physiotherapy

Robotic exoskeletons and assistive devices have achieved clinical maturity, especially in neurological and orthopaedic rehabilitation. These systems facilitate repetitive, high-precision movements needed for neuroplastic change, supporting post-stroke upper and lower limb rehabilitation and recovery post-spinal cord injury.[1] Notable outcomes of robotic-assisted therapy include:

- **Improved Motor Recovery:** Robotic upper limb training in stroke patients results in 30% faster gains in hand and arm function compared to conventional methods.[1]
- **Personalization and Progression:** Advanced sensors and

actuators dynamically adjust assistance based on patient ability, supporting graded progression and optimizing recovery.[2]
- **Reduced Therapist Strain:** Automated systems complement therapist expertise, reducing physical burnout and enabling focus on complex clinical decision-making.[2]

Additive Manufacturing And Personalization

The convergence of AI with 3D printing (additive manufacturing) has unlocked mass-customization in orthopaedic and rehabilitation appliances. AI-driven algorithms design prosthetics, orthoses, and assistive tools based on patient-specific anatomical and biomechanical data:
- Devices can be rapidly prototyped and iteratively refined to maximize fit, comfort, and therapeutic benefit.
- Smart embedded sensors provide continuous performance data, enabling dynamic adjustment of therapy and remote progress tracking.[2]

AI-Driven Assessment, Monitoring, and Feedback

Computer Vision and Pose Estimation

AI-powered computer vision enables objective, scalable movement evaluation using consumer-grade cameras and open-source algorithms. Recent evaluation of systems like YOLO Pose demonstrates:
- **Accurate Real-Time Analyses:** AI algorithms reliably detect physiotherapy-relevant key points for balance, range-of-motion, and postural assessments.
- **Framework Integration:** Semantic mapping converts motion data into clinically meaningful metrics for decision-making and longitudinal tracking.
- **Resource Efficiency:** Compared to traditional motion-capture systems, computer vision delivers reliable analysis using minimal hardware, facilitating clinical and home-based use.[5]

Digital Twins And Predictive Analytics

Emerging research leverages digital twins-virtual models simulating patient anatomy and function-to test and personalize prosthetics or rehabilitation plans before real-world deployment. AI predictive models further anticipate recovery trajectories, optimize therapy intensity, and adapt interventions in real time.[2]

Tele-physiotherapy and Remote Digital Platforms

Tele-rehabilitation Solutions

Tele-physiotherapy has evolved from simple video consultations to comprehensive, AI-enhanced platforms integrating wearables, real-time feedback, and adaptive exercise regimens.[3]

Key impacts:
- **Comparable Efficacy:** Recent RCTs demonstrate equivalence between tele-rehabilitation and in-clinic care for physical function, pain, and satisfaction in musculoskeletal and neurological populations.[6]
- **Enhanced Access and Adherence:** Tele-platforms reduce travel, lower barriers to care for remote populations, and facilitate patient engagement via gamification and personalized prompts.[6]
- **Automated Monitoring:** Wearables and smart devices track metrics such as joint angles, muscle activity, and exercise completion, supporting data-driven clinician review.[3]

AI-Powered Self-Management

Mobile apps employing AI and smart sensors (e.g., Kaia Health, DorsaVi) deliver home-based self-management with algorithmic feedback, automating elements of assessment, correction, and motivation. Machine learning models classify movement patterns and generate tailored reminders or warnings for incorrect performance.[7]

Clinical and Educational Outcomes

Efficacy and Outcome Evidence

Meta-analyses and systematic reviews confirm AI-assisted or automated therapies are at least non-inferior to standard care for non-specific low back pain and other common musculoskeletal conditions:
- No significant advantages in pain, function, or psychological status were observed compared to usual physiotherapy, but key benefits include scalability and improved adherence in supervised home environments.[2]
- In specific settings (e.g., stroke rehabilitation with robotics, digital assessment of movement), automated systems augment outcomes through higher training volumes, objectivity, and consistent progression.[1]

