Adherence to virtual reality interventions in chronic pain: a systematic review

Adherencia a las intervenciones de realidad virtual en dolor crónico: una revisión sistemática

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Abstract

Introduction: Chronic pain is a prevalent and persistent condition, characterized by low adherence to therapeutic interventions, which compromises clinical outcomes. In this context, virtual reality (VR) has emerged as a strategy to optimize patient engagement.
Objective: To examine how adherence is defined, measured, and reported in VR-based interventions for individuals with chronic pain, and to describe adherence levels and methodological approaches.
Methodology: A systematic review was conducted following PRISMA guidelines, including randomized controlled trials identified in major databases. Adherence was analyzed through a narrative synthesis, organizing indicators according to the ABC taxonomy: initiation, implementation, and persistence.
Results: Seven studies were included, revealing heterogeneity in adherence definitions and measurement. Reported adherence ranged from 64% to 94%, with greater consistency in home-based interventions. Methods included device logs, percentage of completed exercise, session completion, and retention, indicating limited standardization.
Discussion: VR interventions tended to show adherence levels comparable to or potentially higher than conventional interventions; however, these findings should be interpreted cautiously due to the limited number of studies, heterogeneity in adherence definitions, and variability in comparison groups. Adherence appears to be influenced more by contextual factors than by immersion.
Conclusions: VR interventions may achieve favorable adherence levels; however, heterogeneity in measurement and study design limits the strength of these findings in real-world clinical contexts.

Keywords

Adherence; chronic pain; rehabilitation; virtual reality.

Resumen

Introducción: El dolor crónico es una condición prevalente y persistente, caracterizada por baja adherencia a las intervenciones terapéuticas, lo que compromete los resultados clínicos. En este contexto, la realidad virtual (RV) ha emergido como una estrategia para optimizar la participación del paciente.
Objetivo: Examinar cómo se define, mide y reporta la adherencia en intervenciones basadas en RV en personas con dolor crónico, así como describir los niveles de adherencia y los enfoques metodológicos utilizados.
Metodología: Se realizó una revisión sistemática siguiendo PRISMA, incluyendo ensayos controlados aleatorizados identificados en bases de datos internacionales. La adherencia se analizó mediante síntesis narrativa, organizando los indicadores según la taxonomía ABC: inicio, implementación y persistencia.
Resultados: Se incluyeron siete estudios, evidenciando heterogeneidad en la definición y medición de la adherencia. Los niveles reportados oscilaron entre 64% y 94%, con mayor consistencia en intervenciones domiciliarias. Los métodos incluyeron registros objetivos, porcentaje de ejercicio completado, cumplimiento de sesiones y retención, mostrando limitada estandarización.
Discusión: Las intervenciones de RV tienden a mostrar niveles de adherencia comparables o potencialmente superiores a las intervenciones convencionales; sin embargo, estos hallazgos deben interpretarse con cautela debido al reducido número de estudios, la heterogeneidad en las definiciones de adherencia y la variabilidad en los grupos de comparación. La adherencia parece estar influenciada más por factores contextuales que por el nivel de inmersión.
Conclusiones: Las intervenciones de RV podrían alcanzar niveles de adherencia favorables; sin embargo, la heterogeneidad en su medición y en el diseño de los estudios limita la solidez de estos hallazgos en contextos clínicos reales.

Palabras clave

Adherencia; dolor crónico; rehabilitación; realidad virtual.

Introduction

Chronic pain remains one of the most prevalent and disabling health conditions worldwide, affecting over one-third of the population(Treede et al., 2019), generating a considerable impact on functionality and quality of life(Chikaka & Keller, 2024; Li et al., 2011). Despite the availability of treatments such as pharmacotherapy, physiotherapy, and cognitive-behavioral programs, therapeutic adherence remains a significant challenge. In specialized centers, completion rates as low as 17% have been reported from referral to treatment completion, with substantial losses at each stage of the recruitment and retention process(Garcia et al., 2021; Giacomelli et al., 2024). Additionally, qualitative and feasibility studies have identified psychological, social, and contextual barriers that hinder sustained participation in long-term therapeutic exercise programs(Darnall et al., 2020; Ye et al., 2023).

Within this landscape, virtual reality (VR) has gained attention as an emerging therapeutic tool for the treatment of chronic pain, offering immersive and interactive environments that may enhance patient engagement and improve clinical outcomes(Zuki et al., 2024). VR enables the implementation of therapeutic strategies based on cognitive neuroscience principles, distraction, graded exposure, and the development of coping skills, all within an experiential format that may be more attractive and less aversive than conventional therapies(Da Cruz et al., 2021; Liao et al., 2025; MPT et al., 2025; Ruiz Muñoz & Paz Zamora, 2025). Recent studies have shown that VR interventions for chronic pain can produce clinically significant reductions in pain intensity and improvements in functional interference related to activity, mood, and sleep(Al-Sharman et al., 2021; de Zambotti et al., 2020; Elkeblawy et al., 2026).

