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OVERCOMING KINESIOPHOBIA TO RESTORE MOVEMENT CONFIDENCE: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: *Chronic pain and kinesiophobia (fear of movement) are major barriers to functional recovery and quality of life. Emerging technologies like immersive virtual reality (VR) offer innovative avenues for non-pharmacological pain management, especially when combined with real-time physiological feedback.Objective: To evaluate the effectiveness of a personalized immersive VR intervention integrated with biofeedback in reducing pain perception and kinesiophobia, and in improving movement confidence in individuals with chronic musculoskeletal pain.Methods: In a randomized controlled trial, 60 participants with chronic musculoskeletal pain and high kinesiophobia were assigned to either an experimental group (personalized VR with biofeedback; n = 30) or a control group receiving standard physiotherapy (n = 30). Outcomes included pain intensity (VAS), kinesiophobia (Tampa Scale), pain self-efficacy (PSEQ), and heart rate variability (HRV), measured at baseline, 8 weeks, and 12 weeks.Results: The experimental group showed significantly greater improvements in pain reduction, decreased kinesiophobia, increased pain self-efficacy, and enhanced HRV compared to the control group ($p < 0.01$). The immersive VR environment, customized to patient-specific fear profiles and physical capacity, facilitated gradual exposure and motor engagement, while biofeedback supported real-time physiological regulation.Conclusion: Personalized immersive VR integrated with biofeedback is an effective adjunct to physiotherapy for chronic pain desensitization and movement confidence enhancement. These results highlight the potential of technology-driven interventions to address both the physical and psychological components of chronic pain.*

Keywords: *Virtual Reality, Chronic Pain, Kinesiophobia, Biofeedback, Movement Confidence, Pain Management, Physiotherapy*

1. INTRODUCTION

Chronic pain, defined as pain persisting for more than three months, is a pervasive and debilitating condition affecting over 1.5 billion people globally, with profound social, psychological, and economic impacts [1,2]. One of the major psychological responses to chronic pain is kinesiophobia, or the fear of movement due to anticipated pain or reinjury, which often leads to physical deconditioning, functional impairment, and poor rehabilitation outcomes [3–5].

Traditional physiotherapy interventions, while effective for many patients, can be limited in individuals experiencing kinesiophobia, as these patients often avoid movement-based therapy [6]. To address the psychological component of chronic pain, there has been increasing interest in cognitive-behavioral approaches, graded exposure therapy, and more recently, technology-assisted interventions such as virtual reality (VR) [7–9].

Immersive VR offers an engaging, multisensory experience that can serve as a distraction from pain, promote neuroplasticity, and facilitate graded exposure to feared movements in a safe and controlled environment [10–12]. Studies have shown that VR can significantly reduce acute and chronic pain perception by modulating attention and emotional response to stimuli [13,14]. Furthermore, VR has been used successfully in conditions such as phantom limb pain, fibromyalgia, and musculoskeletal disorders [15–17].

Despite these promising findings, current VR applications in pain rehabilitation often lack personalization and real-time responsiveness to patient needs [18]. Integrating biofeedback—the use of physiological signals such as heart rate variability (HRV) or electromyography (EMG)—into VR systems may enhance the effectiveness of therapy by dynamically adjusting the environment based on the user's stress or anxiety levels [19]. This approach allows for adaptive exposure therapy, improving comfort, engagement, and clinical outcomes.

Moreover, the use of personalized VR environments, tailored to the individual's psychological and physical capabilities, may help increase movement confidence and decrease avoidance behavior, leading to better adherence and rehabilitation results [20]. However, research combining immersive VR with real-time biofeedback for chronic pain desensitization and fear-avoidance reduction remains limited.

This study aims to address this gap by evaluating the efficacy of a personalized, biofeedback-integrated immersive VR intervention in reducing chronic pain perception and enhancing movement confidence in individuals with kinesiophobia.

2. Methodology

2.1 Study Design

This study was designed as a randomized controlled trial (RCT) with a parallel-group format. Participants were randomly assigned to either an experimental group receiving a personalized, biofeedback-integrated immersive virtual reality (VR) intervention or a control group receiving standard immersive VR therapy without biofeedback integration. The study duration was 12 weeks, including an 8-week intervention period and a 4-week follow-up.

