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Psychological Dimensions of Virtual Reality mediated Exercise programs in Knee Osteoarthritis Management: A Scoping Review

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ABSTRACT

Background: Knee osteoarthritis (KOA) involves substantial psychological complications beyond physical manifestations. While exercise remains the gold standard first line treatment, KOA patients often exhibit poor compliance due to pain-related and motivational obstacles. Immersive virtual reality (IVR) technology may improve exercise participation while targeting psychological dimensions of chronic pain conditions. This scoping review evaluates Virtual Reality (VR) and scope of IVR exercise interventions and their psychological impacts in KOA populations.

Methods: Following Joanna Briggs Institute methodology and PRISMA-ScR guidelines, this scoping review systematically mapped evidence regarding psychological effects of VR interventions in KOA patients. A comprehensive search strategy utilized Boolean operators and MeSH terms focusing on three primary concepts: Virtual reality technologies (Immersive and non-immersive), knee osteoarthritis populations, and psychological outcomes. Six databases were searched from inception: PubMed/MEDLINE, Scopus, Web of Science, PsycINFO, CINAHL Plus, and IEEE Xplore Digital Library.

Results: Fourteen studies meeting inclusion criteria were analysed, including two randomized controlled trials examining IVR in KOA, six cross-sectional studies investigating psychological factors in KOA, and two systematic reviews examining VR effects on kinesiophobia and exercise interventions for psychological parameters in KOA.

Conclusions: VR-mediated and conventional exercise interventions show promise for addressing KOA's psychological components alongside physical rehabilitation through kinesiophobia reduction, self-efficacy enhancement, and modification of related psychological factors. IVR demonstrates effectiveness in improving physical outcomes. Future investigations should establish standardized protocols and explore psychological effects of these interventions in KOA management.

KEYWORDS: virtual reality, knee osteoarthritis, psychological dimensions, exercise interventions, kinesiophobia, rehabilitation.

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INTRODUCTION

Osteoarthritis (OA) is a long-lasting condition characterized by the gradual deterioration of articular cartilage, subchondral bone, ligaments, joint capsule, and synovium.[1] OA is linked not only to unfavourable physical outcomes but also to adverse psychological effects, including depressive symptoms and anxiety.[2] Patients with knee osteoarthritis (KOA) exhibit decreased physical activity along with diminished muscle strength and flexibility, leading to functional impairments, which consequently decrease their quality of life. These changes in quality of life can result in symptoms of depression and anxiety.[2] Osteoarthritis is a long-term chronic pain condition, and the escalation of pain may lead individuals to either avoid or confront it as a coping mechanism; this activity avoidance heightens fear, creating a vicious cycle that underlies the fear of movement (kinesiophobia).[3] The catastrophizing associated with pain initiates the fear of pain cycle, resulting in impairment and disability as outlined in the fear avoidance model.[4] Kay Benyon et al. showed that self-efficacy and active coping are predictive factors for enhanced mood and decreased disability in knee OA patients.[5] Kinesiophobia in osteoarthritis patients primarily negatively impacted quality of life and disability.[3] There was low to moderate evidence supporting their effectiveness in reducing kinesiophobia. Therefore, future research must analyse interventions for kinesiophobia with improved study quality.[6,7] Taking into account psychosocial elements like kinesiophobia and pain self-efficacy, the integration of immersive Virtual Reality (VR) exercise in treating painful conditions appears to offer numerous benefits, including enjoyment, increased adherence, and improved visual and auditory feedback.[8] Hoffman et al. discovered that VR has lowered experimental pain and decreased activity in five brain regions linked to pain.[9] Comparing virtual reality with sensory motor training in cases of post-traumatic and chronic osteoarthritis has demonstrated positive changes in pain levels, functional impairment, and inflammatory biomarkers (CRP, TNF-alpha, IL-2, IL-4, and IL-6).[10,11] , and in a randomised single blind controlled study of game based virtual reality exercises in osteoarthritis it has been observed beneficial changes in dynamic balance, physical domain of quality of life.[12] While exercise remains the gold standard first line treatment[13–15], KOA patients often exhibit poor compliance due to pain-related and motivational obstacles. Immersive virtual reality (IVR) technology may improve exercise participation while targeting psychological dimensions of chronic pain conditions.[8] This scoping review evaluates Virtual Reality (VR) and maps the existing literature as a scope of Immersive virtual reality (IVR) exercise interventions and their psychological impacts in Knee OA populations.