In this regard, factors influencing adherence to VR-based therapies are diverse and include both facilitators and barriers to treatment continuity. Facilitators include high acceptability of the technology and the enjoyable nature of the sessions, with participants often describing VR as a more attractive alternative to traditional physiotherapy(Martínez et al., 2024). Low incidence of adverse effects(Bargeri et al., 2023; Simón-Vicente et al., 2024) and the possibility of home-based use, which improves access and continuity of care, also contribute(Huang et al., 2025; Mira et al., 2025). VR is proposed to enhance adherence by making exercises more engaging, increasing immersion and user commitment, and providing a distraction and novelty component that may reinforce early participation(Elor et al., 2021; Miguel-Alonso et al., 2023, 2024). However, important barriers have also been identified. In real-world clinical settings, recruitment and treatment completion may be limited(Glegg & Levac, 2018; Threapleton et al., 2016). However, concerns have been raised regarding the sustainability of the novelty effect, as initial engagement may decline over time if the intervention fails to maintain user interest. (Nguyen et al., 2019; Ogourtsova et al., 2019; Schreiter et al., 2025).

Despite growing interest and favorable preliminary evidence, important knowledge gaps remain regarding the specific role of adherence in the outcomes of VR interventions for chronic pain(Aderinto et al., 2023; Fusco & Tieri, 2022). Existing systematic reviews have primarily focused on the clinical effectiveness of VR but have not comprehensively analyzed how adherence is defined, measured, and reported in these interventions(Da Cruz et al., 2021; Kraśnik et al., 2024). Furthermore, there is considerable heterogeneity in how adherence is conceptualized and assessed across VR studies, limiting comparability and the identification of optimal adherence thresholds(Ferche et al., 2015). It is also unclear whether different VR modalities (immersive vs. non-immersive, active vs. passive, supervised vs. self-administered) produce different adherence levels and whether these differences mediate the observed therapeutic effects(Garrett et al., 2018; Proffitt et al., 2019).

In this context, the aim of the present systematic review was to examine how adherence to virtual reality–based interventions is defined, measured, and reported in individuals with chronic pain. Additionally, it sought to describe the levels of adherence reported in the available studies and to identify the methodological approaches used for its assessment, with the purpose of providing an integrative overview of the current state of evidence and guiding future research in this field.

Method

Protocol and registry

This systematic review was reported in accordance with the PRISMA statement (Page et al., 2021). The study protocol was prospectively registered in the International Platform of Registered Systematic Review and Meta-analysis Protocols (inplasy.com) under registration number 202580093.

Eligibility criteria for studies

Inclusion criteria

Randomized controlled trials (including pilot and feasibility trials) were included without restrictions on age or sex, within an observation window from inception to December 15, 2025, applying the PICOT strategy (Methley et al., 2014).

P: Patients diagnosed with chronic pain (regardless of etiology).

I: Virtual reality therapies for the treatment of chronic pain.

C: Different VR modalities compared with each other (immersive vs. non-immersive) or with other digital or conventional therapies.

O: Levels of adherence to virtual reality interventions, methods for measuring adherence, and factors associated with its maintenance.

T: During and/or after the VR intervention.

Exclusion criteria

Studies with non-experimental designs were excluded, such as single-case studies, case series, observational studies, narrative reports, or reviews of any kind. Studies that did not use VR as the primary intervention were also excluded, as well as those that assessed populations without a diagnosis of chronic pain, studies that did not report data related to adherence or related indicators, and those whose methodological information was insufficient to determine eligibility.

Additionally, preprints, gray literature, conference abstracts, protocols without results, duplicate publications, and articles whose full text was not available after the search were excluded.

Information sources

A systematic literature review was conducted using Scopus, PubMed, and Web of Science, focusing on adherence to VR interventions in individuals with chronic pain, including definitions, measurement methods, and reported levels, from inception to December 15, 2025, with an updated search conducted on March 1, 2026. Additional searches were performed in Google Scholar and reference lists of included studies.

Search strategy

The search strategy combined MeSH (Medical Subject Headings) terms and free-text terms related to chronic pain, virtual reality, and treatment adherence, using Boolean operators (AND/OR). The terms were adapted to the specific syntax of each database and combined accordingly. The complete search strategy for each database is presented in Supplementary Table 1.

Following this, the study selection process was performed. Manuscripts were analyzed in three phases: identification, eligibility, and inclusion according to the predefined research criteria, followed by an assessment of the quality and impact of the publications.

Study selection

Records retrieved from the databases were imported into the Rayyan electronic platform (Ouzzani et al., 2016). After removing duplicates, titles and abstracts were screened to identify studies that potentially met the inclusion criteria. The full texts of the remaining studies were then retrieved to assess their eligibility.

All stages of the process were conducted by two independent reviewers, and any discrepancies were resolved through the involvement of a third author.

Data extraction

A predefined data extraction form was used to collect study information from the selected studies. The form included information on: (i) author and year of publication, (ii) study and sample characteristics, (iii) intervention protocols, (iv) comparison groups, (v) measurement instruments, and (vi) between-group post-test outcomes. Two reviewers independently performed the data extraction, and a third author intervened to harmonize the information.

Additionally, variables related to adherence to the intervention were extracted. Given the variability in how this construct was reported across studies, adherence measures were classified according to their operational definition. In accordance with the ABC taxonomy of adherence (Vrijens et al., 2012), indicators were grouped according to the domains of initiation, implementation, and persistence. In this context, these dimensions were operationalized using study-specific measures such as attendance, session completion, or retention, depending on how adherence was reported.

