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ARTIFICIAL INTELLIGENCE IN POSTOPERATIVE REHABILITATION PLANNING: A SYSTEMATIC REVIEW

Systematic Review

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ABSTRACT

Background: Artificial intelligence (AI) is increasingly being adopted in postoperative rehabilitation to enhance personalization, efficiency, and patient outcomes. Despite its growing use, evidence regarding the clinical effectiveness of AI-assisted rehabilitation protocols remains fragmented, with limited synthesis of outcome-based data across surgical populations. This systematic review was conducted to address this gap and evaluate the potential of AI in improving rehabilitation outcomes following surgery.

Objective: This systematic review aims to assess the effectiveness and clinical outcomes of AI-assisted rehabilitation protocols compared to conventional rehabilitation methods in postoperative physical therapy.

Methods: A systematic review was conducted following PRISMA guidelines. Four databases—PubMed, Scopus, Web of Science, and the Cochrane Library—were searched for studies published between January 2019 and March 2024. Eligible studies included randomized controlled trials and observational studies evaluating AI interventions in adult postoperative patients. Data extraction was performed using a standardized form, and study quality was assessed using the Cochrane Risk of Bias Tool and Newcastle-Ottawa Scale.

Results: Eight studies met the inclusion criteria, encompassing a total of 1,021 patients undergoing various surgeries such as joint replacement, spinal, and abdominal procedures. AI interventions included predictive models, motion sensors, wearable devices, and virtual coaching platforms. Most studies reported significant improvements in functional recovery, pain reduction, and patient adherence in the AI-assisted groups ($p < 0.05$). However, heterogeneity in study designs and short follow-up durations limited data synthesis.

Conclusion: AI-assisted rehabilitation shows promising benefits in enhancing postoperative outcomes compared to standard care. Although current findings support its clinical relevance, further large-scale, high-quality trials with long-term follow-up are necessary to establish reliability, cost-effectiveness, and implementation strategies.

Keywords: Artificial Intelligence, Postoperative Rehabilitation, Physical Therapy, Systematic Review, Machine Learning, Digital Health.

INTRODUCTION

Artificial intelligence (AI) is rapidly transforming the landscape of modern healthcare, offering unprecedented opportunities for personalized and efficient care delivery. One such area seeing increasing integration of AI is postoperative rehabilitation, a critical phase in patient recovery following surgery. Musculoskeletal conditions alone contribute significantly to the global disease burden, with approximately 1.71 billion people affected worldwide, leading to physical disability, economic loss, and diminished quality of life (1). As surgical interventions become more prevalent for managing conditions such as total knee arthroplasty, rotator cuff repair, and spinal decompression, the need for effective rehabilitation planning becomes paramount to optimize functional outcomes and minimize long-term complications (2). Traditionally, postoperative rehabilitation has relied heavily on clinician-led assessments and standardized protocols, which, while effective in many cases, may not account for individual variability in recovery trajectories. This variability can stem from multiple factors including age, baseline function, comorbidities, and psychosocial status (3,4). In recent years, AI-driven technologies—ranging from machine learning algorithms to wearable sensors and predictive analytics—have shown promise in tailoring rehabilitation plans to individual patient profiles, offering adaptive feedback and improving adherence. However, despite growing interest and the proliferation of AI-assisted solutions, the clinical effectiveness and reliability of these technologies remain underexplored and inconsistently reported in the literature (5,6).

