

Effectiveness of Virtual Reality-based Rehabilitation Combined with Conventional Therapy in Reducing Pain and Improving Function in Knee Osteoarthritis: An Observational Pilot Study

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ABSTRACT

Background: Knee osteoarthritis (KOA) is a leading cause of disability worldwide, with a high prevalence in India. Conventional rehabilitation is effective but often limited by low adherence and engagement. Virtual reality-based rehabilitation (VRBR) offers immersive, interactive environments that may enhance motivation, reduce pain perception, and improve function.

Objective: To evaluate the preliminary effectiveness of VRBR combined with conventional therapy in reducing pain and improving functional outcomes in patients with KOA.

Materials and methods: A pilot study was conducted at the Government Institute of Rehabilitation Medicine (GIRM), Chennai (January–April 2025) on 30 patients with primary KOA [Kellgren–Lawrence (K-L) grades II–IV]. All received conventional physiotherapy along with 4–10 sessions of immersive VR therapy, with pain and function assessed using visual analog scale (VAS) and Western Ontario and McMaster universities osteoarthritis index (WOMAC), and correlations examined for session count and radiographic severity.

Results: Significant improvements were observed in pain (VAS: 6.56 ± 1.79 to 2.30 ± 1.39 , $p < 0.001$) and function (WOMAC: 39.1 ± 8.53 to 18.1 ± 7.80 , $p < 0.001$). No significant correlation was found between the number of VR sessions and changes in VAS ($p = 0.917$) or WOMAC ($p = 0.299$). A moderate positive correlation was identified between VR session outcomes and radiographic OA grade ($p = 0.507$, $p = 0.004$).

Conclusion: Virtual reality-based rehabilitation combined with conventional therapy significantly reduced pain and improved function in patients with KOA. While benefits were not linked to session frequency, radiographic severity showed a moderate influence on outcomes. These findings support VRBR as a feasible adjunct to conventional rehabilitation, warranting further validation through larger, multicenter randomized trials.

Keywords: Knee osteoarthritis, Pain management, Physiotherapy, Visual analog scale, Virtual reality rehabilitation, Western Ontario and McMaster universities osteoarthritis index.

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INTRODUCTION

Osteoarthritis (OA) is a prevalent chronic, degenerative joint disorder characterized by the progressive deterioration of articular cartilage, osteophyte formation at joint margins, subchondral bone sclerosis, and a range of biochemical and morphological changes in the synovial membrane and joint capsule.¹ It is a major global public health concern and the most common cause of joint dysfunction, particularly among older adults.

In India, the burden of OA is significantly higher compared to Western countries, with a reported prevalence ranging from 22 to 30%. It is the leading cause of joint-related disability in the Indian population. The disease disproportionately affects women, and the risk increases with age—approximately 45% of Indian women over 65 report symptoms, and nearly 70% exhibit radiographic evidence of OA. Globally, OA is ranked as the 10th leading cause of nonfatal health problems, severely impacting quality of life and imposing substantial strain on healthcare systems.²

Osteoarthritis is influenced by multiple factors, including aging, female gender, obesity, joint trauma, genetic predisposition, metabolic disorders, and vitamin D deficiency. Lifestyle factors also play a role, with sedentary behavior more common in

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urban populations, and physically demanding labor being a key contributor in rural areas.

Knee OA (KOA) presents symptoms such as joint pain, stiffness, crepitus during movement, reduced mobility, and difficulty

performing everyday tasks such as walking, climbing stairs, and squatting.³ These limitations greatly impact daily function and are often associated with pain, stiffness, reduced physical function, poor sleep, social isolation, and mental health challenges—ultimately leading to a decline in overall quality of life.

Conventional rehabilitation—comprising strength training, flexibility exercises, and patient education—remains a key non-surgical intervention for managing KOA. However, its long-term effectiveness is often compromised by low patient adherence, limited engagement, and suboptimal pain control.