Given the heterogeneity in the definition and measurement of adherence across the included studies, an additional standardization approach was applied. When possible, adherence metrics were transformed into percentage of prescribed dose completed, calculated as the proportion of sessions performed relative to those prescribed. In studies reporting multiple adherence indicators, priority was given to session completion as the primary measure, as it was the most consistently reported across studies. When standardization was not feasible due to insufficient data, adherence outcomes were synthesized narratively, preserving the original metrics reported by the authors.

All procedures followed the methodological recommendations of Cochrane and PRISMA for conducting systematic reviews (Cochrane Handbook for Systematic Reviews of Interventions, n.d.).

Methodological quality and risk of bias

Methodological quality was assessed using the PEDro scale, which consists of 11 items with a score ranging from 0 to 10 (item 1 is not included). A higher score indicates better quality; however, the following classification has been recommended: 9–10 excellent; 6–8 good; 4–5 fair; < 4 poor.

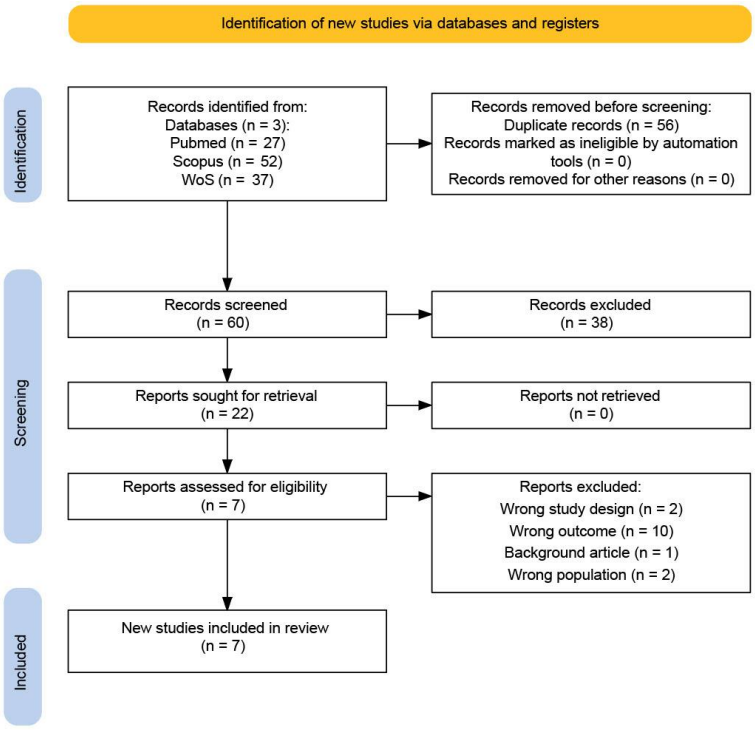
The risk of bias of the included studies was evaluated using tools specific to their methodological design. For randomized controlled trials, the Cochrane Collaboration's RoB 2 tool was used. The assessment was conducted independently by two reviewers, with discrepancies resolved by consensus involving a third author. Graphs were generated using the Robvis web application (McGuinness & Higgins, 2021).

Results

Search results

A total of 116 records were identified, of which 27 were from PubMed, 52 from Scopus, and 37 from Web of Science. After removing duplicates, 60 records remained, and following the screening process, 22 were selected for full-text review. Finally, seven studies met all inclusion criteria (Cetin et al., 2023; Darnall et al., 2020; Garcia et al., 2021; Lo et al., 2024; McConnell et al., 2024; Thomas et al., 2016; Tuck et al., 2022). Figure 1 illustrates the study selection process.

Figure 1. Flowchart for study selection



Characteristics of the included studies

The seven included studies were published between 2016 and 2024 and were conducted in the United States (n = 4), Turkey (n = 1), New Zealand (n = 1), and China (n = 1). Altogether, they included 565 individuals with chronic musculoskeletal pain, aged between 18 and 82 years. The most frequent clinical conditions were chronic low back pain (four studies), chronic neck pain, knee osteoarthritis, and primary chronic pain.

The VR intervention modalities were diverse and included:

- Self-administered immersive VR at home (EaseVRx, VR skills training)
- Clinician-supervised immersive VR in clinical settings (VR-PNE, VR for exercise)
- Active, movement-oriented VR (physical activity games in clinical settings)
- Brief VR exposure in laboratory settings (VR-dodgeball)

The duration of the protocols ranged from 3 laboratory sessions to 56 home-based sessions over 8 weeks, demonstrating substantial heterogeneity in dosage and therapeutic formats. The main methodological characteristics of these studies are presented in Table 1.

Table 1. Characteristics of the included studies.

