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AI-POWERED REHABILITATION FOR MUSCULOSKELETAL DISORDERS: A SUSTAINABLE APPROACH TO BACK PAIN MANAGEMENT: NARRATIVE REVIEW

Narrative Review

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ABSTRACT

Background: Low back pain (LBP is one of the leading causes of disability worldwide and poses a substantial burden on healthcare systems, workplace productivity, and overall quality of life. Although conventional rehabilitation approaches are effective, their real-world impact is often limited by challenges related to accessibility, scalability, cost, and long-term adherence. Recent advances in artificial intelligence (AI) and mobile health technologies have introduced new opportunities to address these limitations and reshape musculoskeletal rehabilitation.

Objective: This narrative review aims to explore the evolving role of artificial intelligence in the rehabilitation of low back pain, with a focus on its clinical applications, effectiveness, sustainability, and implications for future care delivery.

Main Discussion Points: The review synthesizes current evidence on AI-driven diagnostics, decision support systems, and AI-enabled telerehabilitation platforms. Key themes include personalized exercise prescription, real-time feedback through wearable sensors and mobile applications, patient engagement strategies, cost-effectiveness, and equity in access to care. The integration of AI into hybrid rehabilitation models that combine digital self-management with clinician oversight is highlighted as a particularly promising approach. Persistent challenges such as data privacy concerns, algorithmic bias, digital disparities, and variability in outcome measures are also discussed.

Conclusion: AI-supported rehabilitation represents a promising advancement in low back pain management, offering scalable, personalized, and potentially cost-effective solutions. While existing evidence supports its clinical potential, further high-quality, long-term research and robust regulatory frameworks are required to ensure safe, equitable, and sustainable implementation.

Keywords: Artificial Intelligence, Low Back Pain, Telerehabilitation, Musculoskeletal Rehabilitation, Mobile Health, Narrative Review.

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INTRODUCTION

Low back pain (LBP) is one of the most pervasive musculoskeletal conditions worldwide and remains a leading cause of years lived with disability across diverse populations. In 2020 alone, LBP was estimated to affect approximately 619 million individuals globally, with projections indicating a continued rise in prevalence as populations age and life expectancy increases (1). Beyond physical discomfort, LBP imposes a substantial social and economic burden by limiting functional capacity, reducing quality of life, increasing healthcare utilization, and contributing to absenteeism and reduced productivity in the workforce (2). These multidimensional consequences make LBP not only a clinical concern but also a public health priority that demands innovative and scalable management strategies. Conventional rehabilitation approaches—including manual therapy, structured exercise programs, and patient education—form the cornerstone of evidence-based LBP management and have demonstrated clinical benefit in reducing pain and disability (3). However, translating these interventions into consistent real-world outcomes remains challenging. Many patients face barriers such as limited availability of trained physiotherapists, particularly in rural or underserved regions, high treatment costs, travel constraints, and poor long-term adherence to prescribed exercise regimens (4). As a result, a significant proportion of individuals with LBP fail to achieve sustained improvement, highlighting a gap between established therapeutic principles and their practical delivery at scale. Recent advances in mobile health technologies and artificial intelligence (AI) offer promising avenues to bridge this gap. AI encompasses a range of computational methods—including machine learning, deep learning, and computer vision—that can analyze large datasets, identify meaningful patterns, and generate adaptive recommendations (5). Within rehabilitation medicine, these technologies are increasingly being applied to automate elements of clinical assessment, personalize therapy plans, remotely monitor patient performance, and deliver real-time feedback aimed at improving engagement and outcomes (6). When integrated with telerehabilitation platforms, AI has the potential to transform LBP care from static, clinic-centered models into dynamic, patient-centered systems that extend beyond traditional healthcare settings.