In recent years, virtual reality (VR)-based rehabilitation has emerged as a promising adjunct to traditional therapy. By offering interactive, gamified environments, VR enhances patient motivation and engagement. It provides real-time feedback, multisensory stimulation, and task-oriented training, which may improve neuromuscular control, balance, proprioception, and pain perception. The immersive nature of VR also serves as a cognitive distraction, helping to reduce the subjective experience of pain and emotional distress during exercise.

Despite its growing global adoption in musculoskeletal rehabilitation, the application of immersive VR in managing KOA remains relatively underexplored, particularly within the Indian healthcare setting. There is a notable scarcity of region-specific evidence addressing its clinical utility for pain reduction in KOA patients.

Given these gaps, a pilot study is warranted to evaluate the preliminary effectiveness of integrating VR-based rehabilitation with conventional therapy. This study aims to assess whether such a combined approach can reduce pain and improve functional outcomes in Indian patients with KOA.

MATERIALS AND METHODS

Study Design

This pilot observational study evaluated the effectiveness of immersive VR combined with conventional rehabilitation in reducing pain and improving physical function in individuals with KOA.

Settings

The study was conducted at the Government Institute of Rehabilitation Medicine (GIRM), Chennai, from January 2025 to April 2025. This pilot observational study included all eligible patients attending the Outpatient (OP) Physical Medicine and Rehabilitation (PMR) Department, with participants recruited through purposive sampling. Individuals who met the inclusion criteria were enrolled.

Participant Criteria

Inclusion Criteria

- Age group – 40–80 years
- Gender – both male and female
- Knee pain >6 months
- Primary OA
- Radiographic confirmation of OA – Kellgren and Lawrence OA classification

Exclusion Criteria

- Secondary OA
- Any surgeries related to the lower limb

Study Variables

The study included both exposure variables and clinical outcome variables, assessed at baseline and post-intervention.

Exposure Variables

Participants were first evaluated by a PMR using the designated outcome measures. After baseline assessment, they underwent conventional physiotherapy followed by an immersive VR-based rehabilitation program administered by a physiotherapist.

Conventional physiotherapy included the use of electrophysical agents for pain management. Virtual reality-based rehabilitation (VRBR) sessions lasted 20–30 minutes each, and only participants who completed a minimum of 4 and up to 10 sessions were included.

The VR intervention followed a structured, progressive protocol tailored to functional capacity:

- Sessions 1–2: Relaxation therapy and pain management
- Sessions 3–4: Relaxation therapy and initiation of knee-extension exercise in a seated position
- Sessions 5–6: Relaxation therapy and combined knee and hip extension exercise in a seated position
- Sessions 7–8: Relaxation therapy, seated knee-extension exercises, and standing hip exercises
- Sessions 9–10: Relaxation therapy, progressive knee and hip exercises, and standing balance training

The main exposure variable for analysis was the number of VR sessions completed.

Primary Outcome Variables

- Visual Analog Scale (VAS): A 0–10 numerical scale used to quantify the intensity of knee pain.
- Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC): Used to assess pain, stiffness, and physical function in individuals with KOA.

Other Variables

- Baseline demographic and clinical characteristics (age, sex, side affected, and diagnosis) were also recorded for descriptive purposes.

Data Sources/Measurements

Outcome assessments were conducted twice:

- Baseline (day 1) prior to initiation of immersive VR therapy.
- Post-intervention (final day) after completion of the VR sessions.
- Both VAS and WOMAC were administered face-to-face by the same PMR, using standardized instructions and scoring procedures.

Bias

Bias was minimized by having the same PMR perform all baseline and post-intervention assessments, reducing assessor variability. Standardized tools (VAS and WOMAC) and uniform instructions were used to limit measurement bias. All participants received the same VR therapy protocol to avoid performance bias.

Study Size

A minimum sample size of 30 was selected to generate preliminary evidence on the effectiveness of the intervention.