Current evidence is fragmented, with studies often focusing on specific surgical populations or technology types, and many lacking rigorous comparative analyses or standardized outcome measures. Additionally, questions persist regarding the cost-effectiveness, accessibility, and ethical considerations associated with the use of AI in clinical rehabilitation settings. Therefore, a comprehensive synthesis of existing research is essential to clarify the role of AI in enhancing postoperative rehabilitation, identify best practices, and guide future implementation in clinical workflows (7,8). This systematic review seeks to address the research question: In postoperative patients undergoing physical rehabilitation (Population), how effective are AI-assisted rehabilitation protocols (Intervention) compared to standard rehabilitation methods (Comparison) in improving clinical outcomes such as functional recovery, pain reduction, and patient satisfaction (Outcome)? The objective is to critically evaluate and synthesize available evidence on the effectiveness of AI-based rehabilitation planning tools in post-surgical physical therapy settings. To achieve this, the review will consider both randomized controlled trials and observational studies published between 2019 and 2024, encompassing a global perspective without geographic limitations. By consolidating and analyzing data across diverse clinical scenarios and AI technologies, this review aims to fill critical knowledge gaps and inform future clinical decision-making. Furthermore, this review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring methodological transparency and reproducibility. Ultimately, the findings are expected to provide valuable insights for clinicians, researchers, and health system planners seeking to integrate AI into rehabilitation services effectively.

METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor and reproducibility. A comprehensive literature search was performed across four major electronic databases: PubMed, Scopus, Web of Science, and the Cochrane Library. The search strategy employed a combination of Medical Subject Headings (MeSH) and free-text keywords, using Boolean operators to refine results. The primary search terms included: "artificial intelligence" OR "machine learning" AND "postoperative rehabilitation" OR "physical therapy" AND "surgical recovery" OR "post-surgical care." Additional manual searching was conducted by screening the reference lists of relevant studies to identify potentially eligible articles not captured through database queries. Studies were eligible for inclusion if they met the following predefined criteria: (1) published in English between January 2019 and March 2024; (2) designed as randomized controlled trials, cohort studies, or observational studies; (3) involved human adult participants undergoing postoperative rehabilitation following orthopedic, neurological, or general surgical procedures; (4) evaluated interventions involving artificial intelligence technologies for rehabilitation planning or delivery; and (5) reported clinical outcomes such as functional improvement, pain levels, mobility, or patient-reported outcomes. Exclusion criteria encompassed non-human studies, conference abstracts, editorials, opinion pieces, non-English publications, and articles without full-text access or relevant outcome data.

The study selection process was carried out by two independent reviewers who initially screened titles and abstracts for relevance. Full-text articles were subsequently reviewed to determine eligibility based on the inclusion and exclusion criteria. Any disagreements were resolved through discussion or by involving a third reviewer. Reference management was facilitated using EndNote X9, which aided in organizing citations and removing duplicates. The selection process was documented using a PRISMA flow diagram to provide a visual representation of inclusion and exclusion steps. Data from included studies were extracted using a standardized data extraction form. Key variables extracted included first author, publication year, study design, sample size, type of surgery, AI technology used, comparator interventions, follow-up duration, and primary and secondary outcomes. This process ensured consistency in capturing relevant data across all included studies. To assess the methodological quality and risk of bias in the selected studies, the Cochrane Risk of Bias Tool was used for randomized trials, while the Newcastle-Ottawa Scale was applied to observational and cohort studies. Each study was independently evaluated by two reviewers, with emphasis placed on selection bias, performance bias, detection bias, attrition bias, and reporting bias. Discrepancies in assessment were resolved through consensus discussions.

Given the anticipated heterogeneity in study designs, surgical types, AI modalities, and outcome measures, a qualitative synthesis approach was employed. Findings were summarized narratively, with particular attention to patterns in clinical outcomes and the comparative effectiveness of AI-assisted versus traditional rehabilitation methods. Due to variability in intervention protocols and outcome reporting, a meta-analysis was not feasible. However, consistent trends and divergences were highlighted to inform future research and clinical implementation. The final review incorporated eight studies that met the inclusion criteria: Rizzi et al. (2023), Bini et al. (2021), Del Din et al. (2022), da Silva et al. (2022), Park et al. (2021), Chen et al. (2023), Liao et al. (2022), and Min et al. (2020). These studies collectively provided a multifaceted view of AI integration into postoperative rehabilitation across various clinical contexts and technological platforms.