The research questions (RQs) guiding this scoping review are as follows.

RQ1-What types of IVR-mediated exercise interventions have been studied in KOA patients?
RQ2-What psychological outcomes have been assessed in these studies?
RQ3-What are the reported effects of VR-mediated exercise programs on psychological outcomes in KOA?
RQ4-What are the current evidence gaps that should be addressed in future research?

METHOD

2.1 Study Design

This scoping review was conducted according to the Joanna Briggs Institute (JBI) methodology for scoping reviews and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)

2.1.1 Inclusion Criteria

Population: Adults (≥18 years) diagnosed with knee osteoarthritis (primary or secondary)
Intervention: Immersive virtual reality and virtual reality mediated exercise or physical rehabilitation programs using head-mounted displays or CAVE (Cave Automatic Virtual Environment) systems
Outcomes: At least one psychological outcome measure (e.g., depression, anxiety, quality of life, pain catastrophizing, kinesiophobia, motivation, enjoyment)
Study Design: Randomized controlled trials, quasi-experimental studies, observational studies, and pilot studies with pre-post assessments
Language: English-language publications
Time Frame: No date restrictions were applied

2.1.2 Exclusion Criteria

Virtual reality interventions not incorporating exercise or physical activity components, Studies focusing exclusively on physical outcomes without psychological measures, Conference abstracts, commentaries, editorials, or reviews without original data, Studies combining KOA with other conditions where KOA-specific data could not be extracted

2.2 Information sources and search strategies

A comprehensive search was conducted in six electronic databases: PubMed, Scopus, Web of Science, PsycINFO, CINAHL, and IEEE Xplore. The search strategy was developed in consultation with a medical librarian and included controlled vocabulary (MeSH terms) and free-text terms related to four key concepts: (1) immersive virtual reality, (2) knee osteoarthritis, (3) exercise or rehabilitation, and (4) psychological outcomes

The database searches were supplemented by manually screening the reference lists of included studies and relevant review articles. The search was initially conducted in November 2024 and updated in June 2025 to ensure comprehensive coverage of the literature.

2.2.1 Search Terms and Strategy

The search strategy incorporated three primary concept areas using Boolean operators (AND/OR) and Medical Subject Headings (MeSH) terms where applicable:
Concept 1: Virtual Reality Technologies - “Virtual reality” OR “VR” OR “immersive virtual reality” OR “IVR”, “Augmented reality” OR “AR” OR “mixed reality”, “Virtual environment” OR “digital rehabilitation” OR “technology-mediated”
Concept 2: Knee Osteoarthritis Population- “Knee osteoarthritis” OR “KOA” OR “osteoarthritis knee”, “Degenerative joint disease” OR “arthrosis” OR “Knee arthritis” **Concept 3:** Psychological Outcomes- “Kinesiophobia” OR “fear of movement”, “Pain catastrophizing” OR “catastrophic thinking”, “Anxiety” OR “depression” OR “psychological”, “Self-efficacy” OR “motivation” OR “adherence” "Quality of life" OR “mental health”, “Psychological distress” OR “emotional well-being”