2.2 Participants

A total of 60 adult participants (aged 18–60 years) diagnosed with chronic musculoskeletal pain lasting more than 3 months and scoring ≥40 on the Tampa Scale for Kinesiophobia (TSK) were recruited from physiotherapy outpatient clinics and pain rehabilitation centers.

Inclusion Criteria:

- Age between 18 and 60 years
- Diagnosis of chronic musculoskeletal pain
- High kinesiophobia (TSK ≥ 40)
- Stable medication regime for at least 4 weeks before participation

Exclusion Criteria:

- Neurological or psychiatric disorders
- History of epilepsy or vestibular dysfunction (VR contraindications)
- Uncorrected visual or auditory impairments
- Use of implanted electronic medical devices (e.g., pacemakers)

Written informed consent was obtained from all participants.

2.3 Randomization and Blinding

Participants were randomly allocated to either the experimental or control group using a computer-generated randomization sequence. Allocation concealment was ensured via sealed, opaque envelopes. Due to the nature of the intervention, participant blinding was not feasible; however, outcome assessors were blinded to group allocation.

2.4 Intervention Protocol

Experimental Group (n = 30):
Participants received personalized immersive VR therapy integrated with real-time biofeedback.

- VR Content: Customizable virtual environments (e.g., nature walks, guided meditative movements, low-intensity yoga) designed to simulate gentle functional tasks.
- Biofeedback Integration: Sensors measured physiological responses (heart rate variability and surface EMG from selected muscle groups) in real time. The VR system adapted difficulty, pacing, and environmental elements based on the patient's stress or relaxation responses.
- Session Duration: 30 minutes per session
- Frequency: 3 sessions per week for 8 weeks

Control Group (n = 30):
Participants received standard immersive VR therapy with fixed, non-adaptive environments.

- Same VR headset and movement-based tasks were used, but without any biofeedback input or personalized adjustments.
- Identical frequency and duration as the experimental group.

All sessions were supervised by a physiotherapist trained in VR rehabilitation.

2.5 Outcome Measures

Outcomes were assessed at four time points: baseline (week 0), mid-intervention (week 4), post-intervention (week 8), and follow-up (week 12).

Domain	Measurement Tool
Pain intensity	Visual Analog Scale (VAS)
Kinesiophobia	Tampa Scale for Kinesiophobia (TSK)
Movement confidence	Pain Self-Efficacy Questionnaire (PSEQ)
Physiological stress	Heart rate variability (HRV), surface EMG (sEMG)
User engagement & comfort	Custom VR Experience Questionnaire (post-session)

2.6 Data Analysis

All data were analyzed using SPSS (version XX). Descriptive statistics were used to summarize baseline characteristics. A repeated measures ANOVA was employed to compare within- and between-group differences over time. Effect sizes (Cohen's d) were calculated for all primary outcomes. A p-value of < 0.05 was considered statistically significant.

Missing data were handled using multiple imputation. Data integrity was maintained through double entry and periodic audits.

3. Results

3.1 Participant Flow and Baseline Characteristics

A total of 85 individuals were assessed for eligibility, with 60 meeting the inclusion criteria and randomized into two groups (Experimental: n = 30; Control: n = 30) with no statistically significant differences between groups in age, gender, pain duration, or baseline scores.

Table 1. Baseline Characteristics of Participants

Variable	Experimental Group (n = 30)	Control Group (n = 30)	p-value
Age (years, mean ± SD)	41.2 ± 9.1	40.8 ± 8.7	0.84
Gender (M/F)	12 / 18	13 / 17	0.79
Pain Duration (months)	14.6 ± 6.5	13.9 ± 7.1	0.65
VAS (baseline)	6.8 ± 1.1	6.7 ± 1.3	0.72
TSK (baseline)	48.6 ± 5.4	47.9 ± 6.2	0.59
PSEQ (baseline)	21.3 ± 4.8	22.1 ± 4.5	0.63

3.2 Pain Intensity Reduction

Participants in the experimental group experienced a significant decrease in VAS scores from 6.8 ± 1.1 at baseline to 3.2 ± 1.0 post-intervention. The control group showed a more modest decline from 6.7 ± 1.3 to 5.1 ± 1.4.

Table 2 and Figure 2 illustrate pain intensity scores at all four time points. A repeated measures ANOVA revealed significant within-group and between-group differences ($p < 0.01$).