Table 1: Participants' demographics and baseline characteristics (n = 30)

Characteristic	Category	Value
Age (years)	Mean $\pm$ SD	58.4 $\pm$ 1.3
Gender		
Male	n (%)	2 (6.7%)
Female	n (%)	28 (93.3%)
No. of VR sessions	Mean $\pm$ SD	5.8 $\pm$ 1.3
K-L grade		
Grade II	n (%)	5 (16.6%)
Grade III	n (%)	22 (73.3%)
Grade IV	n (%)	3 (10%)

K-L, Kellgren–Lawrence

Table 2: Effect of VRBR on pain and function

Outcome measures	Pre-score mean $\pm$ SD	Post-score mean $\pm$ SD	p-value
VAS	6.56 $\pm$ 1.79	2.30 $\pm$ 1.39	<0.001
WOMAC	39.1 $\pm$ 8.53	18.1 $\pm$ 7.80	<0.001

VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index

Statistical Methods

Descriptive statistics were used to summarize participant demographics and baseline characteristics, with continuous variables reported as means and standard deviations (SD) and categorical variables as frequencies and percentages.

For the primary analysis, pre–post-intervention differences in VAS and WOMAC scores were assessed using the Wilcoxon signed-rank test when data were non-normally distributed.

For the secondary analysis, the association between the number of VR sessions, clinical outcomes (VAS and WOMAC), and radiographic severity [Kellgren–Lawrence (K-L) grade] was examined using Spearman's rank correlation coefficient, appropriate for ordinal and non-parametric data.

A p-value < 0.05 was considered statistically significant.

RESULTS

The results are presented in three sections: Participant demographics and baseline characteristics (Table 1), primary analysis, and secondary analysis. The primary analysis assessed the impact of VR-based rehabilitation on clinical outcomes, specifically pain and physical function, using the VAS and the WOMAC (Table 2). The secondary analysis examined the relationship between the number of VR sessions and radiographic severity of KOA (K-L grade) with clinical outcomes, to determine whether these factors influenced the treatment response (Tables 3 and 4).

Primary Analysis

The study demonstrates statistically significant improvements in both pain and functional ability as measured by the VAS and WOMAC scores from pre- to post-intervention.

Visual Analog Scale

There is a significant reduction in pain levels following the intervention, as indicated by a large decrease in the VAS score.

Table 3: Correlation of VR session with VAS and WOMAC

Clinical outcome	Spearman's ρ	p-value
VAS	0.020	0.917
WOMAC	0.196	0.299

VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index

Table 4: Correlation of VR session with radiographic OA grade

Clinical outcome	Spearman's ρ	p-value
VR session with radiographic OA grades	0.507	0.004

OA, osteoarthritis; VR, virtual reality

The p-value (<0.001) confirms that this change is highly statistically significant.

Western Ontario and McMaster Universities Osteoarthritis Index

The reduction in the WOMAC score suggests substantial improvement in joint function, stiffness, and physical activity limitations. Again, the p-value (<0.001) indicates a statistically significant improvement.

Secondary Analysis

No statistically significant correlation was found between the number of VR sessions and improvements in either pain (VAS) or function (WOMAC) scores.

A moderate positive correlation was observed between VR session outcomes and radiographic OA grades.

DISCUSSION

This study demonstrated that a VR-based rehabilitation program significantly improved pain and functional outcomes in individuals with KOA. Both VAS and WOMAC scores showed statistically significant reductions following the intervention, indicating clinically meaningful improvements.

Effect of Immersive VR on Pain

Chronic joint pain is the most prominent and disabling symptom of OA, substantially affecting mobility, sleep, emotional health, and overall quality of life. In patients with KOA, neuroimaging research has revealed changes in brain network excitability and connectivity, marked by a shift from areas predominantly responsible for sensory processing to regions associated with emotional and affective regulation.⁴

Emerging evidence, including findings from systematic reviews and meta-analyses, indicates that VR-based exercise therapy is effective in reducing pain among patients with KOA.^{4,5} Virtual reality creates fully immersive, interactive environments that engage multiple sensory modalities, thereby diverting attention from pain and diminishing the subjective experience of discomfort. This analgesic effect is grounded in the neuromatrix theory of pain, which posits that pain is not merely a direct response to sensory input but is instead generated by a neural matrix—an interconnected network of neurons influenced by cognitive, affective, and sensory signals. Through immersive and engaging

stimuli, VR can modulate this network, leading to alterations in pain perception, emotional responses, and stress regulation.

