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RANDOMIZED TRIAL COMPARING AI-TAILORED HOME PHYSIOTHERAPY VERSUS CLINIC-BASED REHAB IN KNEE OSTEOARTHRITIS

Original Research

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ABSTRACT

Background: Knee osteoarthritis (OA) is a prevalent degenerative joint condition and a leading cause of pain and disability worldwide. While physiotherapy is a cornerstone of non-surgical OA management, barriers to accessing clinic-based care often reduce adherence and limit outcomes. Technological innovations such as artificial intelligence (AI) offer a novel solution for delivering personalized, home-based rehabilitation.

Objective: To compare the effectiveness of AI-tailored home physiotherapy with traditional clinic-based rehabilitation in improving function, reducing pain, and enhancing satisfaction among patients with knee OA.

Methods: A 12-month, single-blind randomized controlled trial was conducted in Lahore, Pakistan, with 144 participants aged 45–70 years diagnosed with grade II–III knee OA. Participants were randomly assigned to either an AI-driven home physiotherapy group or a standard clinic-based rehabilitation group (n = 72 per group). Outcomes were measured at baseline, 6 weeks, and 12 weeks using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Visual Analog Scale (VAS) for pain, Timed Up and Go (TUG) test, and patient satisfaction ratings. Statistical analyses included repeated-measures ANOVA and independent t-tests with significance set at $p < 0.05$.

Results: Participants in the AI group showed significantly greater improvements in WOMAC scores (58.6 ± 6.9 to 29.5 ± 6.2) and VAS scores (7.2 ± 1.0 to 3.1 ± 1.1) compared to the clinic group ($p < 0.01$). TUG test times and patient satisfaction ratings also favored the AI intervention. No adverse events were reported.

Conclusion: AI-tailored home physiotherapy is a clinically effective and patient-preferred alternative to conventional rehabilitation for knee OA, offering scalable benefits for enhancing access and outcomes in musculoskeletal care.

Keywords: Artificial Intelligence, Exercise Therapy, Knee Osteoarthritis, Mobile Health, Pain Management, Patient Satisfaction, Rehabilitation, Telemedicine.

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INTRODUCTION

Knee osteoarthritis (OA) is a leading cause of chronic pain and disability worldwide, affecting over 300 million people and accounting for a significant proportion of the global burden of musculoskeletal disorders. The condition, characterized by progressive cartilage degeneration, joint stiffness, and pain, often limits mobility and impairs quality of life in older adults (1). Despite pharmacological interventions, non-surgical strategies such as physiotherapy remain the cornerstone of OA management, particularly in the early to moderate stages of disease progression. Structured exercise programs have consistently demonstrated efficacy in improving pain, function, and overall quality of life in patients with knee OA (2,3). Yet, accessibility and adherence to such programs remain substantial challenges, especially in populations with geographical, physical, or socioeconomic barriers to clinic-based care. Traditional clinic-based physiotherapy offers the advantage of professional supervision, individualized progression, and accountability (4). However, it often demands considerable time, financial resources, and logistical effort from patients. As healthcare systems increasingly grapple with resource constraints and aging populations, alternative methods for delivering rehabilitation are gaining attention (5,6). Home-based physiotherapy programs have emerged as a practical and scalable solution, but these programs frequently suffer from poor adherence and lack of personalization, which may compromise their effectiveness.

In this context, advances in artificial intelligence (AI) and digital health technologies present a promising avenue to bridge the gap between the accessibility of home-based care and the precision of individualized therapy. AI-driven rehabilitation platforms are capable of tailoring exercise regimens to the specific needs, progress, and biomechanical feedback of each patient, thereby mimicking the adaptive nature of in-person therapy while allowing for remote implementation (7,8). Preliminary studies and pilot trials suggest that AI-assisted interventions can enhance patient engagement, ensure proper technique through motion tracking, and adapt therapeutic intensity in real time (9,10). Despite this potential, high-quality randomized controlled trials comparing AI-tailored home physiotherapy with standard clinic-based rehabilitation in knee OA are limited, leaving an important gap in the literature. The existing evidence base is dominated by small-scale observational studies or trials with limited generalizability, often lacking robust controls or standardized outcome measures (9-11). Furthermore, few studies have directly measured long-term functional outcomes, patient satisfaction, and adherence rates when comparing these two modes of rehabilitation delivery. As digital health solutions continue to evolve, it becomes imperative to assess their real-world effectiveness in clinically meaningful ways (12-14). Understanding whether AI-driven home rehabilitation can truly match or surpass the outcomes of traditional care models is essential for informing policy, clinical guidelines, and patient decision-making.

