

EFFECTIVENESS OF VIRTUAL REALITY-BASED PHYSIOTHERAPY IN REDUCING CHRONIC LOWER BACK PAIN: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Chronic low back pain (CLBP) is a leading cause of disability worldwide, and conventional physiotherapy, while effective, is limited by modest effect sizes and poor long-term adherence. Virtual reality (VR) has emerged as a technology-assisted adjunct with the potential to increase engagement and target both the sensory and psychological components of chronic pain. **Objective:** To systematically review randomized controlled trial evidence on the effectiveness of VR-based physiotherapy for reducing pain and disability in adults with CLBP. **Methods:** A systematic search of seven electronic databases was conducted to identify randomized controlled trials evaluating VR-based physiotherapy interventions in adults with non-specific CLBP. Data on study characteristics, interventions, and outcomes for pain, disability, and kinesiophobia were extracted and synthesised narratively. **Results:** Seven randomized controlled trials involving 641 participants met the inclusion criteria. VR-based interventions, whether immersive or non-immersive, and whether delivered alone or as an adjunct to conventional physiotherapy, were associated with statistically significant reductions in pain intensity relative to comparator conditions in six of the seven trials. Evidence for disability, kinesiophobia, and quality-of-life outcomes was more variable, and only one trial reported outcomes beyond three months post-treatment. **Conclusions:** VR-based physiotherapy shows promising, though not yet conclusive, evidence of effectiveness for reducing pain in CLBP. Larger, longer-term, and more methodologically standardised trials are required before it can be recommended as a standard component of care.

KEYWORDS: Virtual Reality, Physiotherapy, Chronic Low Back Pain, Rehabilitation, Pain Management.

1. BACKGROUND

Low back pain (LBP) is among the most prevalent and disabling musculoskeletal conditions worldwide. According to the Global Burden of Disease (GBD) 2021 Low Back Pain Collaborators, LBP affected approximately 619 million people globally in 2020, and this number is projected to rise to nearly 843 million by 2050 as populations grow and age (GBD 2021 Low Back Pain Collaborators, 2023). LBP has consistently ranked as the leading cause of years lived with disability (YLDs) across nearly every region of the world for more than three decades, imposing a substantial burden on individuals, health systems, and economies (GBD 2021 Low Back Pain Collaborators, 2023). The burden is not distributed evenly: it falls disproportionately on socioeconomically disadvantaged populations and is projected to grow fastest in Asia and Africa, where health infrastructure is often least equipped to respond (GBD 2021 Low Back Pain Collaborators, 2023).

Chronic low back pain (CLBP), typically defined as pain persisting for longer than twelve weeks, represents a particularly challenging subset of this condition. Unlike acute LBP, which is usually self-limiting and resolves within a few weeks regardless of treatment, CLBP is often recurrent, resistant to single-modality treatment, and associated with long-term functional impairment (Yilmaz Yelvar et al., 2017). Patients with CLBP frequently cycle through multiple health care providers and interventions, including medication, injections, manual therapy, and surgery, often with only modest and transient benefit. The chronicity of the condition contributes heavily to its economic cost, which

includes both direct medical expenditure and indirect costs related to lost productivity, disability payments, and early retirement from the workforce (GBD 2021 Low Back Pain Collaborators, 2023).

Contemporary understanding of CLBP has shifted away from a purely biomedical framework toward a biopsychosocial model that recognises the interplay of physical, psychological, and social factors in the maintenance of pain and disability. Central to this model are constructs such as fear-avoidance beliefs, kinesiophobia (fear of movement or re-injury), and pain catastrophising, all of which have been shown to predict poorer functional outcomes independent of tissue pathology (Yilmaz Yelvar et al., 2017; van der Veen et al., 2026). Patients with high kinesiophobia often restrict movement to avoid anticipated pain, which paradoxically leads to deconditioning, further pain sensitisation, and prolonged disability (van der Veen et al., 2026). This recognition has driven a search for interventions capable of simultaneously addressing the physical and psychological dimensions of CLBP.

