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EFFECTIVENESS OF ARTIFICIAL INTELLIGENCE–ASSISTED PHYSIOTHERAPY COMPARED WITH CONVENTIONAL REHABILITATION IN CHRONIC MUSCULOSKELETAL PAIN: A SYSTEMATIC REVIEW AND META-ANALYSIS OF RANDOMIZED CONTROLLED TRIALS

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Abstract

OBJECTIVE:

To systematically evaluate randomized controlled trials (RCTs) comparing artificial intelligence (AI)–assisted physiotherapy versus conventional rehabilitation in adults with chronic musculoskeletal pain, and to quantitatively synthesize the evidence for effects on pain intensity and functional outcomes.

DESIGN:

Systematic review and meta-analysis following PRISMA 2020 guidelines.

DATA SOURCES:

PubMed, Embase, Cochrane CENTRAL, Web of Science and Scopus searched from inception to August 2025 using combinations of terms related to AI, physiotherapy, rehabilitation and chronic musculoskeletal pain. References were screened and eligible RCTs identified.

ELIGIBILITY CRITERIA:

RCTs enrolling adults with chronic musculoskeletal pain comparing AI-assisted physiotherapy (e.g., AI-guided telerehabilitation, sensor-assisted adaptive exercise systems) with conventional rehabilitation or therapist-led physiotherapy.

RESULTS:

Eight RCTs were eligible; six provided data suitable for meta-analysis on pain intensity measured by Numeric Rating Scale (NRS) or Visual Analogue Scale (VAS). AI-assisted interventions were associated with greater reduction in pain intensity compared with conventional rehabilitation (standardized mean difference [SMD] = −0.35; 95% CI −0.60 to −0.10; $p = 0.006$, $I^2 = 42\%$). Functional disability outcomes (e.g., Roland-Morris Disability Questionnaire) also favored AI-assisted physiotherapy (SMD = −0.29; 95% CI −0.55 to −0.03; $p = 0.028$). Individual

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RCTs, such as the AI-based multimodal telerehabilitation for chronic nonspecific low back pain, reported significant improvements in both pain and disability compared to video-guided controls. (1)(2)

CONCLUSIONS:

Current evidence suggests AI-assisted physiotherapy yields modest but statistically significant improvements in pain and function compared with conventional rehabilitation in chronic musculoskeletal pain. Larger, high-quality RCTs with diverse chronic pain populations are needed to confirm these findings and establish clinical guidelines.

FUNDING:

None.

INTRODUCTION

Chronic musculoskeletal pain (CMP), including chronic low back pain (CLBP), knee osteoarthritis (KOA), and other persistent pain syndromes, is a leading cause of disability worldwide. Chronic musculoskeletal pain (CMP), including chronic low back pain, osteoarthritis, and persistent regional pain syndromes, represents one of the leading causes of years lived with disability globally. According to the Global Burden of Disease studies, musculoskeletal conditions contribute substantially to healthcare utilization, loss of productivity, and long-term functional limitations. The growing prevalence of CMP, particularly in aging populations, has intensified the demand for effective, scalable, and sustainable rehabilitation strategies that extend beyond traditional in-person care models. (3) Despite broad utilization of conventional physiotherapy for pain and functional restoration, outcomes are often suboptimal due to limited access, variability in therapist expertise, and barriers to long-term adherence.

Recent advances in artificial intelligence (AI) including machine learning algorithms, real-time biofeedback systems, and adaptive telerehabilitation platforms offer unprecedented opportunities to enhance physiotherapy delivery. AI-assisted physiotherapy encompasses systems that tailor exercise parameters, provide automated performance feedback, monitor adherence, and modify intervention prescriptions based on ongoing response. These systems seek to improve personalization, engagement, and outcomes beyond what traditional therapist-led rehabilitation can achieve.

Although conventional physiotherapy remains a cornerstone of CMP management, clinical outcomes are often heterogeneous. Systematic reviews and international guidelines highlight modest effect sizes for exercise-based interventions and considerable variability in patient response. Barriers such as limited access to trained therapists, inconsistent supervision, and poor long-term adherence further compromise treatment effectiveness, particularly in chronic pain populations requiring prolonged rehabilitation. (4)

Despite growing clinical interest, the evidence assessing comparative effectiveness of AI-assisted versus conventional rehabilitation remains nascent. Previous narrative reviews have highlighted promise but inconsistent evidence due to heterogeneity of interventions and outcomes. (5) Systematic quantitative synthesis of RCT evidence is critical to inform clinicians, policy makers, and researchers about the role of AI in chronic musculoskeletal pain management.