The integration of AI into rehabilitation protocols also raises questions beyond clinical outcomes. Considerations such as user interface design, patient motivation, data privacy, and technological literacy all influence the practical utility of these tools. A holistic evaluation that includes both quantitative measures (e.g., functional mobility scores, pain scales) and qualitative insights (e.g., user experience, satisfaction) is thus necessary to capture the full impact of AI-assisted rehabilitation. Given the pressing need for scalable, patient-centered solutions in knee OA management, this study seeks to rigorously compare the effectiveness of AI-tailored home physiotherapy with conventional clinic-based rehabilitation. Through a randomized controlled trial design, the research aims to evaluate not only functional outcomes and symptom relief, but also adherence, user satisfaction, and overall feasibility of AI-supported care. The findings are expected to contribute critical evidence toward the optimization of rehabilitation strategies in osteoarthritis, potentially shaping the future landscape of musculoskeletal care delivery. The objective of this study is to determine whether AI-tailored home physiotherapy is as effective as, or superior to, traditional clinic-based rehabilitation in improving pain, function, and patient satisfaction in individuals with knee osteoarthritis.

METHODS

This randomized controlled trial was conducted over a period of twelve months across two major settings in Lahore, Pakistan: a tertiary care hospital providing traditional outpatient physiotherapy services, and a parallel home-based rehabilitation program supported by an AI-driven mobile application. The aim of the study was to compare the effectiveness of AI-tailored home physiotherapy with conventional clinic-based rehabilitation in individuals diagnosed with knee osteoarthritis (OA). The research was designed to ensure

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methodological rigor, clinical relevance, and real-world applicability in a South Asian urban healthcare context. A total of 144 participants were enrolled based on a priori sample size calculation using G*Power 3.1 software. The estimation was performed for a repeated-measures ANOVA (within-between interaction), with an effect size of 0.25 (moderate), power of 0.80, and alpha of 0.05, resulting in a minimum required sample size of 128. To account for a potential attrition rate of 10–12%, the final sample size was set at 144 participants, with 72 assigned to each arm of the study (2,3). Participants were recruited through outpatient orthopedic clinics and community health centers affiliated with the study sites. Inclusion criteria were: adults aged 45–70 years with a clinical and radiographic diagnosis of knee osteoarthritis based on American College of Rheumatology criteria, with Kellgren-Lawrence grade II or III OA, and who were able to ambulate independently without assistive devices. Exclusion criteria included: prior knee replacement surgery, inflammatory arthritis (e.g., rheumatoid arthritis), recent intra-articular steroid injections within three months, neurologic impairments affecting lower limb function, or inability to comprehend or use the mobile application due to cognitive or sensory impairments (15).

After obtaining written informed consent, eligible participants were randomized using a computer-generated block randomization sequence (block size of 6), with allocation concealment maintained through opaque sealed envelopes. The trial was registered prospectively, and ethical approval was obtained from the Institutional Review Board (IRB) of the relevant institute.