2.2.2 Final Search String Example:

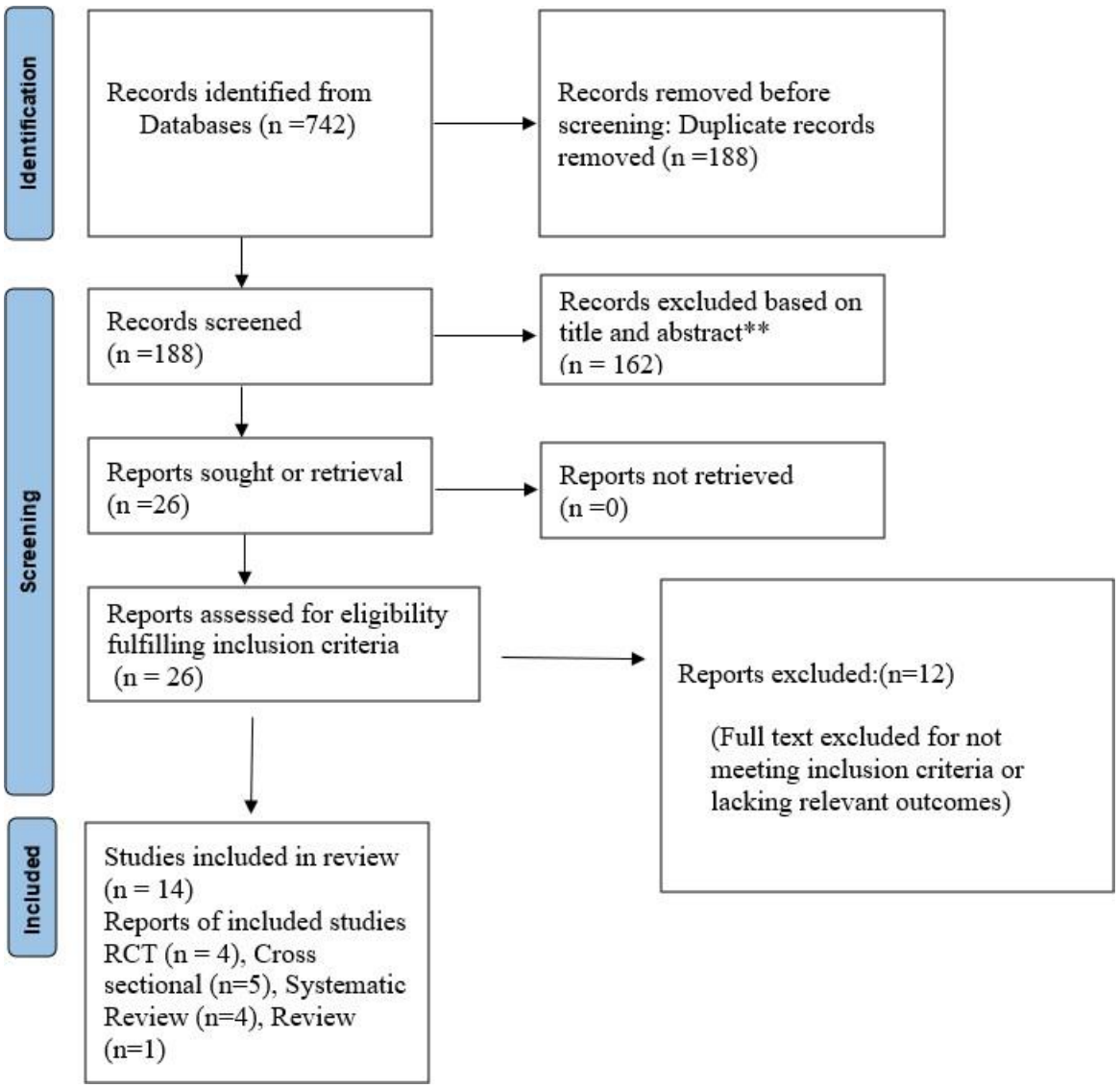
("Virtual reality" OR "VR" OR "immersive virtual reality") AND
("Knee osteoarthritis" OR "KOA" OR "osteoarthritis knee") AND
("Kinesiophobia" OR "psychological" OR "anxiety" OR "depression" OR "self-efficacy")

2.3 Selection process

After removing duplicates, two independent reviewers (XX and YY) screened titles and abstracts against the eligibility criteria. Full-text articles of potentially relevant studies were then independently assessed by the same reviewers. Discrepancies at any stage were resolved through discussion or consultation with a third reviewer (ZZ) when necessary. The selection process was documented using a PRISMA flow diagram.

Data collections and data items

Two reviewers (XX and YY) independently extracted the Study characteristics including first author, publication year, study design, sample size and Population characteristics, age, gender distribution, KOA severity, disease duration along with Intervention details such as type of IVR system, exercise components, duration, frequency, intensity, control/comparison group and key findings related to psychological outcome measures used.



2.4 Data synthesis

Due to the heterogeneity of interventions and outcome measures, a narrative synthesis approach was adopted. Findings were categorized thematically according to: (1) types of IVR systems and exercise programs, (2) psychological outcomes assessed, and (3) reported effects on these outcomes. Table-1 summarizes the key characteristics and findings of included studies.