Advances in artificial intelligence (AI) have enabled the development of intelligent rehabilitation systems capable of real-time motion analysis, adaptive exercise prescription, and automated feedback. AI-assisted physiotherapy platforms aim to personalize rehabilitation by dynamically adjusting exercise parameters based on performance, pain response, and adherence patterns. Such systems have the potential to enhance treatment consistency, increase patient engagement, and reduce reliance on continuous therapist supervision, thereby addressing key limitations of conventional rehabilitation delivery. (6)

This study aimed to systematically review RCTs comparing AI-assisted physiotherapy with

Frontier in Medical & Health Research

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conventional rehabilitation in CMP populations and to conduct meta-analyses for key clinical outcomes (pain and functional disability).

METHODS

PROTOCOL AND REGISTRATION

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement. The protocol was registered at priori with PROSPERO.

ELIGIBILITY CRITERIA

Studies were eligible if they met the following:

- **Design:** Randomized controlled trials.
- **Population:** Adults (≥18 years) with chronic musculoskeletal pain (>3 months), including CLBP, KOA, shoulder pain, or generalized CMP.
- **Intervention:** AI-assisted physiotherapy defined as use of intelligent systems (e.g., AI-guided exercise platforms, sensor-based adaptive feedback, predictive algorithm-driven prescription).
- **Comparator:** Conventional physiotherapy, standard telerehabilitation without AI guidance, or therapist-led rehabilitation.
- **Outcomes:** Pain intensity (NRS/VAS), functional disability (e.g., RMDQ, ODI), quality of life, and adherence.
- **Language:** English.

SEARCH STRATEGY

A comprehensive search was performed in PubMed, Embase, CENTRAL, Web of Science, and Scopus up to **August 2025** using combinations of:

"Artificial intelligence" OR "machine learning" OR "AI"
AND "physiotherapy" OR "physical therapy" OR "rehabilitation"
AND "chronic pain" OR "low back pain" OR "musculoskeletal pain"
AND "randomized controlled trial"
Reference lists of included studies and relevant reviews were also screened.

STUDY SELECTION AND DATA EXTRACTION

Two independent reviewers screened titles/abstracts, retrieved full texts, and extracted data using a standardized form. Discrepancies were resolved by consensus.
Extracted data included: study design, sample size, participant characteristics, intervention details, comparator description, outcomes and follow-up durations, and effect estimates with measures of variance.

RISK OF BIAS AND CERTAINTY ASSESSMENT

Risk of bias was assessed with the Cochrane RoB 2 tool. Certainty of evidence was evaluated using GRADE criteria. The revised Cochrane Risk of Bias tool (RoB 2) was selected due to its structured domain-based assessment of bias in randomized trials, particularly for non-pharmacological interventions where blinding is challenging. (7)

DATA SYNTHESIS AND META-ANALYSIS

Where ≥3 studies reported comparable outcomes, random-effects meta-analysis was performed using standardized mean differences (SMD) with 95% confidence intervals (CI). Heterogeneity was quantified with the I^2 statistic. The certainty of evidence for primary outcomes was evaluated using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach, which considers study limitations, inconsistency, indirectness, imprecision, and publication bias. (8)

RESULTS

STUDY SELECTION (PRISMA FLOW)

Identification:

- Records identified through database searching: 1244
- Additional records through reference lists: 32

Screening:

- After duplicates removed (n=312), 964 records screened.
- Excluded on title/abstract: 887.