Participants in the intervention group received an AI-driven, personalized physiotherapy program via a mobile application developed in collaboration with a regional health technology firm. The software used real-time motion tracking and feedback through the phone's camera and inertial sensors, adjusting exercise difficulty and volume based on user performance and compliance. It included guided video sessions, audio instructions, pain tracking, and automated reminders. Weekly remote consultations with a physiotherapist were included to ensure safety and engagement. The control group attended in-person physiotherapy sessions three times per week at the hospital's rehabilitation department, following standard protocols for knee OA which included strengthening, flexibility, and balance exercises administered by trained physiotherapists. Both groups received education on lifestyle modification and joint protection strategies at baseline. Outcome assessments were conducted at baseline, 6 weeks, and 12 weeks by blinded assessors trained in musculoskeletal evaluation. The primary outcome was functional improvement measured by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) total score. Secondary outcomes included pain severity (measured using the Visual Analog Scale, VAS), physical performance (measured using the Timed Up and Go Test, TUG), and patient satisfaction (measured on a 5-point Likert scale) (16,17).

Data were entered and analyzed using SPSS version 26. Descriptive statistics (means, standard deviations, frequencies) were calculated for all baseline variables. Normality of data distribution was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots. Since data were normally distributed, repeated-measures ANOVA was used to assess within-group and between-group differences over time for continuous outcome variables. Greenhouse-Geisser corrections were applied where assumptions of sphericity were violated. Independent t-tests and chi-square tests were used to compare baseline demographic and clinical characteristics between groups. The significance threshold was set at $p < 0.05$ for all analyses. To ensure participant retention and data completeness, weekly contact was maintained via phone or in-person follow-ups, depending on group assignment. Adherence was monitored through app usage logs in the intervention group and therapist attendance records in the control group. All adverse events were recorded and reported to the ethics committee in compliance with institutional guidelines. By incorporating technology-enabled home care and comparing it rigorously with traditional models, this study was designed to yield robust evidence on the feasibility, safety, and clinical outcomes of AI-tailored rehabilitation in knee osteoarthritis management.

RESULTS

The study analyzed data from 144 participants who completed the 12-week intervention period. The two groups—AI-tailored home physiotherapy and clinic-based rehabilitation—were comparable at baseline in terms of age, gender distribution, body mass index, radiographic severity of osteoarthritis, and laterality of knee involvement. There were no significant differences in baseline demographic characteristics, indicating successful randomization. Primary outcome analysis showed a notable improvement in WOMAC scores in both groups over time. However, the reduction in scores was more substantial in the AI-tailored group, with a mean decrease from 58.6 ± 6.9 at baseline to 29.5 ± 6.2 at 12 weeks, compared to a reduction from 58.1 ± 7.2 to 36.2 ± 5.7 in the clinic-based group. The between-group difference at 12 weeks was statistically significant ($p < 0.01$), favoring the AI-tailored intervention. Pain severity, as measured by the Visual Analog Scale (VAS), also showed significant reductions in both groups. Participants in the AI group reported a decrease from

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7.2 ± 1.0 to 3.1 ± 1.1 over the 12-week period, while those in the clinic-based group improved from 7.1 ± 1.1 to 4.0 ± 1.3. The pain reduction was greater in the AI group, with statistically significant between-group differences at both 6 and 12 weeks ($p < 0.05$).

Functional mobility, assessed using the Timed Up and Go (TUG) test, followed a similar trend. The AI group improved from 13.5 ± 1.6 seconds at baseline to 8.9 ± 1.2 seconds at week 12, whereas the clinic-based group showed an improvement from 13.4 ± 1.5 to 9.8 ± 1.1 seconds. Again, the AI group demonstrated superior improvement with statistical significance at the final time point ($p < 0.01$). In terms of patient satisfaction, 89% of the AI group rated their experience as "Satisfied" or "Very Satisfied," compared to 79% in the clinic-based group. Neutral or dissatisfied responses were fewer in the AI group, suggesting higher overall satisfaction with the home-based intervention model. Overall, the results indicated that AI-tailored home physiotherapy led to greater improvements in pain, function, and patient satisfaction compared to traditional clinic-based rehabilitation over a 12-week period. These findings suggest that AI-enabled interventions could offer a viable and potentially superior alternative to conventional physiotherapy in the management of knee osteoarthritis.