Exercise-based physiotherapy remains the cornerstone of conservative management for CLBP and is recommended as a first-line treatment in most international clinical guidelines. Approaches such as motor control exercise, graded activity, and general strengthening programmes have demonstrated modest but consistent benefits for pain and function. However, the effect sizes of conventional physiotherapy are frequently small, and clinical gains are not always maintained over time (Li et al., 2024). A substantial proportion of patients also disengage from prescribed home exercise programmes, undermining the dose of therapy actually delivered (Afzal et al., 2023).

Poor adherence is a long-recognised barrier to the effectiveness of physiotherapy for CLBP. Repetitive therapeutic exercise is often perceived by patients as monotonous, and pain-related fear can further discourage engagement with movement-based therapy (Afzal et al., 2023). Additionally, access to in-person physiotherapy is constrained in many settings by cost, transportation, workforce shortages, and, more recently, by public health restrictions such as those experienced during the COVID-19 pandemic (Garcia et al., 2021). These barriers have generated considerable interest in technology-assisted interventions that can increase engagement, enable home-based or remote delivery, and be scaled cost-effectively across health systems.

Virtual reality (VR) has emerged as one of the most promising technology-assisted approaches in musculoskeletal rehabilitation. VR refers to computer-generated simulated environments with which a user can interact, ranging from fully immersive systems delivered through head-mounted displays (HMDs) to non-immersive systems using motion-sensing devices such as the Microsoft Kinect or Nintendo Wii, viewed on a conventional screen (Afzal et al., 2022; Alsobayel et al., 2025). Immersive VR blocks out external visual and auditory stimuli, replacing them entirely with a synthetic environment, while non-immersive VR allows the user to remain visually connected to the physical environment, which may make it easier to combine with conventional physiotherapist supervision (Afzal et al., 2023). Several overlapping mechanisms have been proposed to explain the therapeutic potential of VR for pain conditions. The distraction-analgesia hypothesis suggests that the highly immersive and attention-capturing nature of VR competes for limited cognitive resources otherwise available for the processing of nociceptive signals, consistent with the gate control theory of pain (Matheve, Bogaerts and Timmermans, 2020). In a randomized controlled trial using non-immersive VR games during standardised pelvic tilt exercises, Matheve, Bogaerts and Timmermans (2020) demonstrated that VR distraction produced a measurable hypoalgesic effect during and immediately after exercise, together with a reduction in the amount of time patients reported thinking about their pain, relative to the same exercise performed without VR.

A second, complementary mechanism relates to graded exposure and the remediation of movement-related fear. By embedding therapeutic movements within engaging game mechanics, VR can encourage patients with high kinesiophobia to perform movements, such as lumbar flexion, that they would otherwise avoid, while manipulating visual and proprioceptive feedback to modify the perceived risk of the movement (van der Veen et al., 2026). The Virtual Immersive Gaming to Optimize Recovery (VIGOR) programme, for example, was explicitly designed around this principle, using immersive gaming to gradually increase lumbar flexion excursions in patients with CLBP and elevated fear of movement (van der Veen et al., 2026). Other behavioural-skills VR programmes combine pain neuroscience education, cognitive-behavioural strategies, diaphragmatic breathing, and biofeedback within the virtual environment, extending the mechanism of action beyond simple distraction or exposure toward broader self-management skill acquisition (Garcia et al., 2021).

Despite this growing theoretical and clinical interest, the empirical evidence base for VR-based physiotherapy in CLBP remains heterogeneous and, in places, contradictory. A 2024 systematic review and meta-analysis of twenty randomized controlled trials involving 1,059 participants reported that VR-based training produced significant immediate improvements in pain, kinesiophobia, and disability compared with control interventions, yet these between-group differences were not sustained when outcomes were re-assessed three to six months later (Li et al., 2024). Such findings raise important questions about the durability of VR-based effects, the influence of intervention dose and immersion level, and the comparative performance of VR relative to standard physiotherapy rather than to no treatment or sham conditions.

Given the rapid proliferation of VR platforms marketed for pain and rehabilitation, ranging from low-cost non-immersive gaming systems to regulatory-cleared, prescription-only immersive programmes, there is a pressing need to systematically appraise and synthesise the available randomized evidence specific to CLBP. The present systematic

review was therefore conducted to critically evaluate and synthesise findings from randomized controlled trials examining the effectiveness of VR-based physiotherapy, whether used as a stand-alone intervention or as an adjunct to conventional care, in reducing pain intensity and disability in adults with chronic lower back pain, and to characterise the intervention features and outcome domains associated with more favourable outcomes.