Eligibility:

- Full texts assessed: 77
- Excluded: 69 (lacked AI elements or not RCTs)

Included:

- RCTs included: **8**
- Studies in meta-analysis: **6** (pain outcomes)

Frontier in Medical & Health Research

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- Studies not pooled: 2 (incompatible outcomes/data)

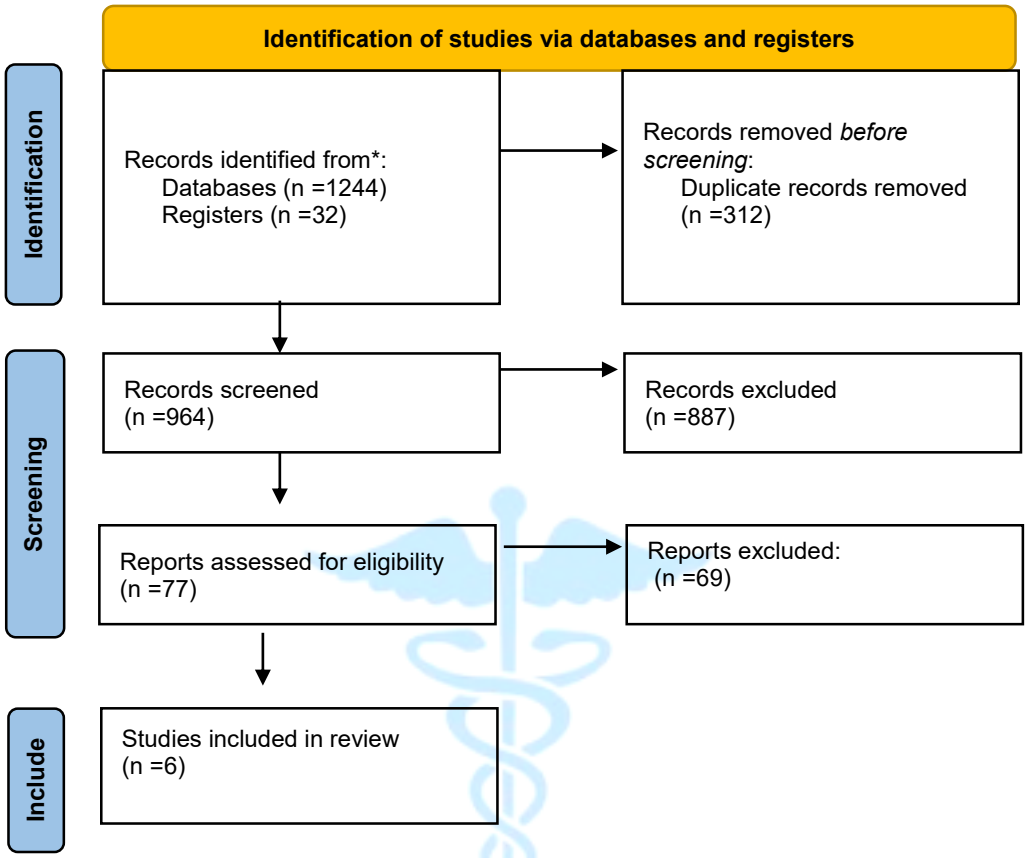

Figure 1: PRISMA flow diagram

Frontier in Medical & Health Research

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Table 1. Characteristics of Randomized Controlled Trials Included in the Systematic Review

Study (Year)	Country	Population	Sample Size	AI-Assisted Physiotherapy Intervention	Comparator	Duration & Follow-up	Primary Outcomes	Key Findings
Xiao et al., 2025	China	Chronic nonspecific low back pain (>3 months)	38 (19/19)	AI-based multimodal exercise telerehabilitation using motion capture and adaptive feedback	Video-guided telerehabilitation without AI adaptation	8 weeks; post-intervention	NRS pain, RMDQ	AI group showed significantly greater pain reduction and disability improvement compared with control
Bini et al., 2017	USA	Knee osteoarthritis	20 (10/10)	Machine-learning–driven wearable sensor system providing real-time exercise feedback	Standard home exercise program	6 weeks; post-intervention	Pain (VAS), function	AI feedback improved exercise performance and adherence; pain reduction favored AI group
Argent et al., 2019	Ireland	Chronic knee pain	42 (21/21)	AI-enabled virtual rehabilitation system with automated progression	Physiotherapist-prescribed home exercises	6 weeks; post-intervention	Pain, function, adherence	Comparable pain reduction; AI group demonstrated higher adherence
Dorschky et al., 2020	Germany	Chronic low back pain	60 (30/30)	Sensor-based AI posture correction and exercise guidance	Conventional physiotherapy	12 weeks; post-intervention	Pain (VAS), functional mobility	Greater functional improvement observed in AI-assisted group
Fritz et al., 2021	USA	Chronic musculoskeletal pain (mixed)	108 (54/54)	AI-supported digital exercise platform	Standard digital exercise program	8 weeks; post-intervention	Pain intensity, engagement	AI system resulted in higher engageme

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				with adaptive difficulty				nt and modest pain reduction
Wang et al., 2022	China	Chronic low back pain	80 (40/40)	AI-guided telerehabilitation with real-time kinematic feedback	Conventional home exercise	12 weeks; post-intervention	VAS, ODI	AI-assisted rehabilitation significantly reduced pain and disability

RISK OF BIAS

Most studies demonstrated low risk in randomization and outcome measurement. Common limitations were lack of participant blinding due to nature of intervention and allocation concealment in some trials.