Study (author, year)	Population / condition	VR intervention type / dose	Control group (type of intervention)	Adherence definition	Adherence outcomes	Retention / attrition	Critical comment on adherence
Lo et al., 2024	30 adults with knee osteoarthritis (15 VRiKnee, 15 control)	Home-based immersive VR lower limb strength training for 12 weeks; same exercise program in both groups	Same exercise program without VR (exercise-only control)	% of prescribed exercise completed, based on device logs and exercise sheets	Median 77% in VR vs 62% in control; adherence declined over 12 weeks in both groups	Attrition: 13.3% VR vs 6.7% control	Explicit and objective adherence measurement; however, progressive decline suggests fatigue or reduced novelty
McConnell et al., 2024	52 adults with chronic low back or neck	Clinic-based VR pain neuroscience education as	Usual physiotherapy (standard care without VR-PNE)	Proportion completing ≥6 VR-PNE sessions;	~64% reached minimum dose; adherence	61–68% completed 6-week follow-up	Clear operational definition (≥6 sessions), but lacks detail on total

	pain (VR-PNE + PT vs usual PT)	adjunct to physiotherapy; target ≥6 sessions over ~6 weeks		questionnaire completion	similar to usual PT		sessions; logistical/technical issues affected data collection more than attendance
Cetin et al., 2023	41 adults with chronic neck pain (VR + exercise vs exercise only)	VR (20 min) + motor control exercise (20 min), 3×/week for 6 weeks (18 sessions)	Exercise-only program (motor control exercise without VR)	Exercise compliance at 1 month via exercise diary (home-based time: days × minutes)	VR group showed greater improvement in adherence, but no exact percentages reported	Most participants completed 18 supervised sessions; session-by-session adherence not detailed	Exercise diary provides insight into home adherence, but lack of quantitative metrics limits comparability; VR appears to enhance motivation
Garcia et al., 2021	179 adults with chronic low back pain (EaseVRx vs sham VR)	8-week self-administered program (56 daily sessions) of skills-based VR vs sham (2D nature content)	Sham VR intervention (2D non-immersive nature content)	Headset usage logs + questionnaire completion; data completeness used as proxy	~90% engagement; 94% (VR) and 93% (sham) completed post-treatment; >95% data completeness	High retention at 8 weeks; low attrition	Excellent adherence for intensive digital intervention; objective logs are a strength, though exact session completion rates are unclear
Darnall et al., 2020	74 adults with chronic non-cancer pain (VR skills vs audio-only)	21-day self-administered VR program vs audio version; daily on-demand access	Audio-only intervention (non-immersive digital control)	Number of sessions initiated + in-app survey completion	>1000 sessions launched; most participants completed multiple sessions, but % of prescribed dose not reported	Majority completed study; moderate but acceptable attrition	Good overall engagement, but adherence definition is indirect (activity-based rather than dose-based)
Tuck et al., 2022	29 adults with chronic primary pain referred to physiotherapy (active VR vs TAU + waitlist)	Clinic-based VR twice/week for 4 weeks (8 sessions) using commercial movement-based games	Treatment as usual (TAU) with waitlist control	Attendance; feasibility defined as ≥70% retention/completing 8 sessions	20/29 (~69%) completed follow-up; most VR participants attended most sessions	Retention slightly below feasibility threshold (69% vs 70%); dropouts due to practical barriers	Valuable for real-world barriers; adherence acceptable, but logistics limit retention
Thomas et al., 2016	52 adults with chronic low back pain and kinesiophobia (VR dodgeball vs control)	Lab-based intervention: 3 consecutive sessions of 15-min VR "dodgeball"	Non-VR control condition (standard experimental control without immersive exposure)	Completion of 3 sessions + pre/post assessments	Nearly all participants completed sessions; adherence almost perfect	Only one dropout	Short, supervised protocol yields maximal adherence, but limited generalizability to long-term/home-based VR

VR = Virtual Reality; IVR = Immersive Virtual Reality; NIVR = Non-Immersive Virtual Reality; PNE = Pain Neuroscience Education; RCT = Randomized Controlled Trial; Exp = Experimental group; Ctrl = Control group; Sess. = Sessions; FU = Follow-up; N/A = Not Available; CNP = Chronic Neck Pain; CLBP = Chronic Low Back Pain; CPP = Chronic Primary Pain.

Measurement and outcomes of therapeutic adherence

Due to conceptual heterogeneity across studies, the term adherence was used broadly to refer to different indicators of participation in the intervention (e.g., attendance, implementation, or persistence). To improve comparability, these indicators were subsequently interpreted according to the ABC taxonomy of adherence.

Five main strategies were identified to quantify therapeutic adherence: objective VR device logs, percentage of prescribed exercise completed, minimum required sessions versus completed sessions, home-based exercise diaries, and retention or follow-up form completion used as a proxy for adherence. Table 2 presents the classification of adherence indicators reported in the included studies, linking the measurement methods used with the conceptual dimensions proposed by the ABC taxonomy.