Table-1

Study Type	Author (Year)	nple / Populat	Intervention	Psychological Outcomes Assessed	Main Findings
RCT	Özlü et al. (2023)	KOA, n=73	VR gamified exercise	ain, function, balance disability	IVR+ conservative therapy reduces pain, improves function, balance, and disability
Cross-sectional	Aydemir et al. (2021)	KOA, n=37	-	Kinesiophobia, ctivity, pain, strength	Lower muscle strength predicts lower activity via higher kinesiophobia
Systematic Review	Wei et al. (2024)	KOA	VR/IVR-based exercise	Pain, function, strength, engagement	VR/IVR exercise gnificantly improves pain, function, strength versus traditiona rehab
Systematic Review	Plavoukou et al. (2025)	KOA	VR/AR/ sensor-based rehab	Adherence, gagement, pain, mobil	VR enhances Engagement and pain management; lack of standardization

Cross-sectional	Gunn et al. (2017)	KOA, n=350	-	Fear of movement, physical function	r of movement associated with poor function and lower phys activity
Cross-sectional	Somers et al. (2009)	OA, n=301	-	in catastrophizing, fea pain, disability	Pain catastrophizing/fear predicts higher pain and disability
RCT	Erdogan et al. (2025)	KOA, n=54	R vs. conventional therapy	ain, function, balance fall risk	l interventions effective; conventional or combined superior VR-only
Cross-sectional	Murphy et al.	S Adults with OA	-	Anxiety, depression	High prevalence of anxiety and depression in arthritis, likely compounding disability
Systematic Review	Cojă et al.	-	R in musculoskeletal rehal	Kinesiophobia	effective at reducing kinesiophobia in musculoskeletal patie
Systematic Review	Chen et al. (2024)	OA	Rehab interventions	Pain, kinesiophobia	erventions (including VR) effective for pain and kinesiophob
Pilot RCT	LO et al. (2024)	KOA, n=30	R in lower limb strengthen exercises	Motivation, adherence	High acceptability, improved engagement

RESULTS

Psychological Domains in KOA and VR

3.1 Kinesiophobia and Exercise Avoidance

Kinesiophobia is consistently associated with reduced activity and poorer functional status in KOA. Mediation analyses confirm that muscle weakness leads to inactivity primarily via increased fear of movement, rather than pain alone. Interventions addressing kinesiophobia are crucial for successful rehabilitation.[2,16]

3.2 VR/IVR and Fear Modification

Multiple RCTs and systematic reviews found significant reductions in kinesiophobia and pain catastrophizing following VR/IVR-based exercise programs. Benefits include pain relief, increased functional confidence, and engagement. VR provides safe exposure to feared movements, potentially normalizing fear responses and improving compliance.[6,17,18]

3.3 Pain, Self-Efficacy, and Psychological Distress

VR exercise interventions in KOA lead to substantial improvements in pain scores, self-efficacy, and self-reported quality of life. Systematic reviews indicate VR also enhances patient engagement and motivation, which are critical for overcoming psychological barriers.[2,16,17,19,20]

3.4 VR/IVR in other outcomes

In a recent RCT and a systematic review the VR/IVR exercise treatment were applied and there was improvement in functional outcomes like, WOMAC and pain with visual analogue scale (VAS) and in balance through Berg balance scale[21,22]

3.4 Risk-of-Bias/Quality Assessment Table

Quality ratings are based on main criteria for randomized controlled trials, cross-sectional studies, and systematic reviews such as randomization/blinding, sampling bias, outcome measurement, confounding, selective reporting, and clarity of methods in Table-2.

Table-2

Study (Author, Year)	Design	Randomization Blinding	Population Representativeness	Measurement Validity	Confounding Control	Selective Reporting	Overall Risk of Bias
Özlü et al., 2023	RCT	Adequate	Good	High	Moderate	Low	Low
Gunn et al., 2017	Cross-sectional	N/A	Good	High	Moderate	Low	Moderate
Somers et al., 2009	Cross-sectional	N/A	Good	High	Moderate	Low	Moderate
Murphy et al., 2012	Cross-sectional	N/A	Good	High	Moderate	Low	Moderate
Wei et al., 2024	Systematic review	N/A	High (Multiple studies)	High	High	Low	Low
Plavoukou et al., 2025	Systematic review	N/A	High (Multiple studies)	Moderate-High	Moderate	Low	Low-Moderate
Erdogan et al., 2025	RCT	Adequate	Moderate	High	Moderate	Low	Moderate
Cojă et al., 2023	Systematic review	N/A	Moderate	Moderate-High	Moderate	Low	Low
Chen et al., 2024	Systematic review	N/A	High	High	High	Low	Low
Lo et al., 2023	Pilot RCT	Adequate for pilot	Moderate	High	Moderate	Low	Moderate