Therapist And Patient Perspectives

Survey data indicates generally positive therapist attitudes toward AI as a supportive tool for assessment and decision-making, but a substantial knowledge gap and reticence to cede clinical autonomy exist. Patients often appreciate the real-time feedback and flexibility, but some express concerns about the reduced human connection, privacy, and technical reliability.[8]

DISCUSSION

1. The Hybrid Model: Augmenting, Not Replacing, Human Expertise

Despite optimism around automation, evidence consistently argues for a blended model, pairing AI reliability and efficiency with the critical interpersonal and clinical judgment skills of trained physiotherapists.[8]

Intelligent systems can:
- Offset workforce shortages by automating monitoring, routine assessment, and data management;
- Provide objective, reproducible measurements and remote supervision beyond human capacity;
- Free practitioners to focus on complex care, emotional support, motivation, and patient advocacy.

Yet challenges remain:
- **Loss of Empathy and Motivation:** Patients often value personal interaction for encouragement, empathy, and individualized goal setting—elements not easily automated.[4]
- **Workflow Integration:** Seamless incorporation of data from AI platforms into clinical workflows, without additional administrative burden, is essential to avoid technology fatigue.[9]

Ethical, Legal, and Privacy Concerns

Data Protection

AI and tele-health systems collect sensitive biometric and health data, triggering concerns over data security, sharing, and potential misuse.
- **GDPR and International Compliance:** Adherence to privacy regulations is paramount. Emerging federated learning models—in which institutions share model updates rather than patient data—may balance data utility and confidentiality for AI model training.[10]
- **Transparency and Bias:** Algorithmic decision-making must be explainable, auditable, and free from socio-demographic or clinical bias. Training datasets must be diverse to avoid perpetuating inequity.[8]

Professional Responsibility

As AI takes on a larger role in decision support, therapists remain legally and ethically responsible for interpreting and applying recommendations. Training programs need to address critical appraisal of AI outputs, oversight of autonomous systems, and risk mitigation.[9]

Educational and Regional Challenges

Digital Literacy and Training

Recent cross-sectional surveys indicate widespread deficits in knowledge regarding AI among physiotherapists-particularly in low-resource settings-despite general openness to its potential. Consistent recommendations include:[4]
- Mandatory digital health and AI literacy modules in both undergraduate and CPD curricula;
- Interdisciplinary upskilling (engineering, informatics, clinical sciences);
- Exposure to hands-on platforms and simulation-based AI/robotic training.[9]

Resource Disparity And Access

While AI and digital health can democratize care, disparities in infrastructure (internet access, hardware), funding, and technical support remain. Open-source, scalable platforms and cost-effective sensor solutions are needed for equitable access in low- to middle-income countries.[4]

Research Gaps And Future Directions

Future research should prioritize:
- Longitudinal, large-scale studies evaluating long-term clinical and cost-effectiveness of automated and AI-driven physiotherapy;
- Development of inclusive datasets and testbeds reflecting regional, ethnic, and condition-specific diversity;

- Ongoing assessment of psychological, motivational, and relational impacts of digital interventions on patients and practitioners.[4]

CONCLUSION

The integration of AI and automation is not a distant future for physiotherapy—it is a vibrant, growing reality with the potential to transform the delivery, efficiency, and outcomes of rehabilitation care globally.

- AI-driven robotics, computer vision, and remote care platforms deliver data-driven assessment, tailored interventions, and expanded access, often equalling or surpassing standard care for specific outcomes.
- Ethical, legal, and practical challenges must be addressed proactively: upskilling human practitioners, ensuring transparent and fair AI, protecting privacy, and embedding automation in a way that enhances—not undermines—the therapeutic alliance.
- A patient- and practitioner-centered approach, informed by rigorous evidence, strong ethical frameworks, and robust digital infrastructure, will ensure AI realizes its promise in physiotherapy while preserving the field's humanistic roots.

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Author Contributions

All authors contributed to the conception, design, drafting, and revision of this review.

Data Availability Statement

This article is based on published literature. No new datasets were generated.

Competing Interests

The authors declare no competing interests.

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