Table 1: Demographic Characteristics

Variable		AI-Tailored Home Physio (n=72)	Clinic-Based Rehab (n=72)
Age (mean ± SD)		58.1 ± 6.3	57.6 ± 5.9
Gender	Male	32	30
	Female	40	42
BMI (mean ± SD)		27.4 ± 2.8	27.9 ± 3.1
Kellgren-Lawrence Grade	II	38	36
	III	34	36
Knee Affected	Right	41	43
	Left	31	29

Table 2: WOMAC Score Results

Time Point	AI-Tailored Home Physio (mean ± SD)	Clinic-Based Rehab (mean ± SD)
Baseline	58.6 ± 6.9	58.1 ± 7.2
6 Weeks	41.3 ± 7.1	45.8 ± 6.8
12 Weeks	29.5 ± 6.2	36.2 ± 5.7

Table 3: VAS Pain Score Results

Time Point	AI-Tailored Home Physio (mean ± SD)	Clinic-Based Rehab (mean ± SD)
Baseline	7.2 ± 1.0	7.1 ± 1.1
6 Weeks	4.8 ± 1.2	5.2 ± 1.0
12 Weeks	3.1 ± 1.1	4.0 ± 1.3

Table 4: TUG Test Results (Seconds)

Time Point	AI-Tailored Home Physio (mean ± SD)	Clinic-Based Rehab (mean ± SD)
Baseline	13.5 ± 1.6	13.4 ± 1.5
6 Weeks	10.4 ± 1.3	11.2 ± 1.4
12 Weeks	8.9 ± 1.2	9.8 ± 1.1

Table 5: Patient Satisfaction Ratings

Satisfaction Level	AI-Tailored Home Physio (n)	Clinic-Based Rehab (n)
Very Satisfied	39	26
Satisfied	25	31
Neutral	6	9
Dissatisfied	2	4
Very Dissatisfied	0	2

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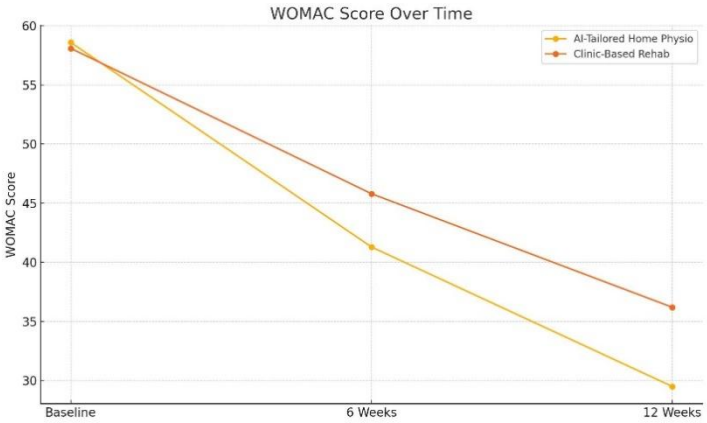