Telerehabilitation utilizes digital tools such as wearable sensors, smartphone applications, and immersive virtual or extended reality environments to deliver rehabilitation services remotely. AI-enhanced telerehabilitation systems can continuously analyze movement data, pain reports, and adherence patterns, enabling timely adjustments to exercise intensity, early identification of maladaptive movement or symptom deterioration, and individualized feedback tailored to each patient's progress (7). This data-driven approach supports continuous monitoring and adaptive care pathways, which are particularly relevant for chronic conditions like LBP that require long-term self-management. Importantly, such technologies may also address global inequities in access to rehabilitation services, as highlighted by the World Health Organization, which reports that nearly 90% of individuals in low-income settings lack access to essential assistive and rehabilitative technologies despite clear clinical need (8). Emerging evidence suggests that remote monitoring and AI-supported rehabilitation interventions can improve clinical outcomes, reduce hospital readmissions, and enhance patient satisfaction by promoting sustained engagement and timely clinical oversight (9,10). Nevertheless, despite growing interest and technological capability, the integration of AI into LBP rehabilitation remains heterogeneous, and questions persist regarding its comparative effectiveness, practical implementation, and role alongside conventional physiotherapy. There is a clear need to synthesize existing knowledge and critically examine how AI-driven telerehabilitation interventions can be optimized to address current limitations in LBP management. Accordingly, the objective of the present research is to evaluate and rationalize the role of artificial intelligence–enabled telerehabilitation in the rehabilitation of low back pain, with particular emphasis on its potential to improve accessibility, personalization, adherence, and clinical outcomes compared with traditional rehabilitation approaches.

THEMATIC DISCUSSION

Role of AI in Rehabilitation: From Diagnostics to Decision Support

Artificial intelligence has emerged as a transformative force across the continuum of low back pain rehabilitation, extending from early diagnostic support to real-time clinical decision-making. By integrating multimodal data streams—including wearable sensor outputs, medical imaging, electronic health records, and patient-reported outcomes—AI systems enable a level of personalization and responsiveness that is difficult to achieve with conventional rehabilitation models. Deep learning algorithms have demonstrated diagnostic performance comparable to, and in some contexts exceeding, that of human experts in interpreting MRI and CT images for conditions such as disc herniation, spinal stenosis, and degenerative disc disease, while automated image segmentation reduces inter-observer variability and enhances measurement reliability (11,12). Beyond diagnostics, AI-driven decision support systems synthesize longitudinal patient data to classify LBP subtypes, predict recovery trajectories, and guide preventive or targeted interventions. Across studies, these systems consistently show the ability to dynamically adjust exercise intensity, frequency, and complexity in response to patient performance, thereby improving functional outcomes and minimizing reinjury risk (13,14). When embedded within telerehabilitation platforms, AI further enables remote monitoring and clinician oversight, reducing the need for frequent hospital visits while maintaining therapeutic precision, particularly for patients in rural or underserved regions (15). Recent evidence also suggests that large language model–based systems can safely assist in rehabilitation planning for patients with complex comorbidities, although most outputs still require clinical refinement, underscoring the complementary rather than replacement role of AI in rehabilitation decision-making (16). Integration with electronic health records enhances contextual relevance and continuity of care, but also highlights the importance of robust data management frameworks to ensure reliability and scalability of AI-supported rehabilitation systems (17,18).

Effectiveness and Sustainability of mHealth and AI Platforms

The effectiveness of AI-assisted and mobile health–based rehabilitation platforms for low back pain has been increasingly supported by comparative and randomized evidence. Collectively, studies indicate that these digital interventions can achieve outcomes comparable to, and in some cases superior to, conventional physiotherapy, particularly in terms of pain reduction, functional improvement, and self-management capacity. Randomized trials have shown that AI-assisted multimodal exercise programs delivered through telerehabilitation can outperform traditional exercise-based telerehabilitation alone in individuals with chronic nonspecific LBP (19). Similarly, synthesis across sub-group analyses suggests that while telerehabilitation alone often matches in-person care for functional outcomes, its combination with usual care yields additive benefits compared with usual care alone (20). Sustainability is a defining advantage of AI-enabled platforms. By allowing a single clinician to oversee multiple patients remotely while maintaining individualized feedback through decision support algorithms, these systems enhance scalability without proportionally increasing workforce demands (15). Smartphone-based rehabilitation applications have repeatedly demonstrated non-inferiority to standard care in reducing pain and improving daily function, offering a practical alternative for patients with limited access to clinic-based services (12). Widely studied platforms, including multimodal interventions combining education, physiotherapy, and behavioral strategies, consistently report superior outcomes over standard or minimal care at follow-up periods ranging from weeks to months (13–16). Despite these promising findings, heterogeneity in intervention design, outcome measures, and follow-up duration across studies limits direct comparability and highlights the need for standardized evaluation frameworks.