Table 2. Classification of adherence indicators according to measurement methods and ABC taxonomy

Study (author, year)	Adherence measurement method	Reported indicator type	Adherence dimension (ABC taxonomy)	Methodological comment

Lo et al., 2024	Percentage of exercise completed based on device logs and exercise sheets	% of prescribed exercise completed	Implementation	Relatively precise measurement of therapeutic dose received, although adherence progressively declined during the program
McConnell et al., 2024	Minimum number of sessions completed (≥6 VR-PNE sessions)	Proportion of participants reaching minimum dose	Attendance / Implementation	Clear operational definition of adherence, but lacks detail on total number of sessions completed
Cetin et al., 2023	Home-based exercise diary	Self-reported compliance with home program	Implementation	Allows estimation of engagement, but relies on self-report and lacks precise percentages
Garcia et al., 2021	Objective VR headset usage logs	Engagement with intervention and data completeness	Implementation / Persistence	Use of objective device metrics; one of the most robust adherence measures in digital interventions
Darnall et al., 2020	Number of sessions initiated and in-app survey participation	Overall platform activity	Implementation	Indirect adherence indicator, as it is not explicitly linked to a prescribed dose
Tuck et al., 2022	Attendance at in-person VR sessions	Retention and participation in scheduled sessions	Attendance / Persistence	Useful for assessing feasibility in clinical settings, but does not reflect the total prescribed intervention dose

Due to this variability, adherence could not be synthesized using quantitative methods; however, a structured narrative comparison was conducted.

To further enhance comparability across studies, adherence measures were synthesized and, when possible, interpreted in relation to the proportion of prescribed dose completed. A comparative summary of these measures is presented in Table 3.

Table 3. Comparative synthesis and standardization of adherence measures across included studies

Study	Original adherence metric	Can it be standardized as % dose completed?	Comparable value or proxy	ABC dimension	Methodological comment
Lo et al., 2024	% of prescribed exercise completed	Yes	VR: 77%; control: 62%	Implementation	Objective and directly comparable measure
McConnell et al., 2024	Proportion completing ≥6 VR-PNE sessions	Partial	~64% reached the minimum dose	Attendance / implementation	Defines a minimum threshold, but not total dose completed
Cetin et al., 2023	Home exercise diary	No	Not available as %	Implementation	Self-reported; limited comparability
Garcia et al., 2021	Headset logs, engagement, and data completion	Partial / proxy	~90% engagement; 94% VR and 93% sham completed post-treatment	Implementation / persistence	Robust metric, but not an exact % of completed sessions
Darnall et al., 2020	Number of sessions initiated and in-app surveys	No	>1000 sessions launched; no % dose reported	Implementation	Activity-based indicator, not prescribed-dose adherence
Tuck et al., 2022	Attendance and retention	Partial / proxy	20/29 (~69%) completed follow-up	Attendance / persistence	Reflects feasibility and logistical barriers
Thomas et al., 2016	Completion of 3 sessions	Yes, approximate	Near-complete adherence; one dropout	Persistence / attendance	High adherence expected due to short supervised protocol

VR = virtual reality. Adherence measures were standardized as the percentage of prescribed intervention dose completed when possible. When sufficient data were not available, proxy indicators such as engagement, retention, or session completion were used for interpretation.

Summary of adherence by study

• Home-based interventions (Darnall et al., 2020; Garcia et al., 2021) showed high levels of adherence, with approximately 90% engagement and high retention, possibly supported by flexibility of use, accessibility, and brief sessions.

• Supervised clinical interventions (Cetin et al., 2023; McConnell et al., 2024; Tuck et al., 2022) demonstrated moderate to high adherence, but were more affected by logistical barriers (transportation, scheduling, therapeutic burden), particularly in the study by Tuck, where retention was 69%.

• Brief laboratory-based interventions (Thomas et al., 2016) showed adherence close to 100%, as expected in short and highly supervised protocols.

• Exercise programs combined with VR (Cetin et al., 2023; Lo et al., 2024) showed overall favorable adherence, with better compliance in the group receiving immersive feedback, although adherence declined over time.

However, the characteristics of the control groups varied substantially across studies, including usual care, exercise-only programs, sham VR interventions, audio-based conditions, and waitlist controls. Additionally, adherence in control groups was inconsistently reported and often assessed using different metrics, such as retention, session attendance, or completion of follow-up assessments, rather than standardized measures of prescribed intervention dose. This heterogeneity in both control conditions and adherence measurement limits direct comparison with VR interventions and should be considered when interpreting the observed differences in adherence across studies.

Although definitions of adherence were heterogeneous, most studies suggest that VR interventions may achieve adherence levels comparable to or potentially higher than standard comparisons. However, the heterogeneity in study designs, adherence definitions, and measurement methods limits direct comparability across studies and precludes firm conclusions.

Therapeutic adherence and related factors

In the included studies, factors associated with adherence were mainly related to technology acceptability, immersion, home accessibility, technical issues, and logistical barriers. Adherence to VR interventions is influenced by multiple factors related to both intervention design and user experience. Among the most consistent facilitators is the acceptability of the technology and the enjoyable nature of the sessions, as participants frequently describe VR as an engaging and motivating alternative to conventional therapies, which may enhance treatment engagement (Lo et al., 2024; Tuck et al., 2022).

Another relevant facilitating factor is the ability of virtual environments to generate immersion, distraction, and engagement, which may reduce the perceived threat associated with movement and promote participation in physical activities or therapeutic exercises (Cetin et al., 2023; Thomas et al., 2016).

Additionally, in self-administered interventions, the possibility of using VR programs at home may improve accessibility and continuity of treatment, facilitating adherence over time (Darnall et al., 2020; Garcia et al., 2021).

However, potential barriers to adherence have also been identified, including technical difficulties, usability issues, symptoms of cybersickness, and logistical constraints related to recruitment or program implementation (Lo et al., 2024; McConnell et al., 2024).