2. METHODOLOGY

Protocol and Registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework. A review protocol specifying the objectives, eligibility criteria, search strategy, and planned methods of analysis was drafted prior to the commencement of study selection in order to minimise reporting bias and to ensure methodological transparency.

Eligibility Criteria

Eligibility was defined using the Population, Intervention, Comparator, Outcome, and Study design (PICOS) framework. Population: adults aged 18 years or older with a clinical diagnosis of non-specific chronic low back pain, defined as pain localised to the lumbosacral region persisting for a minimum of twelve weeks. Intervention: any virtual reality-based physiotherapy or rehabilitation programme, delivered using either immersive (head-mounted display) or non-immersive (screen-based, motion-sensor-driven) VR technology, whether administered as a stand-alone intervention or in combination with conventional physiotherapy. Comparator: any active comparator, including conventional physiotherapy, sham or placebo VR, usual care, or no treatment. Outcomes: the primary outcome of interest was pain intensity, measured using validated instruments such as the Visual Analogue Scale (VAS), Numeric Pain Rating Scale (NPRS), or the Defense and Veterans Pain Rating Scale (DVPRS); secondary outcomes included functional disability (for example, the Oswestry Disability Index), kinesiophobia (for example, the Tampa Scale of Kinesiophobia), pain-related fear-avoidance beliefs, and adverse events. Study design: only randomized controlled trials, including parallel-group, cross-over, and pilot or feasibility randomized trials, published in peer-reviewed journals in the English language, were eligible for inclusion. Studies involving acute or subacute LBP exclusively, LBP secondary to malignancy, fracture, infection, or cauda equina syndrome, non-randomized designs, conference abstracts without full-text availability, and studies that did not report an extractable pain or disability outcome were excluded.

Information Sources and Search Strategy

A comprehensive literature search was performed across the following electronic databases: PubMed/MEDLINE, Embase, Cochrane Central Register of Controlled Trials (CENTRAL), CINAHL, Web of Science, PEDro (Physiotherapy Evidence Database), and Scopus, from database inception up to the search cut-off date. The search strategy combined controlled vocabulary (for example, MeSH terms) and free-text keywords relating to three concepts: (1) low back pain (e.g., "low back pain", "lumbago", "chronic low back pain"), (2) virtual reality (e.g., "virtual reality", "VR", "head-mounted display", "immersive technology", "exergaming", "serious games"), and (3) physiotherapy or rehabilitation (e.g., "physiotherapy", "physical therapy", "rehabilitation", "exercise therapy"). Boolean operators ("AND"/"OR") and truncation symbols were used to maximise sensitivity, and the reference lists of included studies and relevant prior systematic reviews were hand-searched to identify additional eligible trials. The clinical trial registries ClinicalTrials.gov and the World Health Organization International Clinical Trials Registry Platform were also screened to identify completed but potentially unpublished trials.

Study Selection

Search results from all databases were exported into a reference management program, and duplicate records were removed. Two reviewers independently screened titles and abstracts against the eligibility criteria. The full texts of records deemed potentially eligible were then retrieved and independently assessed in full by the same two reviewers. Disagreements at either stage were resolved through discussion, and where consensus could not be reached, a third reviewer was consulted for adjudication. The study selection process, including reasons for exclusion at the full-text stage, was documented and reported using a PRISMA flow diagram.

Data Extraction

A standardised, piloted data extraction form was used to extract the following information from each included study: first author and year of publication, country of study, sample size and allocation per group, participant characteristics (mean age, sex distribution, duration of symptoms), details of the VR intervention (hardware and software platform, immersion level, content, session frequency, and total treatment duration), details of the comparator condition, outcome measures used, timing of outcome assessment, and reported between- and within-group results for pain, disability, and any secondary outcomes. Data were extracted independently in duplicate, and discrepancies were resolved by consensus. Study authors were not contacted for missing data, given the nature of this review; where a needed statistic was not reported, this was noted as not available in the evidence tables.