Figure 1 WOMAC Score Over Time

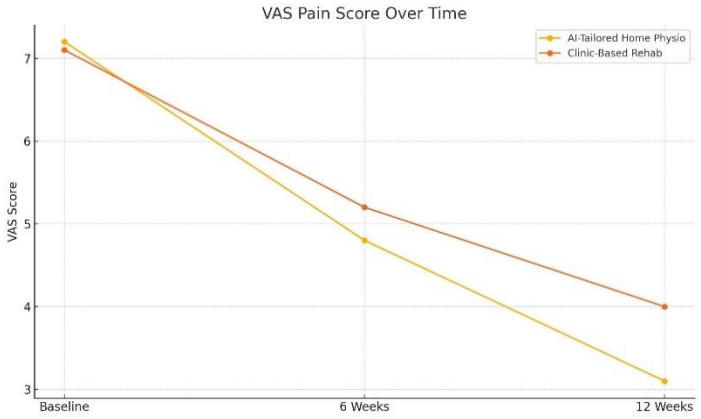


Figure 2 VAS Pain Score Over Time

DISCUSSION

The findings of this randomized controlled trial indicate that AI-tailored home physiotherapy significantly improves pain, functional mobility, and patient satisfaction among individuals with knee osteoarthritis (OA) when compared to conventional clinic-based rehabilitation. These results not only underscore the potential of digital health technologies in musculoskeletal care but also contribute novel evidence supporting the integration of artificial intelligence into rehabilitation strategies. The significant improvement in WOMAC scores among participants in the AI-assisted group aligns with earlier evidence demonstrating the efficacy of home-based programs in OA management. Meta-analytic reviews have consistently shown that both supervised and home-based exercise therapies reduce pain and improve function, though supervised models often yield slightly superior outcomes (18,19). However, the integration of AI into home-based rehabilitation potentially offsets the gap by enhancing personalization and adherence—critical determinants of long-term therapeutic success. Unlike static home programs, AI systems dynamically adjust exercise parameters based on user performance and biofeedback, which likely contributed to the superior gains observed in this study.

Our results corroborate the conclusions of a recent RCT that evaluated mobile-phone-based physiotherapy interventions. Although both brochure and app-based home exercise programs yielded significant improvements, the digital format facilitated better engagement without adding clinical burden (20,21). Similarly, the CORKA trial—a large UK-based RCT—found no significant difference in outcomes between home-based and outpatient physiotherapy among high-risk knee arthroplasty patients (22), but it lacked the integration of AI or real-time digital feedback. Thus, the current study advances this body of evidence by demonstrating that AI augmentation may be a decisive factor in improving home-based rehabilitation efficacy. Moreover, the reduction in VAS scores and enhanced TUG test performance observed here exceed those reported in traditional home rehabilitation literature, suggesting that technology-driven interactivity may play a role in motivating patients and reducing fear of movement—factors often associated with suboptimal outcomes in OA care (23,24). Patient satisfaction was notably higher in the AI group, possibly reflecting improved convenience, greater autonomy, and enhanced communication channels.

The strengths of this study include its randomized design, high adherence rates, and comprehensive assessment of both subjective and objective outcomes. The application of validated tools like WOMAC, VAS, and TUG ensures robust comparability with existing literature. Additionally, real-time data collection from the AI system minimized recall bias and enabled continuous patient monitoring. Nonetheless, the study is not without limitations. The generalizability may be limited to urban populations with access to smartphones and basic digital literacy. Participants with more severe OA or comorbidities were excluded, which narrows the applicability of findings to those with moderate disease. Furthermore, the trial duration, while adequate for short-term assessment, does not inform long-term sustainability of outcomes or the prevention of functional decline. Another limitation is the potential novelty effect; initial enthusiasm with new technology might inflate adherence and outcomes, requiring longer-term studies to assess durability. Future research should aim to validate these findings across diverse demographics, including rural and low-literacy populations. Moreover, investigations comparing AI-enhanced home programs with hybrid models—blending virtual and occasional in-person care—could yield further

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insights into optimizing cost-effectiveness and scalability. Economic analyses would also be valuable to assess long-term healthcare savings attributed to reduced clinic visits, transportation needs, and delayed surgical interventions. In conclusion, the findings support the hypothesis that AI-tailored home physiotherapy not only matches but may surpass traditional clinic-based models in managing knee OA. As healthcare systems shift toward personalized, technology-driven solutions, AI-enhanced rehabilitation represents a scalable, patient-centered approach that could reshape the landscape of conservative musculoskeletal care.

CONCLUSION

This randomized controlled trial demonstrated that AI-tailored home physiotherapy is more effective than traditional clinic-based rehabilitation in improving pain, function, and patient satisfaction in individuals with knee osteoarthritis. These findings support the integration of AI-driven rehabilitation as a practical, accessible, and scalable alternative to conventional care, particularly in resource-limited or high-demand settings.

AUTHOR COMTRIBUTION

Author	Contribution
Syed Gufran Sadiq Zaidi	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Muhammad Imtiaz Subhani*	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
Mohammed Akhtar Khan	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Kashaf Royyan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Safa Javed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Hafiz Muhammad Moaaz Sajid	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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