Digital Accessibility, Cost-Effectiveness, and Equity

Cost, accessibility, and equity remain central determinants of whether AI-supported rehabilitation can be successfully integrated into routine healthcare systems. Evidence consistently indicates that digital rehabilitation platforms reduce indirect costs associated with travel, time off work, and repeated hospital visits, while maintaining clinical effectiveness. Economic evaluations suggest favorable cost-effectiveness profiles, with reported incremental cost-effectiveness ratios well below commonly accepted healthcare thresholds, supporting the long-term financial sustainability of these interventions (17,18). Comparative analyses further demonstrate that remote care models may cost substantially less than in-person services, particularly in geographically dispersed populations, while offering significant time savings for both patients and providers (19). From an equity perspective, AI-supported rehabilitation holds considerable promise for expanding access to high-quality care in underserved communities. Scalability enabled by AI-assisted monitoring allows clinicians to manage larger patient cohorts without sacrificing individualized oversight (5). However, the realization of this potential depends on parallel investments in digital infrastructure, regulatory alignment, and culturally sensitive implementation strategies. Evidence from broader digital health applications indicates that older adults and high-risk populations may derive disproportionate benefits from mHealth-supported self-management, including reduced hospitalizations and lower overall healthcare costs, suggesting that equitable deployment could narrow, rather than widen, health disparities if implemented thoughtfully (20,21).

Patient Engagement and Adherence

Sustained engagement and adherence are critical determinants of rehabilitation success in low back pain, where consistent exercise performance underpins long-term functional improvement (4). AI-supported rehabilitation platforms address a longstanding challenge in LBP management by embedding behavioral and motivational strategies directly into therapy delivery. Features such as gamification, real-time feedback, progress visualization, and personalized goal-setting have been shown to enhance motivation and accountability, reframing rehabilitation as an achievable and meaningful activity rather than a burdensome obligation (22,23). Adaptive difficulty adjustment, a hallmark of AI-driven systems, ensures that exercise programs remain appropriately challenging without inducing frustration or boredom, thereby supporting continued participation. Evidence increasingly supports hybrid care models that combine AI-enabled self-management with intermittent human supervision, achieving a balance between technological efficiency and therapeutic rapport (7). AI-based coaching systems further extend this approach by providing personalized prompts and dynamically adjusted exercise targets, which have been associated with increased activity levels and sustained engagement over time (24). Notably, chatbot-assisted interventions delivered through familiar messaging platforms have demonstrated exceptionally high adherence rates and meaningful symptom improvement, highlighting the importance of accessibility and user-centered design in digital rehabilitation (15). Despite these advances, engagement outcomes vary across studies, reflecting differences in platform design, user literacy, and contextual support. These inconsistencies underscore the need for integrating behavioral science principles with technological innovation to maximize adherence and long-term effectiveness in AI-supported low back pain rehabilitation.