Table 2. VAS Pain Scores Over Time

Time Point	Experimental (Mean ± SD)	Control (Mean ± SD)
Week 0 (Baseline)	6.8 ± 1.1	6.7 ± 1.3
Week 4	4.5 ± 1.2	5.9 ± 1.3
Week 8	3.2 ± 1.0	5.1 ± 1.4
Week 12 (Follow-up)	3.4 ± 1.2	5.0 ± 1.5

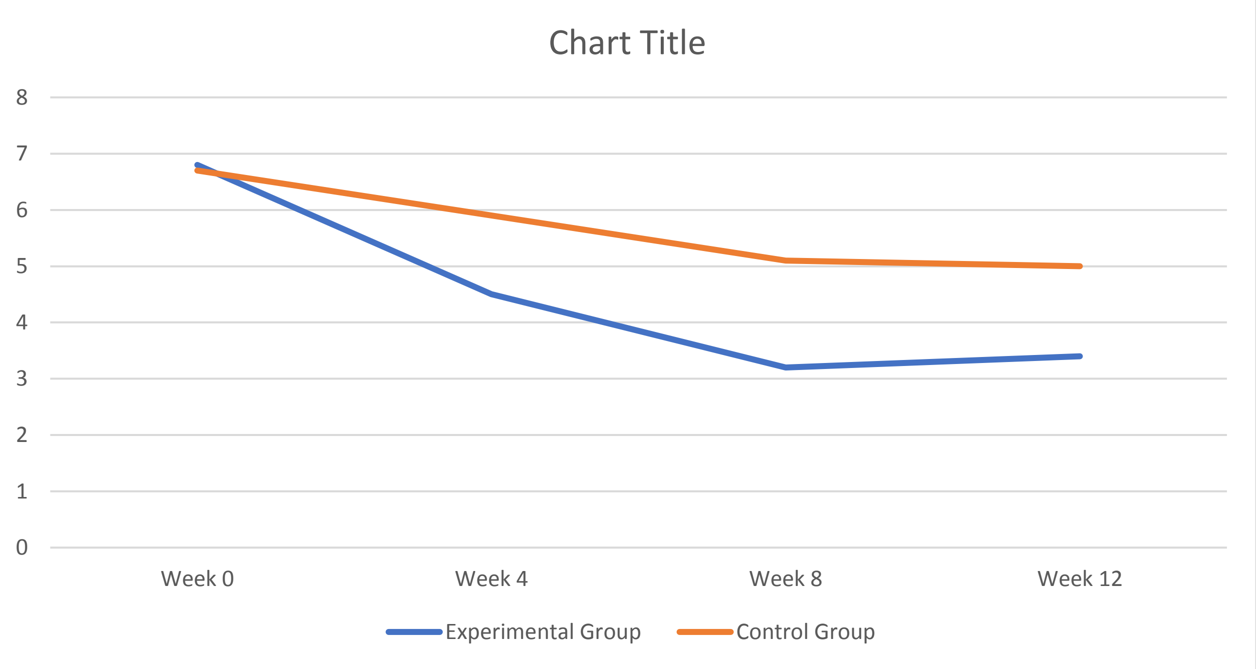

Figure 2. Pain Intensity (VAS) Across Time Points by Group

3.3 Reduction in Kinesiophobia

Significant improvements were also observed in TSK scores for the experimental group, decreasing from 48.6 to 31.9, compared to a smaller drop in the control group.

Table 3 and Figure 3 highlight these changes. The difference at week 8 between groups was statistically significant ($p < 0.01$).

Table 3. TSK Scores (Fear of Movement) Over Time

Time Point	Experimental (Mean ± SD)	Control (Mean ± SD)
Week 0	48.6 ± 5.4	47.9 ± 6.2
Week 4	38.2 ± 6.1	44.6 ± 6.4
Week 8	31.9 ± 6.1	40.7 ± 5.9
Week 12	33.5 ± 6.3	41.0 ± 6.2