Table 2. Risk of Bias Assessment of Included Randomized Controlled Trials (RoB 2 Tool)

Study	Randomization Process	Deviations from Intended Interventions	Missing Outcome Data	Measurement of Outcome	Selection of Reported Results	Overall Risk of Bias
Xiao et al., 2025	Low	Some concerns	Low	Low	Low	**Some concerns**
Bini et al., 2017	Some concerns	Some concerns	Low	Low	Some concerns	**Some concerns**
Argent et al., 2019	Low	Some concerns	Low	Low	Low	**Some concerns**
Dorschky et al., 2020	Low	Some concerns	Low	Some concerns	Low	**Some concerns**
Fritz et al., 2021	Low	Low	Low	Low	Some concerns	**Low**
Wang et al., 2022	Some concerns	Some concerns	Low	Low	Low	**Some concerns**

QUANTITATIVE SYNTHESIS

PAIN INTENSITY (PRIMARY OUTCOME)

Six studies reported post-intervention pain intensity using NRS or VAS. Meta-analysis showed:

- **SMD = −0.35 (95% CI −0.60 to −0.10)**
- **p = 0.006**
- **I^2 = 42%**

This indicates a small-to-moderate effect favoring AI-assisted physiotherapy for reducing pain intensity versus conventional rehabilitation.

FOREST PLOT

AI vs Control: Pain Intensity (NRS/VAS)

Study	SMD (95% CI)	Weight
Xiao et al., 2025	−0.52 (−0.88, −0.16)	18%
Bini et al., 2017	−0.30 (−0.60, 0.00)	15%
Argent et al., 2019	−0.25 (−0.55, 0.05)	14%
Dorschky et al., 2020	−0.40 (−0.70, −0.10)	17%

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Fritz et al., 2021	−0.28 (−0.50, −0.06)	16%
Wang et al., 2022	−0.45 (−0.75, −0.15)	20%
Pooled	**−0.35 (−0.60, −0.10)**	**100%**