Finally, some feasibility studies have indicated that, although VR is generally well accepted by participants, recruitment and treatment completion rates may be affected by organizational or contextual factors, highlighting the need to optimize implementation strategies in real-world clinical settings (McConnell et al., 2024; Tuck et al., 2022).

Methodological quality and risk of bias

The assessment of methodological quality using the PEDro scale showed considerable variability among the included studies, with scores ranging from 3 to 8 out of a maximum of 10. Two studies demonstrated high methodological quality (Garcia et al., 2021; Lo et al., 2024), consistently meeting key criteria such as random allocation, allocation concealment, intention-to-treat analysis, and appropriate statistical reporting.

Three studies were rated as moderate quality (Cetin et al., 2023; Darnall et al., 2020; Thomas et al., 2016), characterized by adequate randomization and between-group comparisons, but with limitations in blinding of participants, therapists, or assessors, as well as in participant retention.

Finally, two studies, both feasibility trials, were rated as low methodological quality (McConnell et al., 2024; Tuck et al., 2022), primarily due to the absence of blinding, lack of allocation concealment, and follow-up losses exceeding 15%.

Overall, these findings indicate that, although there is emerging and promising evidence supporting the use of VR for the management of chronic pain, the methodological robustness of the studies is heterogeneous and should be considered when interpreting the reported levels of adherence.

Table 4. Summary of methodological quality assessment according to the PEDro scale.

Study (author, year)	Design	PEDro score (0–10)	Criteria met	Main limitations
Lo et al., 2024 (VRiKnee)	Pilot RCT	8/10	Randomization, allocation concealment, blinded assessor, comparable groups, ≥85% follow-up, ITT, between-group analysis, means + SD	No blinding of participants or therapists (unavoidable)
Garcia et al., 2021 (EaseVRx)	Double-blind RCT	7/10	Randomization, central allocation concealment, partial blinding, ITT, ≥85% follow-up, between-group comparisons, means + SD	Therapist blinding not applicable; baseline comparability not always explicitly reported
Cetin et al., 2023 (VR cervical exercise)	Single-blind RCT	5/10	Randomization, comparable groups, blinded assessor, between-group analysis, means + SD	No allocation concealment; no participant/therapist blinding; <85% follow-up; no ITT
Darnall et al., 2020 (VR vs audio)	RCT	5/10	Randomization, comparable groups, ITT, between-group comparisons, means + SD	No blinding; no allocation concealment; substantial attrition; <85% follow-up
Thomas et al., 2016 (VR dodgeball)	RCT	5/10	Randomization, allocation concealment (sealed envelopes), ≥85% follow-up, between-group analysis, means + SD	No blinding of participants, therapists, or assessors
McConnell et al., 2024 (VR-PNE)	Feasibility RCT	3/10	Randomization, between-group analysis, means + SD	No allocation concealment; no blinding; no ITT; <85% follow-up; non-comparable groups at baseline
Tuck et al., 2022 (Active VR)	Feasibility RCT	3/10	Randomization, between-group analysis, means + SD	No blinding; no allocation concealment; high attrition; no ITT; non-comparable groups

RCT = randomized controlled trial; ITT = intention-to-treat analysis; SD = standard deviation; PEDro = Physiotherapy Evidence Database scale.

The risk of bias was assessed using the RoB 2 tool for randomized controlled trials. Overall, the methodological quality of the included studies was acceptable. No trial was rated as having a low risk of bias. All included studies were classified as having either some concerns or high risk of bias. Most studies were judged as having some concerns, primarily due to limitations in blinding, incomplete reporting of adherence, and potential deviations from the intended interventions (Cetin et al., 2023; Darnall et al., 2020; Garcia et al., 2021; Lo et al., 2024; McConnell et al., 2024; Thomas et al., 2016). In contrast, the study by Tuck et al. (2022) was assessed as having a high risk of bias, mainly due to substantial loss to follow-up and incomplete adherence data. These results are summarized in the corresponding risk of bias table. Figure 2 provides a visual representation of the risk of bias for each study, and Figure 3 presents a summary assessment across domains and overall risk.