1. "Adequate" randomization/blinding indicates use of appropriate sequence generation/concealment measures.
2. "Good"/ "High" population representativeness denotes selection methods minimizing selection/sampling bias.
3. "Measurement validity" signifies robust, validated outcome measures for psychological and physical parameters.
4. "Confounding control" reflects attempts to adjust for baseline and interventional confounders.
5. "Selective reporting" is "Low" when outcomes listed a priori are reported.
6. Overall risk-of-bias summarizes all domains, critical for interpreting aggregate findings.

4 DISCUSSION

The findings from this scoping review demonstrate that virtual reality (VR) and immersive VR (IVR) interventions hold significant promise for addressing key psychological barriers such as kinesiophobia, pain catastrophizing, and low self-efficacy in patients with knee osteoarthritis (KOA). Multiple randomized controlled trials and systematic reviews suggest that VR-enhanced rehabilitation not only improves physical outcomes but also positively influences psychological wellbeing, contributing to better exercise adherence and engagement. Cross-sectional studies further establish robust associations between psychological factors and the severity of disability in KOA, confirming the relevance of integrating psychological parameters into treatment planning.[2,16,20,23]

Despite these encouraging trends, there are notable limitations affecting both the interpretation and generalizability of current evidence. First, existing studies often employ heterogeneous VR protocols, devices, and outcome measures, leading to variability in results and limiting cross-study comparability. Second, most included trials are single-Centered and feature small sample sizes or pilot designs, which restricts the ability to draw broad conclusions about effectiveness and safety. Third, psychological outcomes are often measured as secondary endpoints with variable assessment tools, rather than as primary outcomes, reducing the clarity regarding direct psychological benefits. Moreover, the duration of follow-up in most studies is limited, preventing insight into long-term impacts or sustainability of VR interventions.[2,16,20,23]

In terms of research gaps, there remains a lack of standardized, validated protocols for VR-based rehabilitation specifically targeting psychological dimensions of KOA. Few studies conduct head-to-head comparisons between immersive and non-immersive VR, or between VR and conventional rehabilitation, beyond basic physical outcomes. Additionally, the influence of patient-specific factors such as baseline psychological status, digital health literacy, and comorbid conditions is infrequently addressed. Future research should prioritize multi-center randomized controlled trials with larger sample sizes, clearly defined psychological primary outcomes, and extended follow-up periods. Inclusion of qualitative methods to explore patient acceptability, motivational shifts, and engagement drivers may also enrich understanding of VR's holistic benefits.[16]

Finally, while adverse effects are rare and largely transient, systematic reporting of possible VR-related discomforts is needed in future work to assess safety comprehensively. Addressing these methodological and conceptual gaps will be crucial for developing robust, evidence-based guidelines for integrating VR technology as part of psychological and physical management in KOA.[23]

4.1 Adverse Events and Limitations

No major adverse events have been reported; mild side effects (nausea, headache) are generally transient. Studies emphasize the need for larger trials with standardized intervention protocols and explicit measurement of psychological endpoints.[6,18,19]

4.2 Contradictory Evidence in Previous Systematic Reviews: Misclassification of VR Modalities

A critical examination of prior evidence, particularly the systematic review and meta-analysis by Wei Wei et al. (2024), reveals a methodological discrepancy that may have influenced the interpretation of virtual reality (VR) efficacy in knee osteoarthritis (KOA). In that review, several studies—such as those by Nambi et al. (2020), Mete and Sari (2022), and Abdelazeem et al. (2016)—were categorized as employing immersive VR interventions. However, a detailed appraisal of the original studies indicates that these utilized non-immersive VR platforms. This misclassification holds substantial clinical and psychophysiological implications. Immersive VR, characterized by head-mounted displays and multisensory engagement, elicits stronger affective, cognitive, and neuromotor responses than non-immersive systems, which rely on screen-based or gesture-controlled interfaces. Aggregating these distinct modalities may therefore conflate outcomes and obscure the true psychological and rehabilitative potential of immersive VR. In contrast, our scoping review delineates the two modalities separately, demonstrating that immersive VR uniquely enhances embodiment, attentional focus, and pain-related self-efficacy—dimensions not equivalently observed with non-immersive applications. Recognizing and addressing this inconsistency is essential for refining future meta-analytic syntheses and guiding evidence-based implementation of immersive technologies in KOA rehabilitation.