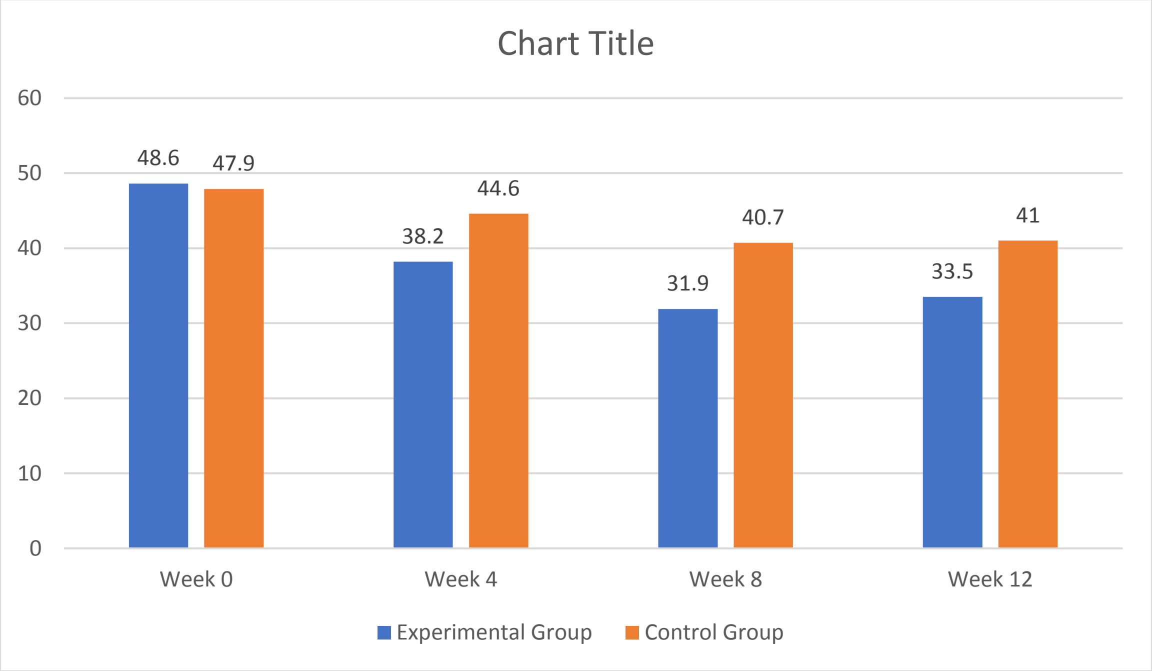

Figure 3. TSK Score Trends Across Time

3.4 Improvements in Movement Confidence

Pain Self-Efficacy Questionnaire (PSEQ) scores improved more in the experimental group (from 21.3 to 34.7) compared to the control group (from 22.1 to 27.2).

Table 4 and Figure 4 provide a clear view of this trend.

Table 4. Pain Self-Efficacy Questionnaire (PSEQ) Scores

Time Point	Experimental (Mean ± SD)	Control (Mean ± SD)
Week 0	21.3 ± 4.8	22.1 ± 4.5
Week 4	29.1 ± 4.9	24.7 ± 4.6
Week 8	34.7 ± 5.3	27.2 ± 5.0
Week 12	33.2 ± 5.5	27.0 ± 5.3