Risk of Bias and Quality Assessment

The methodological quality of included randomized controlled trials was independently appraised by two reviewers using the Cochrane Risk of Bias 2 (RoB 2) tool, which evaluates five domains: bias arising from the randomization

process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported result. Each domain was rated as "low risk," "some concerns," or "high risk," and an overall risk-of-bias judgement was derived for each study. The Physiotherapy Evidence Database (PEDro) scale was applied as a supplementary quality metric given its widespread use in the physiotherapy literature. Quality assessment findings were used to inform the interpretation of the synthesised evidence but were not used to exclude studies from the review.

Data Synthesis and Analysis

Given the anticipated heterogeneity in VR platforms, comparator conditions, outcome measures, and follow-up durations across the included trials, a narrative synthesis approach, structured around outcome domains (pain intensity, disability, and secondary psychosocial and functional outcomes), was adopted as the primary method of evidence synthesis. Where data were sufficiently homogeneous and reported in a compatible format, results were also tabulated to allow visual and narrative comparison of effect direction and magnitude across studies. Findings were grouped and discussed according to the level of immersion of the VR intervention (fully immersive versus non-immersive), the nature of the comparator (active physiotherapy versus sham or usual care), and the timing of outcome assessment (immediate post-treatment versus longer-term follow-up), consistent with recommended approaches for synthesis without meta-analysis (SWiM) when pooling of effect estimates is not appropriate.

3. RESULTS

The literature search and subsequent screening process identified seven randomized controlled trials that met the full eligibility criteria and were included in the qualitative synthesis of this review (Garcia et al., 2021; Thomas et al., 2016; Matheve, Bogaerts and Timmermans, 2020; Yilmaz Yelvar et al., 2017; Afzal et al., 2022; van der Veen et al., 2026; Alsobayel et al., 2025). Collectively, these trials enrolled 641 participants with chronic or subacute-to-chronic non-specific low back pain across five countries (the United States, Pakistan, Belgium, Turkey, and Saudi Arabia), reflecting a reasonably broad geographic distribution of the current evidence base. Sample sizes ranged from 28 participants in the smallest pilot trial (Alsobayel et al., 2025) to 188 participants in the largest, fully powered efficacy trial (Garcia et al., 2021). Four of the included trials evaluated non-immersive, screen-based VR systems (Matheve, Bogaerts and Timmermans, 2020; Yilmaz Yelvar et al., 2017; Afzal et al., 2022; Thomas et al., 2016), while three evaluated fully immersive, head-mounted-display VR systems (Garcia et al., 2021; van der Veen et al., 2026; Alsobayel et al., 2025). Treatment duration ranged from a single exercise session (Matheve, Bogaerts and Timmermans, 2020) to an eight-week, fifty-six session home-based programme (Garcia et al., 2021). Table 1 summarises the characteristics of the included studies.

Table 1. Characteristics of Included Studies

Study (Year)	Country	Design	N (VR/Comp.)	VR technology	Comparator	Duration	Key outcome measures
Thomas et al. (2016)	USA	RCT (feasibility)	52 (26/26)	Immersive VR dodgeball game	Usual/standard care	Single 6-week programme	VAS pain, feasibility/safety, spinal kinematics
Yilmaz Yelvar et al. (2017)	Turkey	RCT	46 (22/22 approx.)	Non-immersive virtual walking video (video glasses)	Physiotherapy modalities alone	2 weeks, 10 sessions	VAS, Tampa Scale of Kinesiophobia, ODI, TUG, 6MWT, NHP
Matheve, Bogaerts & Timmermans (2020)	Belgium	RCT (single session)	84 (42/42)	Non-immersive VR games during exercise	Same exercise without VR	Single session	NPRS pain (during/after exercise), time spent thinking of pain
Garcia et al. (2021)	USA (remote/home-based)	Double-blind RCT	188 (94/94)	Immersive VR — EaseVRx (skills-based)	Sham VR (2D nature content in headset)	8 weeks, 56 sessions	DVPRS pain intensity, pain interference, PGIC, sleep, physical function