Potential Mechanisms and Theoretical Considerations

Several mechanisms may explain the psychological benefits observed with IVR-mediated exercise in KOA patients:

1. **Attention diversion:** The immersive nature of IVR can redirect attention away from pain sensations, potentially disrupting the pain-fear-avoidance cycle[24]. This may explain the observed reductions in pain-related distress and fear of movement.
2. **Flow state and presence:** IVR can induce "flow states" characterized by immersion and focused attention, which have been associated with positive emotional experiences and reduced awareness of negative sensations
3. **Gamification and reward systems:** Many IVR interventions incorporated game elements such as point systems, achievements, and progressive challenges, which can enhance motivation through positive reinforcement and measurable progress
4. **Safe environment for movement exploration:** VR creates a controlled environment where patients can practice movements without fear of judgment or failure, potentially addressing kinesiophobia[25]. This may be particularly valuable for KOA patients who have developed movement avoidance behaviours.
5. **Enhanced self-efficacy:** Successful completion of gradually challenging tasks in VR may improve patients' confidence in their physical abilities, which could translate to reduced psychological distress and improved quality of life[26].

The relationships observed between physical and psychological improvements in several studies support the biopsychosocial model of chronic pain, suggesting bidirectional influences between these domains [27]. This highlights the potential value of interventions like IVR that can simultaneously address multiple aspects of the condition.

4.3 Recommendations & Future Directions

VR/IVR exercise should be considered as an adjunct to conventional rehabilitation for KOA, targeting both physical and psychological sequelae, Standardized assessment of psychological domains is required across studies, Individual tailoring and gradual VR-based exposure to feared activities are suggested for patients with high kinesiophobia, Further high-quality, multicentre RCTs, preferably with long-term follow-up on psychological as well as functional endpoints, are needed to inform clinical practice.

CLINICAL IMPLICATIONS

The findings of this review have several implications for clinical practice. The positive effects on motivation, enjoyment, and adherence suggest that IVR may be particularly valuable for patients who struggle to engage with conventional exercise programs. The psychological benefits observed alongside physical improvements support a more holistic approach to KOA rehabilitation that addresses both dimensions simultaneously.

However, practical considerations such as cost, technological requirements, and the need for initial supervision may limit immediate widespread implementation. Some patients, particularly older adults with limited technology experience, may require additional support to effectively engage with IVR systems. Clinicians considering IVR implementation should carefully select appropriate systems and programs based on patient characteristics, rehabilitation goals, and available resources. Hybrid approaches combining conventional rehabilitation with periodic IVR sessions might offer a practical middle ground that leverages the engagement benefits of IVR while maintaining the personalized guidance of traditional therapy.

CONCLUSION

This scoping review suggests that Virtual reality-based exercise programs show promise for addressing psychological aspects of knee osteoarthritis, particularly in enhancing motivation, enjoyment, and exercise adherence. Improvements in depression, anxiety, and quality of life were observed in most studies, though with varying magnitudes and comparative advantages over conventional approaches. The immersive, interactive nature of IVR appears to create an engaging rehabilitation environment that can potentially break the cycle of pain, psychological distress, and reduced physical activity common in KOA. However, the current evidence base is characterized by methodological limitations and heterogeneity in interventions and outcome measures. Thus, VR based exercises shows promise for enhancing psychological and physical rehab in KOA, meanwhile IVR demonstrates effectiveness in improving physical outcomes. Hence future investigations can establish standardized protocols and explore psychological effects of these interventions in KOA management and prioritize comprehensive psychological assessments.

Declarations

Ethics approval and consent to participate
Not applicable as this study did not involve human participants.
Consent for publication
Not applicable.
Competing interests
The authors declare that they have no competing interests.
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Authors' contributions
R. Kamalakannan: Conceptualization, Methodology, Data curation, Writing – original draft.

Ajay Kumar: Supervision, Validation, Writing – review & editing. Madhuripu P.: Data extraction, Formal analysis, Writing – review & editing. Radhika Gopal S.: Literature search, Resources, Visualization. Vivek V. Menon: Methodology, Writing – review & editing, Final approval.

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