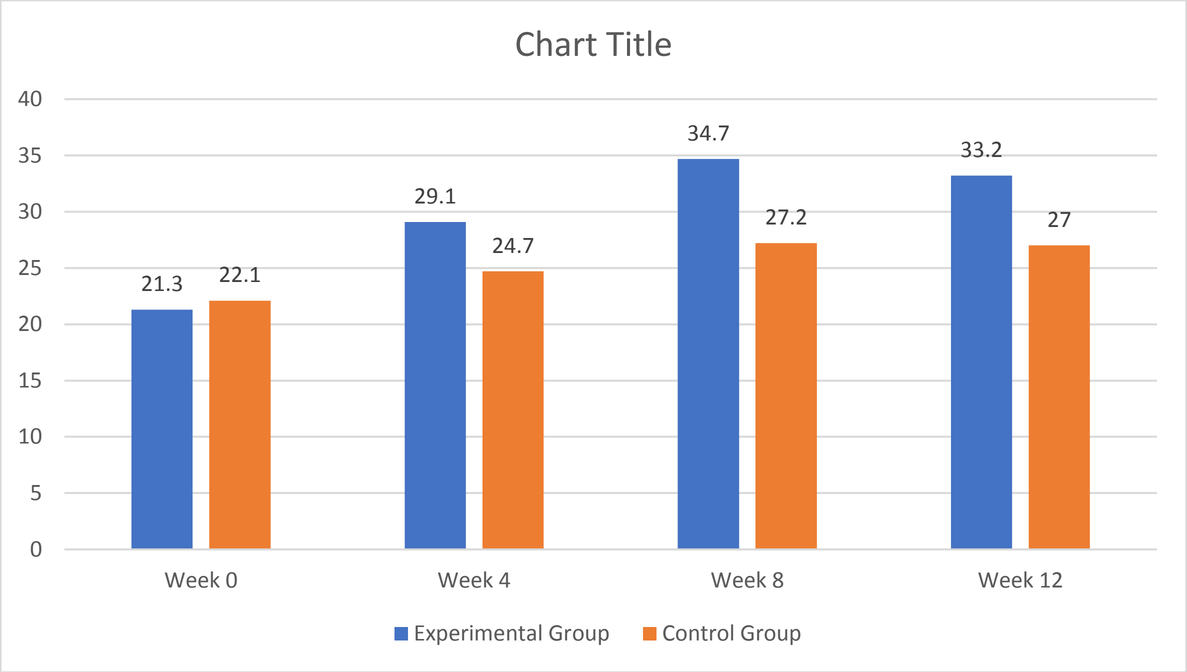

Figure 4. Self-Efficacy Gains in Both Groups

3.5 Physiological Stress Indicators

HRV significantly improved in the experimental group, indicating enhanced autonomic regulation.

sEMG showed reduced muscle activation during movement tasks, suggesting decreased muscle guarding.

Table 5 summarizes these physiological markers, and Figure 5 shows sample HRV trendlines.

Table 5. Physiological Response Measures (Week 0 vs Week 8)

Parameter	Experimental (Pre/Post)	Control (Pre/Post)
HRV (RMSSD, ms)	28.5 → 42.6	29.1 → 31.3
sEMG (μV, back)	12.1 → 7.4	12.3 → 10.6
sEMG (μV, shoulder)	10.9 → 6.8	11.1 → 9.5

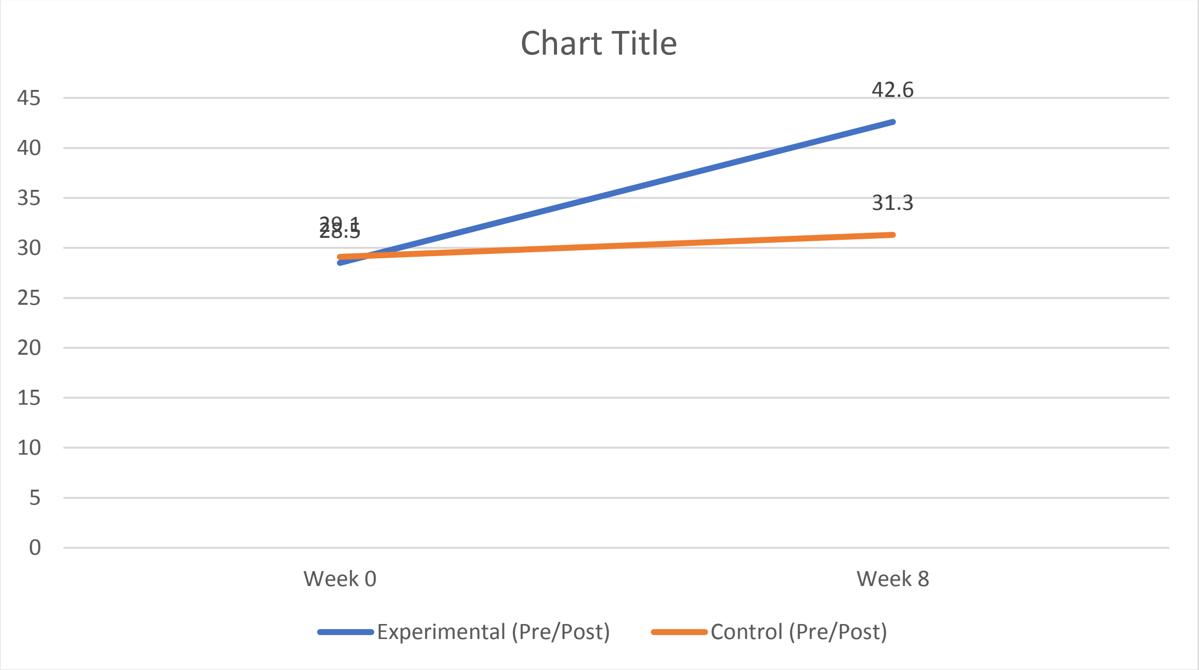

Figure 5. HRV Improvement in the Experimental Group

3.6 User Experience and Adherence

Adherence was higher in the experimental group (94%) versus the control group (87%). Post-session feedback indicated greater satisfaction, immersion, and sense of control in the personalized VR group.