Study (Year)	Country	Design	N (VR/Comp.)	VR technology	Comparator	Duration	Key outcome measures
Afzal et al. (2022)	Pakistan	Single-blind RCT	84 (42/42)	Non-immersive VR (Kinect-based games) + routine PT	Routine physical therapy alone	12 sessions	VAS, Modified Oswestry Disability Index
van der Veen et al., VIGOR (2026)	USA	Phase II RCT (triple-blind)	159 enrolled	Immersive VR gaming (high- vs low-flexion arms)	Low lumbar-flexion VR game (active comparator)	9 weeks	Pain intensity, disability, kinesiophobia, expectations of pain/harm
Alsobayel et al. (2025)	Saudi Arabia	Single-blind pilot RCT	28 (approx. 14/14)	Fully immersive VR exercise game	Conventional exercise therapy	Not reported in detail (pilot protocol)	NPRS, FABQ, ODI, BBQ, functional performance tests

As shown in Table 1, the included trials varied considerably in the comparator condition used, ranging from an inert sham VR programme designed to control for expectancy and attention effects (Garcia et al., 2021) to active conventional physiotherapy (Afzal et al., 2022) and unstructured usual care (Thomas et al., 2016; Yilmaz Yelvar et al., 2017). This heterogeneity in comparator selection has direct implications for the interpretation of effect sizes, since trials comparing VR against an inert sham condition are more likely to isolate the specific contribution of the virtual environment itself, whereas trials comparing VR-augmented physiotherapy against physiotherapy alone are better placed to inform decisions about whether VR should be added to existing care pathways.

Table 2. Pain Intensity Outcomes

Study	Outcome tool	Group	Baseline	Post-treatment	Between-group result
Garcia et al. (2021)	DVPRS (0–10)	EaseVRx (immersive VR)	5.1 (SD 1.2)	≈30.3% mean reduction	Significantly greater reduction vs sham ($p<.05$); 46.8% vs 31.2% achieved $\geq 30\%$ reduction
		Sham VR	5.2 (SD 1.1)	≈15.8% mean reduction	
Afzal et al. (2022)	VAS (0–10)	VR + routine PT (Group B)	6.50 (SD 1.24)	1.00 (SD 0.60)	Group B improved significantly more than Group A ($p<.05$)
		Routine PT alone (Group A)	6.62 (SD 1.04)	3.32 (SD 0.81)	
Matheve et al. (2020)	NPRS (during/after exercise)	VR distraction	Comparable at baseline	Significant hypoalgesic effect	Significantly lower pain during/after exercise vs control ($p<.05$)
		No-VR control	Comparable at baseline	No hypoalgesic effect	
Yilmaz Yelvar et al. (2017)	VAS (0–10)	Virtual walking + PT	Improved in both groups	Greater improvement	Significant advantage for VR group ($p<.05$)
		PT modalities alone	Improved in both groups	Lesser improvement	

Study	Outcome tool	Group	Baseline	Post-treatment	Between-group result
Alsobayel et al. (2025)	NPRS (0–10)	Fully immersive VR exercise	Comparable at baseline	Greater reduction	Significant between-group difference (p=.044)
		Conventional exercise	Comparable at baseline	Smaller reduction	
Thomas et al. (2016)	VAS (0–10)	VR dodgeball	Reported at baseline	Feasibility outcome; efficacy not formally powered	Feasible/safe; preliminary pain data only
		Usual care	Reported at baseline	—	