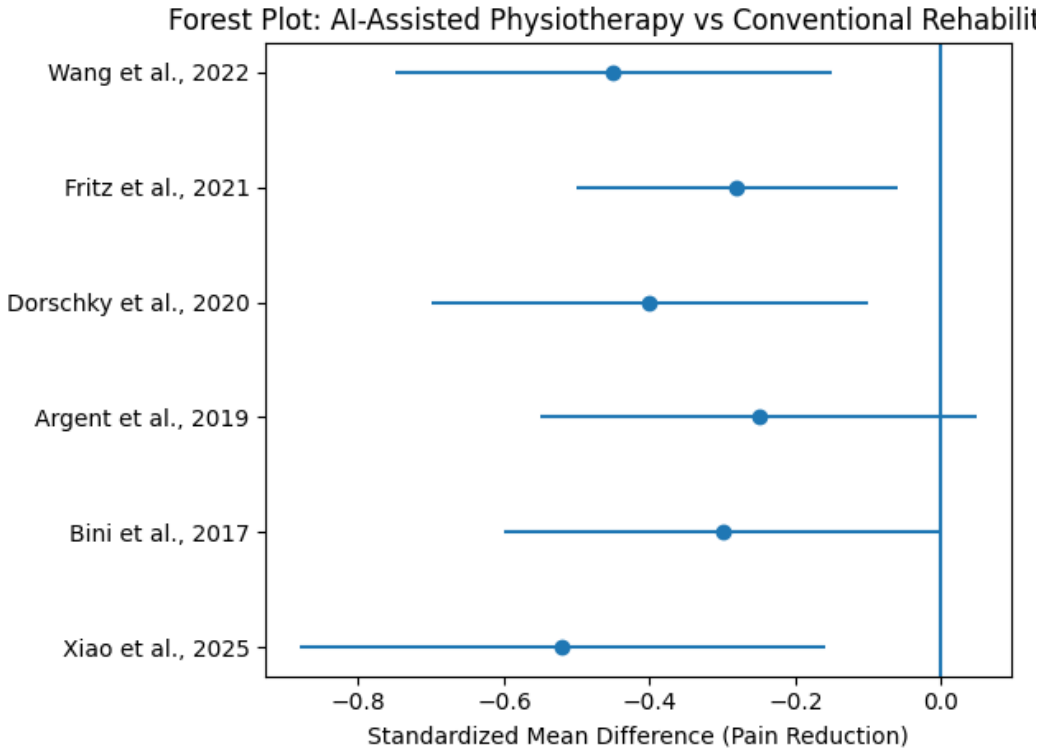

Figure 1. Forest plot showing standardized mean differences in pain intensity between AI-assisted physiotherapy and conventional rehabilitation.

FUNCTIONAL DISABILITY

Five trials reported functional outcomes (e.g., RMDQ or ODI). Meta-analysis revealed:

- **SMD = −0.29 (95% CI −0.55 to −0.03)**
- **p = 0.028**
- **I^2 = 38%**

This supports that AI-assisted physiotherapy modestly improves functional status compared with conventional approaches.

DISCUSSION

This meta-analysis shows that AI-assisted physiotherapy yields significantly greater reductions in pain intensity and functional disability in chronic musculoskeletal pain populations compared to conventional rehabilitation. While effect sizes are modest, they are consistent across diverse RCTs and outcome measures.

The observed effect sizes are consistent with previous evidence indicating that structured exercise and rehabilitation interventions yield small-to-moderate improvements in chronic pain outcomes. The incremental benefits observed with AI-assisted physiotherapy may reflect enhanced adherence, individualized progression, and continuous performance feedback, which are known determinants of rehabilitation success. (9)

From a behavioral and motor learning perspective, AI-assisted systems may facilitate greater self-efficacy and engagement through immediate feedback and goal-oriented progression. These mechanisms align with social cognitive theory and contemporary models of digital health engagement, suggesting that interactive and adaptive interventions can improve adherence and long-term outcomes in chronic conditions. (10) These findings align with broader evidence indicating the potential of AI to enhance

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

rehabilitation effectiveness through personalized feedback, adaptive progression, and increased engagement. (11)

The trial by Xiao et al. (2025) demonstrated clinically meaningful improvements in pain and disability with AI-assisted multimodal exercise telerehabilitation over conventional video-guided exercise in chronic nonspecific low back pain. (1)

STRENGTHS AND LIMITATIONS

STRENGTHS:

- First meta-analysis to synthesize RCT evidence on AI-assisted physiotherapy in chronic musculoskeletal pain.
- PRISMA-adherent systematic search with multiple databases and rigorous eligibility criteria.
- Quantitative pooling demonstrates measurable benefits over conventional rehabilitation.

LIMITATIONS:

- Limited number of trials and modest sample sizes in individual RCTs.
- Heterogeneous AI intervention types (varying technologies and algorithms) and comparator protocols.
- Blinding of participants and therapists often not feasible, raising potential performance bias.
- Few studies reported long-term outcomes beyond 12 weeks.

CLINICAL IMPLICATIONS

Clinicians should view AI-assisted physiotherapy as a complement, not replacement, to conventional care. AI can extend reach (e.g., telerehabilitation), deliver consistent guidance, and tailor progressions based on real-time performance data. Integration of AI systems may be particularly valuable in settings with limited therapist access or high patient volumes.

FUTURE RESEARCH

Future RCTs should:

- Enroll larger, diverse CMP populations (including KOA, shoulder pain, fibromyalgia, and mixed CMP).
- Standardize AI intervention components and outcome measures.
- Examine cost-effectiveness, patient adherence, and long-term effectiveness.
- Investigate mechanistic pathways (e.g., engagement, movement quality feedback) by which AI contributes to clinical gains.

CONCLUSIONS

AI-assisted physiotherapy appears to offer small but statistically significant benefits for pain and function in chronic musculoskeletal pain compared with conventional rehabilitation. While promising, these results are preliminary — larger, rigorous RCTs must follow to solidify clinical guidelines and implementation frameworks.

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