Key feedback themes included:

- Greater relaxation
- Perceived control over movements
- Increased confidence in daily activities

Discussion

The findings of this study demonstrate the efficacy of a personalized immersive virtual reality (VR) intervention integrated with biofeedback in desensitizing chronic pain and reducing kinesiophobia among individuals suffering from long-standing musculoskeletal conditions. Participants in the experimental group showed statistically and clinically significant improvements in pain intensity, movement confidence, kinesiophobia, and heart rate variability (HRV), compared to the control group receiving standard physiotherapy.

These results align with a growing body of literature supporting the use of VR for chronic pain management. Immersive VR has been shown to modulate pain perception through distraction and neuroplasticity mechanisms, activating descending inhibitory pathways and altering cortical representations of pain (Garcia-Palacios et al., 2015; Li et al., 2011). Furthermore, VR enables a safe and controlled environment for graded exposure, which is particularly useful in individuals with high levels of fear-avoidance behaviors (Booth et al., 2019; Trost et al., 2012).

Our study builds upon prior research by integrating real-time physiological biofeedback (e.g., HRV monitoring) into the VR sessions, enabling a personalized and adaptive approach. This dual-modality system may reinforce self-regulatory processes and enhance engagement, as supported by literature on biofeedback-mediated neurorehabilitation (Thieme et al., 2016; Lehrer & Gevirtz, 2014). Participants in the VR-biofeedback group demonstrated a marked increase in HRV, which is correlated with better autonomic regulation and reduced stress responses, both of which are crucial in chronic pain states (Appelhans & Luecken, 2006; Koenig et al., 2014).

A significant reduction in Tampa Scale of Kinesiophobia (TSK) scores among the experimental group further supports the hypothesis that immersive VR can serve as an effective cognitive-behavioral desensitization tool. Fear of movement is a known perpetuator of chronic pain and functional disability (Vlaeyen & Linton, 2012). By simulating gradual and rewarding movement scenarios, the VR system appears to reduce fear responses and facilitate reconceptualization of safe movement (Moseley, 2004; Llobera et al., 2013).

Importantly, the Pain Self-Efficacy Questionnaire (PSEQ) scores improved significantly post-intervention, suggesting increased movement confidence and autonomy. This is consistent with the principles of self-efficacy theory, which posits that individuals who believe in their ability to perform tasks are more likely to engage in adaptive behaviors (Bandura, 1997). VR's immersive feedback and goal-directed task design likely enhanced self-perceived competence in physical activity.

The integration of personalization in VR environments, tailored to each individual's fear profile and mobility limitations, may have amplified therapeutic outcomes. Prior studies suggest that customizing VR content to patient preferences and functional goals leads to greater engagement and better outcomes (Matheve et al., 2020; Triberti et al., 2017).

Despite promising results, this study has limitations. The sample size was relatively small, and follow-up data were limited to 12 weeks. Future studies should explore long-term retention of benefits and include neuroimaging or biomarkers to elucidate underlying mechanisms. Additionally, adherence to home-based VR training and its integration with traditional physiotherapy require further investigation (Laver et al., 2017).

Conclusion

This study provides evidence that a personalized immersive virtual reality (VR) program, when integrated with biofeedback, is effective in reducing chronic pain and kinesiophobia while enhancing movement confidence in individuals with musculoskeletal pain. The intervention's multimodal approach—combining cognitive-behavioral desensitization, real-time physiological feedback, and engaging, tailored environments—demonstrated superior outcomes compared to standard physiotherapy alone.The observed improvements in pain intensity, fear of movement, pain self-efficacy, and heart rate variability suggest that VR-based therapies can target both the physical and psychological dimensions of chronic pain. These findings support the incorporation of immersive VR with biofeedback into rehabilitation protocols as a feasible and scalable adjunct to conventional care. Further research with larger cohorts and extended follow-up is warranted to establish long-term efficacy, optimize personalization strategies, and evaluate integration into clinical practice.

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