Table 2 summarises the pain intensity outcomes reported across the included trials. In the largest trial (N=188), Garcia et al. (2021) reported that mean baseline pain intensity was closely matched between the EaseVRx group (5.1, SD 1.2) and the sham VR group (5.2, SD 1.1) (p=.612), confirming adequate randomization. Following eight weeks of treatment, the EaseVRx group achieved a mean pain-intensity reduction of 30.3%, compared with 15.8% in the sham VR group, and a significantly greater proportion of EaseVRx participants achieved a clinically meaningful ($\geq 30\%$) reduction in pain (46.8%, 36/77) relative to sham VR participants (31.2%, 24/77). This superiority for pain intensity was maintained at three-month, six-month, and twelve-month follow-up in subsequent publications from the same research group, with sustained between-group effect sizes in the small-to-moderate range (ds 0.44–0.54) at six months. In the trial by Afzal et al. (2022), both the physiotherapy-alone group (Group A) and the VR-plus-physiotherapy group (Group B) demonstrated statistically significant within-group reductions in pain from baseline to the twelfth session, but the magnitude of improvement was substantially larger in the VR-augmented group: mean VAS scores fell from 6.50 (SD 1.24) to 1.00 (SD 0.60) in Group B, compared with a fall from 6.62 (SD 1.04) to 3.32 (SD 0.81) in Group A (p<.05 for the between-group comparison). Matheve, Bogaerts and Timmermans (2020) similarly reported a significant hypoalgesic effect of non-immersive VR distraction during and immediately after a single bout of therapeutic exercise, alongside a significant reduction in the time participants spent thinking about their pain during the exercise, relative to the same exercise performed without VR. Yilmaz Yelvar et al. (2017) reported that VAS pain scores improved significantly more in the group receiving physiotherapy integrated with virtual walking than in the group receiving physiotherapy modalities alone. Alsobayel et al. (2025), in the smallest included trial, reported a statistically significant between-group difference favouring the fully immersive VR exercise group over conventional exercise for reduction in NPRS pain scores (p=.044). By contrast, in the feasibility trial of a VR dodgeball intervention, Thomas et al. (2016) reported that, while the intervention was feasible, safe, and well tolerated, the trial was explicitly designed and powered to test feasibility rather than efficacy, and pain outcomes should accordingly be interpreted as preliminary.

Table 3. Disability and Secondary Outcomes

Study	Outcome tool	Group	Baseline	Post-treatment	Between-group result
Afzal et al. (2022)	Modified ODI (0–100)	VR + routine PT (Group B)	69.16 (SD 9.13)	16.04 (SD 6.82)	Group B improved significantly more than Group A (p<.05)
		Routine PT alone (Group A)	65.08 (SD 8.94)	40.56 (SD 8.59)	
Yilmaz Yelvar et al. (2017)	Tampa Scale of Kinesiophobia; TUG; 6MWT	Virtual walking + PT	Improved in both groups	Greater improvement	Significant advantage for VR group on TSK, TUG, 6MWT (p<.05); NHP quality-of-life not significant

Study	Outcome tool	Group	Baseline	Post-treatment	Between-group result
		PT modalities alone	Improved in both groups	Lesser improvement	
van der Veen et al., VIGOR (2026)	Disability index; pain/harm expectations	High-flexion VR game	Elevated disability/fear	Significant reduction, maintained to 48 weeks	Both VR arms improved; improvement mediated by reduced pain/harm expectations, not ROM change
		Low-flexion VR game	Elevated disability/fear	Significant reduction, maintained to 48 weeks	
Alsobayel et al. (2025)	FABQ; ODI; functional tests	Fully immersive VR exercise	Elevated fear-avoidance	No significant change vs comparator	No significant between-group difference in FABQ or disability
		Conventional exercise	Elevated fear-avoidance	No significant change vs comparator	

Table 3 summarises secondary outcomes, principally functional disability and kinesiophobia. Afzal et al. (2022) reported that mean Modified Oswestry Disability Index scores decreased from 69.16 (SD 9.13) to 16.04 (SD 6.82) in the VR-plus-physiotherapy group, compared with a decrease from 65.08 (SD 8.94) to 40.56 (SD 8.59) in the physiotherapy-alone group ($p<.05$), representing the largest between-group difference in disability reduction observed among the included trials. Yilmaz Yelvar et al. (2017) reported significantly greater improvement in the Tampa Scale of Kinesiophobia, Timed Up-and-Go performance, and six-minute walk distance in the virtual-walking group relative to the comparator group, although quality-of-life scores did not differ significantly between groups. The VIGOR trial (van der Veen et al., 2026) reported that both VR arms (differing only in the amount of lumbar flexion required to progress through the game) achieved significant and clinically meaningful reductions in both pain and disability at the one-week post-treatment assessment, with these gains maintained across a 48-week follow-up period; mediation analyses indicated that reductions in patients' expectations of pain and harm, rather than objectively measured increases in lumbar range of motion, were most closely associated with clinical improvement. Alsobayel et al. (2025) reported no statistically significant between-group differences in fear-avoidance beliefs (FABQ) or disability outcomes, despite the significant advantage observed for pain intensity, illustrating that improvements in pain do not necessarily translate uniformly to improvements in disability or psychological outcomes within the same trial.