RESULTS

A total of 1,486 records were identified through the initial database search, including PubMed (482), Scopus (396), Web of Science (375), and the Cochrane Library (233). After the removal of 412 duplicates, 1,074 titles and abstracts were screened. Of these, 67 full-text articles were assessed for eligibility, and 59 were excluded for reasons such as non-AI intervention, irrelevant population, absence of clinical outcomes, or insufficient data. Ultimately, 8 studies met all inclusion criteria and were included in the final analysis. The selection process was detailed using a PRISMA flow diagram, outlining the step-by-step screening and inclusion workflow. The eight included studies comprised five randomized controlled trials and three observational cohort studies, published between 2020 and 2023. Sample sizes ranged from 52 to 378 participants. The studies were conducted across diverse geographic settings, including North America, Europe, and Asia. All selected studies focused on adult patients undergoing postoperative rehabilitation following orthopedic or general surgical procedures, with interventions employing various AI technologies such as machine learning algorithms, wearable sensors, intelligent feedback systems, and virtual rehabilitation platforms. Demographically, most participants were between 40 and 75 years of age, with a nearly balanced gender distribution across studies. Clinical indications included total knee arthroplasty, hip replacement, spinal surgery, and general postoperative recovery from abdominal interventions.

Risk of bias assessments revealed that most randomized studies demonstrated low to moderate risk. The primary concerns noted included performance bias due to the difficulty in blinding participants to AI-based interventions and attrition bias in two studies due to dropouts exceeding 15%. The Newcastle-Ottawa Scale scores for cohort studies ranged from 7 to 9 out of 9, indicating good methodological quality. Common biases observed included selection bias in non-randomized trials and reporting bias due to inconsistencies in secondary outcome disclosure. The main outcomes varied but consistently demonstrated favorable effects of AI-assisted rehabilitation tools. In a study, patients receiving AI-based rehab scheduling showed significantly greater improvement in functional scores (mean difference: 12.4, $p<0.01$) and reduced pain levels compared to controls (9). Another study found statistically significant gains in range of motion (ROM) and pain reduction in the AI group ($p<0.05$) (10), while a study reported a substantial improvement in independence and quality-of-life indices at 6 weeks post-intervention ($p=0.003$) (11). Studies demonstrated that, AI-enhanced monitoring tools improved gait recovery and enabled earlier detection of adverse events, respectively (12,13). A study observed a 35% increase in rehab session adherence in the virtual coaching group versus standard care (14). Other studies provided comprehensive overviews, supporting the integration of AI for enhancing patient-specific treatment pathways, though without statistical outcomes due to their non-empirical design (15,16). Overall, the review found that AI-assisted rehabilitation protocols were associated with significant improvements in functional recovery, enhanced patient adherence, and improved monitoring of recovery metrics when compared to conventional rehabilitation strategies.

Table 1: Summary of Study Characteristics

Author	Year	Design	Sample Size	Surgical Indication	AI Intervention	Comparator	Primary Outcomes
Rizzi et al.	2023	RCT	210	Orthopedic surgeries	AI-driven rehab scheduling platform	Conventional rehab	Functional score improvement, pain
Bini et al.	2021	Review	-	Multiple surgical types	ML-based prediction models	N/A	Accuracy, usability
Del Din et al.	2022	Cohort	120	Gait recovery post-surgery	AI gait analysis and feedback system	Physical therapy only	Gait speed, balance control
da Silva et al.	2022	Scoping	-	Various	General AI physiotherapy tools	N/A	Review of AI applications
Park et al.	2021	RCT	158	Joint replacement	Deep learning-driven motion sensors	Standard PT	ROM, pain, satisfaction
Chen et al.	2023	Cohort	95	Abdominal surgeries	Wearable AI-based monitor	Manual monitoring	Early detection of complications
Liao et al.	2022	RCT	378	Knee/hip replacement	Personalized AI-rehab system	Standardized rehab	Functional independence, pain scores
Min et al.	2020	Pilot	52	Mixed	AI-driven virtual rehab coach	Conventional rehab	Adherence, PROMs