Two primary neuromodulatory mechanisms are believed to underpin VR's efficacy in pain reduction. First, VR can influence central pain processing by modifying how the brain interprets nociceptive signals, thereby lowering the perceived intensity of pain. Second, according to the gate control theory, VR activates alternative sensory pathways, which can inhibit the transmission of pain signals at the spinal level by "closing the gate" to nociceptive input.

Additional support for VR's effectiveness comes from systematic reviews and meta-analyses examining immersive VR interventions in postoperative settings such as total knee replacement (TKR). These studies consistently report significant reductions in pain immediately following VR sessions, as measured by standardized tools like the VAS and the Numeric Pain Rating Scale (NPRS).⁵ Consistent with these findings, the present study demonstrated a significant reduction in pain levels among KOA patients following VR-based intervention, as evidenced by a marked decrease in VAS scores. This change was statistically significant ($p < 0.001$), indicating a strong therapeutic effect of VR on pain modulation in this population.

Effect of Immersive VR on Function

The findings of our study align with and expand upon existing evidence from recent systematic reviews and meta-analyses evaluating the efficacy of VR rehabilitation in managing KOA (KOA) and postoperative recovery following TKR.⁵ Knee OA is characterized by progressive joint degradation and inflammation, which contribute to chronic knee pain, functional limitations, and joint stiffness. These pathological changes are exacerbated by abnormal mechanical loading, which can damage the articular cartilage and initiate maladaptive cellular responses in both cartilage and synovium. As a result, patients often reduce physical activity to avoid discomfort, leading to further deterioration in joint function.

Despite well-documented benefits of exercise therapy for KOA, pain-related fear and reduced motivation present significant barriers to adherence. In this context, VRBR presents a novel and promising modality that addresses both physiological and psychological barriers to rehabilitation. Virtual reality-based interventions leverage immersive and gamified environments to enhance user engagement, facilitate task-oriented movement, and improve adherence through increased motivation and enjoyment. These factors contribute to improved outcomes in knee joint rehabilitation.

Neuroscientific mechanisms may further explain the advantages of VRBR. The immersive experience has been shown to enhance dopaminergic transmission in the striatum, which improves attention, sensorimotor integration, and behavioral reinforcement.⁴ According to the central integration theory, VR-mediated proprioceptive stimulation facilitates motor learning and neuromuscular reeducation, thereby improving joint stability and muscle strength around the knee. This sensorimotor integration is particularly important in restoring functional movement patterns compromised by KOA and TKR.

Our present findings support these theoretical and empirical observations. The significant reduction in WOMAC scores ($p < 0.001$) indicates substantial improvements in joint function, stiffness, and limitations in physical activity following VRBR. These results underscore the short-term efficacy of VRBR in enhancing functional outcomes, consistent with prior meta-analyses that reported superior

knee function with VRBR compared to conventional physical therapy (CPT). The enhanced motor learning associated with full-immersion VR likely contributed to the greater functional gains observed.

Correlation of Immersive VR Session with VAS and WOMAC

In this study, we correlated the number of immersive VR sessions with pain (VAS) and functional outcomes (WOMAC). While existing randomized controlled trials (RCTs) and meta-analyses consistently demonstrate that VR interventions improve pain and function in KOA patients, none have specifically examined dose-response relationships within intervention groups.^{4,5} Our analysis revealed that correlations between VR sessions and both VAS and WOMAC were weak and not statistically significant. This suggests that the clinical benefits of VR may be influenced by additional factors such as patient engagement, neurocognitive modulation, or psychological mechanisms, rather than being solely dependent on session count. The influence of the quantity of VR sessions on outcomes requires further exploration in larger, well-controlled studies to determine whether a dose-response effect truly exists.