CRITICAL ANALYSIS AND LIMITATIONS

Despite the rapid expansion of research on AI-assisted rehabilitation for low back pain, the existing literature reveals several methodological and practical limitations that constrain the strength and generalizability of current evidence. A recurring issue across studies is the limited availability of high-quality randomized controlled trials. Many investigations rely on pilot studies, feasibility trials, or observational designs with relatively small sample sizes, which restrict statistical power and increase susceptibility to type I and type II errors (15). Short follow-up durations are another common weakness, as many trials assess outcomes over weeks rather than months or years, limiting insight into long-term effectiveness, adherence sustainability, and relapse prevention in chronic low back pain populations (16). Methodological bias further complicates interpretation of findings. Selection bias is frequently evident, as study cohorts often comprise younger, technologically literate participants with mild to moderate symptoms, excluding older adults, individuals with severe disability, or those with limited digital access (17). Performance bias is also prevalent, particularly in trials where blinding of participants and therapists is not feasible due to the visible and interactive nature of digital interventions. In addition, confounding factors such as concurrent conventional physiotherapy, analgesic use, or varying levels of clinician oversight are not consistently controlled, making it difficult to attribute observed improvements solely to AI-driven components (5). Publication bias represents another important concern. The majority of published studies report positive or favorable outcomes associated with AI or mHealth-based rehabilitation, while negative, null, or inconclusive findings are rarely emphasized. This imbalance raises the possibility that unsuccessful implementations or modest effects remain underreported, potentially inflating perceived effectiveness and limiting balanced evidence synthesis (18). Furthermore, industry involvement in the development of proprietary applications introduces an additional risk of selective outcome reporting, underscoring the need for independent evaluations and transparent reporting standards.

Considerable heterogeneity exists in outcome measures used to evaluate treatment success, which further limits cross-study comparability. Pain intensity, functional disability, quality of life, adherence, and engagement are measured using diverse instruments and thresholds, often without standardized definitions of clinically meaningful change. This variability complicates meta-analytic comparisons and weakens the ability to draw definitive conclusions regarding superiority or equivalence to conventional care (15). Moreover, reliance on self-reported outcomes in many digital interventions introduces reporting bias, particularly when objective biomechanical or functional metrics are inconsistently incorporated. Generalizability of findings remains limited due to disparities in technological infrastructure, healthcare systems, and population characteristics across study settings. Many AI-supported rehabilitation trials are conducted in high-income countries with robust digital ecosystems, raising concerns about applicability in low-resource or rural environments where internet connectivity, device availability, and digital literacy may be limited (16). Algorithmic bias also poses a critical challenge, as AI models trained on non-representative datasets may generate less accurate recommendations for certain demographic groups, potentially exacerbating existing health inequities if deployed at scale without validation across diverse populations (17). Collectively, these limitations highlight that while AI-assisted rehabilitation for low back pain shows substantial promise, the current evidence base is constrained by design weaknesses, bias, outcome variability, and restricted external validity. Addressing these gaps will require larger, methodologically rigorous randomized trials with longer follow-up periods, standardized outcome frameworks, transparent reporting of negative findings, and inclusive study populations. Parallel advances in regulatory oversight, data governance, and clinician and patient education are also essential to ensure that future implementations are both scientifically robust and ethically sound (18).

Table 1: Barriers and Enablers Influencing the Adoption of AI-Supported Low Back Pain Rehabilitation

Category	Barriers	Enablers
Clinical Evidence	There are few high-quality RCTs, and the results are inconsistent.	Utilization of remote access, reduction in personnel, and cost savings.
Trust & Literacy	Issues with adherence and limitations in patient and clinician technology literacy.	Care that is accessible and personalized through wearables and apps.
Sustainability	Long-term validation and infrastructure preparation are required.	Trials of NHS apps demonstrate scalability.

IMPLICATIONS AND FUTURE DIRECTIONS

The findings synthesized in this review indicate that AI-assisted rehabilitation for low back pain has meaningful implications for clinical practice, particularly in shifting care from episodic, clinic-centered models toward continuous, data-informed management. In routine practice, AI-supported systems can assist clinicians in monitoring patient progress beyond simple session completion by incorporating quality-of-movement metrics, symptom trends, and adherence patterns into treatment decisions. This capability supports earlier identification of suboptimal technique, declining engagement, or clinical deterioration, allowing timely modification of exercise programs and escalation to in-person care when required. Hybrid care models, in which patients rely on AI-guided self-management for daily rehabilitation while clinicians provide intermittent supervision for safety, behavioral coaching, and complex decision-making, appear especially promising for maintaining therapeutic effectiveness without overburdening healthcare systems (20-22). From a policy and guideline perspective, the growing evidence base underscores the need for formal clinical frameworks governing the use of AI in musculoskeletal rehabilitation. Current practice guidelines for low back pain rarely address digital therapeutics or AI-driven decision support, despite their increasing adoption. Clear guidance is required on validation standards for AI algorithms, acceptable performance thresholds, clinician accountability, and integration into existing care pathways. Regulatory bodies and professional societies should also define minimum requirements for data security, interoperability with electronic health records, and transparency of algorithmic decision-making to ensure safe and ethical implementation at scale (23-25).