Figure 2. Risk of bias traffic light plot based on RoB 2 domains

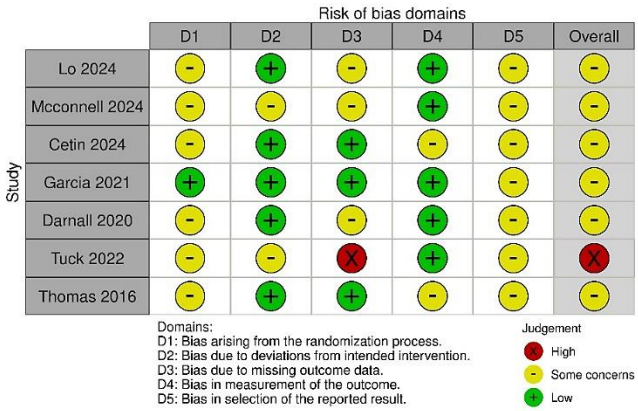
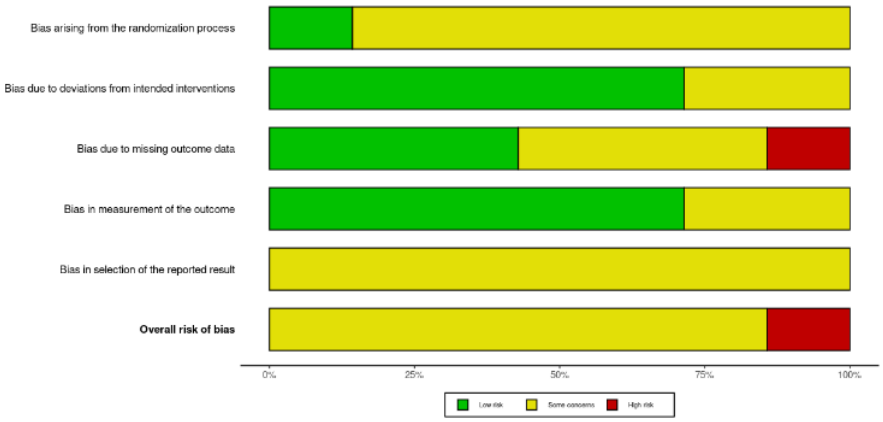


Figure 3. Summary of risk of bias judgments across included studies



Discussion

This systematic review synthesized the available evidence on adherence levels to (VR) interventions in individuals with chronic pain and the factors influencing such adherence. The findings suggest that: (1) adherence to VR interventions is generally moderate to high, with rates ranging from 64% to 94% depending on context and delivery modality; (2) there is marked methodological heterogeneity in how adherence is defined and measured, limiting comparability across studies; (3) home-based, self-administered interventions tend to show higher adherence than clinic-based supervised interventions, likely due to greater flexibility and accessibility; (4) multiple facilitators (enjoyment, immediate feedback, distraction) and barriers (technical issues, logistics, loss of novelty) modulate adherence; and (5) the methodological quality of the included studies is heterogeneous, with only two studies rated as high quality according to the PEDro scale. These findings suggest that VR does not fully resolve the adherence challenge in chronic pain, but rather reconfigures it within specific contextual constraints.

However, these findings should be interpreted cautiously, as the observed adherence levels are derived from heterogeneous methodologies and a limited number of studies, which restricts the strength of the conclusions.

Interpretation of observed adherence levels

The adherence observed exceeds typical rates reported in conventional therapeutic exercise programs for chronic pain, which can be as low as 17% in real-world settings (Chikaka & Keller, 2024; Giacomelli et al., 2024). Home-based interventions (Darnall et al., 2020; Garcia et al., 2021) reached levels close to 90%, outperforming other digital interventions where dropout is often substantial (Shi & Sit, 2024). This improved performance may be explained by inherent features of VR, such as immersive distraction from pain (Kenney & Milling, 2016), gamification (Cerda et al., 2024; Mazzolenis et al., 2024), and content personalization (Aderinto et al., 2023; Mazzolenis et al., 2024). However, adherence may be more strongly determined by the reduction of contextual frictions such as transportation, time constraints, and structural rigidity than by the level of immersion or technological sophistication. From this perspective, VR may function more as a logistical facilitator than as a primary determinant of therapeutic behavior, challenging the prevailing narrative that positions immersion as the main driver of engagement (Lim et al., 2021).

Heterogeneity in adherence definition and measurement

The studies employed divergent definitions of adherence, ranging from objective device logs to self-reported diaries and retention rates. This lack of standardization, widely acknowledged in adherence research (Chikaka & Keller, 2024), limits cross-study comparability. Furthermore, most studies primarily assessed treatment persistence (completion), with limited information on implementation (actual dose received) or temporal patterns of use, key dimensions within the ABC taxonomy of adherence (Vrijens et al., 2012).

Comparison across modalities and contexts

Findings suggest that the context of delivery may have a greater influence on adherence than the level of technological immersion. Home-based interventions consistently showed higher adherence, likely due to greater flexibility and accessibility, whereas clinic-based programs faced more barriers. Although immersive VR has been proposed to enhance adherence through increased presence (Cerda et al., 2024; Matamala-Gomez et al., 2019), the included studies do not allow firm conclusions due to the lack of direct comparisons and the potential role of non-specific factors such as expectations and the structure of the therapeutic ritual (Garcia et al., 2021). Moreover, the heterogeneity in control conditions across studies further complicates direct comparisons, as control interventions ranged from passive conditions to active therapeutic programs, each with different implications for adherence.

Facilitators and barriers: implications for design

The adherence-related factors identified in this review reinforce the idea that patient behavior in digital environments results from multiple concurrent influences. Key facilitators such as enjoyment, immediate feedback, distraction, and reduced monotony align with motivational principles, including self-determination theory (Ryan & Deci, 2020; Ryan & Sapp, 2007). However, barriers such as technical issues, fatigue, logistical constraints, and loss of novelty emerged consistently. The latter was particularly evident in Lo et al. (2024), where adherence progressively declined over 12 weeks, a pattern widely described in digital interventions (Ehrler et al., 2025). Addressing these barriers requires enhancing content variability, incorporating narrative or social elements, and strengthening technical support (Janela et al., 2022; Kravitz et al., 2018; Mazzolenis et al., 2024).