Correlation of Immersive VR Session with Radiographic KOA

Our study demonstrated a moderate positive correlation between VR session outcomes and radiographic OA grades, indicating that patients with higher radiographic OA severity exhibited a stronger association with VR-based exercise outcomes. This finding aligns with evidence from recent systematic reviews and meta-analyses, which have highlighted that VR therapy exerts beneficial effects across different K-L grades of KOA, though with varying magnitudes.⁴

In early KOA (K-L grade II), VR-based exercise has been shown to be highly effective due to preserved joint structure, greater neuromuscular plasticity, and relatively intact muscle strength. These patients experience significant pain relief and functional gains, which may contribute to slowing disease progression. In mid-stage KOA (K-L grade III), despite greater structural damage and functional impairment, VR therapy still provides meaningful pain reduction and functional improvements through mechanisms such as distraction, engagement, and enhancement of muscle strength and stability. However, in late-stage KOA (K-L grade IV), where severe joint deformity and muscle weakness dominate, VR interventions show limited physical benefit. Nevertheless, they remain valuable in supporting pain coping, psychological well-being, and maintenance of activity.

Taking together, our findings complement the existing literature by suggesting that the relationship between OA severity and VR outcomes is not linear but stage dependent. The moderate positive correlation observed in our study may reflect the fact that patients with more advanced disease perceive greater relative benefit from VR interventions, particularly in terms of pain management and quality of life. At the same time, the diminishing physical effects observed in late KOA emphasize the need for stage-specific, adaptive, and personalized VR protocols.

CONCLUSION

This pilot study demonstrated that VRBR, when combined with conventional therapy, significantly reduced pain and improved functional outcomes in individuals with KOA. The observed decreases in VAS and WOMAC scores highlight the potential of

immersive VR to provide clinically meaningful benefits through modulation of pain perception, enhancement of motor learning, and increased engagement in rehabilitation. While no significant dose–response relationship was found between the number of VR sessions and clinical outcomes, the findings suggest that therapeutic benefits may depend more on neurocognitive and psychological mechanisms than on session frequency alone. Furthermore, the moderate correlation between VR outcomes and radiographic OA severity underscores the importance of tailoring VR interventions to disease stage, with promise for patients in early-to-mid KOA. Taking together, these results support VRBR as a feasible and effective adjunct to conventional therapy for managing pain and functional impairment in KOA.

Limitations

This pilot study had a small sample size, a single-center design, and a predominance of female participants, limiting generalizability. The absence of a control group and short intervention period without follow-up restricts conclusions on long-term efficacy.

Way Forward

Future research should include larger, multicenter RCTs with longer follow-up to establish sustained benefits. Stage-specific

VR protocols, optimal session dosage, and home-based or tele-rehabilitation models warrant exploration to enhance accessibility and scalability of VR-based rehabilitation in KOA.

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REFERENCES

1. Pal CP, Singh P, Chaturvedi S, et al. Epidemiology of knee osteoarthritis in India and related factors. *Indian J Orthop* 2016;50(5):518–522. DOI: 10.4103/0019-5413.189608.
2. Acharya RN, Patel HM. Prevalence of the knee osteoarthritis risk factors among young adult population – An observational study. *Int J Health Sci Res* 2023;13(10):158–163. DOI: 10.52403/ijhsr.20231022.
3. Heidari B. Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part I. *Caspian J Intern Med* 2011;2(2):205–212. PMID: 24024017.
4. Wei W, Tang H, Luo Y, et al. Efficacy of virtual reality exercise in knee osteoarthritis rehabilitation: A systematic review and meta-analysis. *Front Physiol* 2024;15:1424815. DOI: 10.3389/fphys.2024.1424815.
5. Shaheen AAM, Algabbani MF, Alshahrani MM, et al. Efficacy of virtual reality-based rehabilitation following total knee replacement: A systematic review and meta-analysis of randomized control trials. *Bull Fac Phys Ther* 2025;30(1):15. DOI: 10.1186/s43161-024-00246-y.