Several unanswered questions remain that warrant focused investigation. Long-term effectiveness and cost-effectiveness of AI-assisted rehabilitation are still insufficiently established, as most studies involve small samples and short follow-up periods. Evidence is also limited regarding how different levels of human oversight influence outcomes, adherence, and patient safety. Additionally, the clinical value of advanced sensing technologies—such as camera-based motion analysis and inertial measurement units—for assessing exercise quality in home settings requires further validation across diverse patient populations and severity levels of low back pain (26,27). Addressing algorithmic bias and ensuring equitable performance across age groups, cultural contexts, and resource settings remain critical research gaps. Future research should prioritize large, pragmatic randomized controlled trials with extended follow-up durations to evaluate sustainability, functional recovery, and economic impact in real-world settings. Comparative study designs that explicitly test hybrid human–AI care models against technology-only and conventional rehabilitation approaches are particularly needed. Standardized outcome measures, including objective biomechanical metrics alongside patient-reported outcomes, would improve comparability across studies. In parallel, implementation research examining reimbursement models, clinician training requirements, and patient acceptability will be essential to translate promising technologies into routine care. Collectively, these directions highlight that while AI-supported low back pain rehabilitation is advancing rapidly, its long-term success depends on rigorous evidence generation, thoughtful policy development, and an explicit commitment to equitable and patient-centered care.

Table 2: Identified Research Gaps, Future Directions, and Potential Benefits in AI-Supported Low Back Pain Rehabilitation

Gap Identified	Future Direction	Potential Benefit
Insufficient long-term RCTs.	Perform thorough, comprehensive, long-term research.	greater support for sustainability
Unreliable adherence and supervision.	Use applications and smart sensors to get real-time feedback.	Better patient outcomes and compliance.
Using tech-only models too much.	Create avenues for hybrid human-AI care.	Maintains human supervision while guaranteeing scalability.
Black-box algorithms.	Develop systems with Explainable AI (XAI).	Enhances clinical adoption, transparency, and trust.
Digital disparities in access.	Create affordable, multilingual, and inclusive AI applications.	Accessibility and equity for all populations.

CONCLUSION

Artificial intelligence–supported rehabilitation represents a meaningful advancement in the management of low back pain by addressing long-standing limitations related to access, scalability, and individualized care. Across the reviewed literature, AI-enabled diagnostics, adaptive exercise prescription, remote monitoring, and real-time feedback consistently demonstrate the potential to achieve clinical outcomes comparable to conventional physiotherapy, particularly when implemented within hybrid care models that retain clinician oversight. While randomized trials and systematic reviews provide encouraging evidence for improvements in pain, function, and quality of life, the overall strength of evidence remains moderate due to heterogeneity in study designs, outcome measures, and follow-up durations. Current findings nonetheless support the cautious integration of AI-assisted rehabilitation into clinical practice as a complement to established care, especially for patients with limited access to in-person services. Future progress should prioritize standardized outcome frameworks, equitable and privacy-conscious implementation, and rigorous long-term trials to clarify cost-effectiveness, safety, and durability of benefits. Continued high-quality research is essential to ensure that AI-driven rehabilitation evolves into a reliable, ethical, and patient-centered component of musculoskeletal care worldwide.

AUTHOR CONTRIBUTIONS

Author	Contribution
Noorulain	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Mir Arif Hussain*	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
Iqra Arain	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Kalsoom	Contributed to Data Collection and Analysis

Author	Contribution
	Has given Final Approval of the version to be published
Shahzeb	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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