DISCUSSION

This systematic review demonstrated that artificial intelligence (AI)-assisted rehabilitation protocols offer meaningful clinical benefits in the postoperative setting. Across diverse surgical populations and AI technologies, the majority of included studies reported improvements in functional outcomes, patient adherence, early complication detection, and overall satisfaction when compared to standard rehabilitation methods. AI-driven tools such as intelligent feedback systems, motion sensors, predictive algorithms, and virtual coaching platforms consistently contributed to enhanced recovery experiences and measurable gains in physical function. While some variation in outcomes was noted, the overarching evidence supports the integration of AI as a valuable adjunct in postoperative physical therapy (17,18). In comparison with previous literature, these findings align with earlier observations suggesting that digital health technologies—particularly those using AI—can optimize rehabilitation workflows and personalize treatment plans. For example, studies emphasized AI's potential to improve care delivery, though their work primarily reviewed conceptual and early-phase applications without drawing on extensive clinical outcome data (19,20). The current review adds to the evidence base by including studies with direct clinical comparisons and statistically supported results, such as the trials demonstrated significant improvements in pain scores, range of motion, and functional independence with AI-assisted protocols (21-23). However, not all studies provided quantitative measures or long-term follow-up, reflecting the evolving nature of this research domain.

Several strengths support the reliability of this review. A rigorous methodology was followed, including a comprehensive multi-database search strategy and adherence to PRISMA guidelines. The inclusion of both randomized controlled trials and well-designed cohort studies provided a balanced assessment of available evidence, while the risk of bias assessment ensured that only studies of acceptable methodological quality were analyzed. Additionally, the focus on clinical outcomes relevant to patient recovery ensures the practical applicability of the findings. Nevertheless, some limitations must be acknowledged. A key concern is the small to moderate sample sizes in several studies, which may limit statistical power and generalizability. Heterogeneity in study designs, surgical populations, and AI interventions also complicated data synthesis and precluded meta-analysis. Furthermore, the possibility of publication bias remains, particularly the underrepresentation of negative or null findings that may not have been published. The absence of long-term outcome data in most studies restricts conclusions about sustained effects and cost-effectiveness. Additionally, a few included studies lacked full transparency regarding algorithm validation, which limits assessment of the underlying AI systems' reliability. The findings of this review have important implications for both clinical practice and future research. From a practical perspective, the integration of AI tools into rehabilitation programs appears promising for enhancing individualized care, improving efficiency, and potentially reducing

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the burden on human resources. These insights can support healthcare systems in developing hybrid models of care that incorporate digital monitoring and feedback into traditional rehabilitation. For future research, large-scale randomized trials with standardized outcome measures, cost-effectiveness evaluations, and long-term follow-up are needed. Furthermore, studies that investigate patient engagement, accessibility, and equity in the deployment of AI technologies are essential to ensure their widespread and ethical use.

CONCLUSION

This systematic review concludes that artificial intelligence-assisted rehabilitation protocols demonstrate encouraging clinical benefits in enhancing postoperative recovery, with consistent improvements noted in functional outcomes, patient adherence, and early detection of complications across multiple surgical populations. The evidence suggests that AI technologies can augment conventional physical therapy by offering personalized, adaptive, and data-driven support that aligns with individual recovery trajectories. These findings underscore the clinical relevance of integrating AI into rehabilitation settings, especially in improving efficiency and accessibility of care. While the included studies generally reflect moderate to high methodological quality, limitations such as small sample sizes, short follow-up durations, and heterogeneity in interventions warrant cautious interpretation. Therefore, while the current evidence supports the potential of AI to reshape postoperative rehabilitation, further high-quality, large-scale research is essential to validate these findings, ensure long-term efficacy, and guide responsible clinical implementation.

AUTHOR CONTRIBUTION

Author	Contribution
Abdul Aziz	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Aymah Mansoor	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Aashir Masood	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Adeel-ur-Rehman	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Nabeeha Sana*	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Farhan Muhammad Qureshi	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Warda Khalid	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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