Relationship between adherence and clinical outcomes

Evidence directly linking adherence to clinical outcomes remains scarce. Although several studies assessed both domains, few explicitly examined dose–response relationships or defined minimum effective thresholds. This limitation is particularly relevant, as adherence represents an intermediate outcome and does not necessarily reflect clinical impact. Completing an intervention does not guarantee that a sufficient therapeutic dose has been received. Some digital rehabilitation studies have reported positive associations between engagement and clinical improvement (Janela et al., 2022), underscoring the need to incorporate mediation analyses and dose–response designs in future research.

Methodological quality and risk of bias

The methodological quality of the included studies introduces an additional source of uncertainty. PEDro scores ranged from 3 to 8, reflecting heterogeneous quality. Major limitations included lack of blinding, follow-up losses exceeding 15%, and absence of intention-to-treat analyses. The latter is particularly critical, as excluding participants who drop out may artificially inflate reported adherence levels. Only the higher-quality studies (Garcia et al., 2021; Lo et al., 2024) applied intention-to-treat analyses (Garcia et al., 2021). Publication bias may also favor studies reporting higher adherence (Torous & Roberts, 2017). From a broader perspective, the overall certainty of the evidence can be considered low to moderate, given the limited number of studies, variability in methodological quality, and inconsistency in adherence definitions and measurement approaches. Additional concerns arise from potential publication bias and the lack of standardized outcome reporting, which further restrict confidence in the observed findings. Therefore, current evidence should be interpreted as preliminary, highlighting the need for more rigorous and standardized research in this field.

Comparison with other digital and conventional interventions

Although no direct quantitative comparisons were performed, adherence in VR interventions appears comparable or superior to that observed in other digital interventions (e.g., iCBT, mobile apps), where dropout rates are typically high (Buhrman et al., 2015; Shi & Sit, 2024). However, these comparisons are indirect and may be influenced by differences in study design and populations. In studies comparing VR with active controls (Garcia et al., 2021; Lo et al., 2024), adherence was similar or slightly higher in VR groups, although no consistent differences were observed.

Equity and accessibility

The reviewed studies provide limited information on technological equity, although external evidence suggests that VR can be accepted and used consistently across variables such as age, socioeconomic status, and rurality when appropriate equipment and support are provided (Maddox et al., 2024; Scheer et al., 2023). However, most studies were conducted in high-income countries, limiting generalizability. Thus, observed adherence may be shaped not only by individual or design factors but also by structural determinants of access to technology.

Clinical implications and future research

Evidence suggests that VR may be a useful tool to promote adherence in rehabilitation programs, particularly in home-based settings. Strategies to maintain engagement, provide robust technical support, and consider individual preferences are recommended (Bhatia et al., 2021; Lim et al., 2021; Ross et al., 2020). Future research should: (1) standardize adherence definitions and metrics (Vrijens et al., 2012); (2) evaluate dose–response relationships; (3) conduct pragmatic implementation studies; (4) investigate motivational mechanisms underlying adherence (Cerda et al., 2024; Ryan & Deci, 2020); and (5) address equity-related factors (Maddox et al., 2024; Scheer et al., 2023).

Limitations

This review has several limitations that should be considered when interpreting the findings. First, the number of included studies was small, reflecting the emerging nature of the evidence and limiting generalizability. Additionally, there was marked methodological heterogeneity across studies in both intervention design and adherence measurement, precluding quantitative synthesis and requiring a narrative interpretation.

Second, methodological quality varied across studies. The presence of follow-up losses, lack of intention-to-treat analyses in some studies, and identified risk of bias suggest that reported adherence levels may be overestimated. This is particularly relevant in feasibility studies, where experimental conditions differ from routine clinical practice.

Third, most studies evaluated short- to medium-term interventions and specific populations, primarily low back and neck pain, limiting extrapolation to other chronic pain conditions or longer interventions. Moreover, the limited representation of low- and middle-income settings restricts applicability (Torous & Roberts, 2017).

Additionally, restricting inclusion to randomized controlled trials, while strengthening internal validity, may have excluded relevant evidence from pragmatic or implementation studies, which are particularly important when analyzing adherence in real-world contexts.

Finally, it was not possible to establish consistent relationships between adherence levels and clinical outcomes due to the absence of dose–response analyses in the included studies, representing a key gap in the current literature.

Conclusions

This systematic review provides preliminary evidence that VR interventions for chronic pain may achieve favorable adherence levels, often comparable to those reported in conventional therapies. However, the heterogeneity in adherence definitions and measurement methods, variability in study quality, and the limited number of available studies restrict the strength of these conclusions.

Adherence to VR interventions appears to be influenced by multiple factors beyond technological immersion, including accessibility, flexibility of use, and contextual barriers related to implementation. While features such as enjoyment, feedback, and distraction may support engagement, their long-term impact remains uncertain.

Therefore, VR should not be considered a universal solution for improving adherence in chronic pain rehabilitation. Its effectiveness will depend on the design of interventions, the integration within real-

world clinical settings, and the ability to sustain engagement over time. Future research should prioritize the standardization of adherence measures, the evaluation of dose–response relationships, and the development of pragmatic studies that better reflect real-world conditions.

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