Risk of Bias Across Studies

Overall, risk-of-bias assessment using the Cochrane RoB 2 tool indicated considerable variability in methodological quality across the included trials. The larger, industry-affiliated trial of a commercially available behavioural-skills VR programme (Garcia et al., 2021) was judged to be at low overall risk of bias, incorporating double-blinding of participants (through use of an active sham VR comparator), pre-registration, and low attrition. Several of the smaller trials (Yilmaz Yelvar et al., 2017; Afzal et al., 2022) were judged to raise some concerns, principally relating to the feasibility of blinding participants to a physically distinct intervention (VR versus no VR) and limited reporting of allocation concealment procedures. The feasibility trial (Thomas et al., 2016) and the smallest pilot trial (Alsobayel et al., 2025) were judged to raise some concerns primarily due to small sample size and consequent imprecision, rather than structural flaws in trial conduct. No included trial was judged to be at high overall risk of bias, though the general difficulty of blinding participants to whether or not they are using an immersive headset represents a structural limitation affecting most trials in this field.

4. DISCUSSION

This systematic review synthesised evidence from seven randomized controlled trials, comprising 641 participants, examining the effectiveness of virtual reality-based physiotherapy for chronic lower back pain. Taken together, the included trials provide reasonably consistent evidence that VR-based interventions, whether delivered as fully immersive, home-based behavioural-skills programmes or as non-immersive, clinic-based adjuncts to conventional

physiotherapy, are associated with statistically significant reductions in pain intensity relative to a range of comparator conditions, including inert sham VR (Garcia et al., 2021), conventional physiotherapy alone (Afzal et al., 2022), and standard exercise without VR (Matheve, Bogaerts and Timmermans, 2020). These findings are broadly consistent with the wider VR-for-CLBP literature, including the meta-analytic estimate reported by Li et al. (2024), who pooled twenty randomized trials and reported a significant immediate-term reduction in pain (MD -1.43 , 95% CI -1.86 to -1.00) associated with VR-based training.

The magnitude of benefit observed, however, was not uniform across the included trials, and appeared to be influenced by the nature of the comparator condition employed. The largest effect sizes for pain reduction were observed in trials comparing VR against either an inactive comparator or conventional physiotherapy alone (Afzal et al., 2022; Garcia et al., 2021), whereas trials employing an active, attention- and expectancy-matched sham VR condition, as in the EaseVRx trial (Garcia et al., 2021), yielded a smaller, though still statistically and clinically significant, between-group difference. This pattern is consistent with a well-recognised phenomenon in pain intervention research, whereby non-specific factors such as novelty, attention, and expectation contribute meaningfully to observed treatment effects, and rigorous sham-controlled designs are essential for isolating the specific contribution of the virtual environment itself from these non-specific factors.

The trial by Afzal et al. (2022) merits particular attention, as it directly compared VR exercise combined with routine physiotherapy against routine physiotherapy alone, providing evidence most directly relevant to the clinical question of whether VR should be adopted as an adjunct within existing physiotherapy pathways rather than as a replacement for them. The substantially greater improvement observed in both pain (VAS reduction from 6.50 to 1.00 versus 6.62 to 3.32) and disability (Modified ODI reduction from 69.16 to 16.04 versus 65.08 to 40.56) in the VR-augmented group supports the proposition that VR may enhance, rather than substitute for, the benefits of conventional exercise therapy, potentially through improved engagement, adherence, and enjoyment of the prescribed exercise.

The single-session trial by Matheve, Bogaerts and Timmermans (2020) offers important mechanistic insight that complements the longer-duration efficacy trials included in this review. By demonstrating an immediate hypoalgesic effect of non-immersive VR during a single bout of standardised exercise, together with a reduction in pain-related cognitive interference, this trial provides direct experimental support for the distraction-analgesia mechanism proposed to underlie at least part of the therapeutic effect of VR, consistent with gate control theory (Matheve, Bogaerts and Timmermans, 2020). This mechanistic evidence is important because it suggests that even brief, low-cost, non-immersive VR exposure integrated into a single physiotherapy session may confer measurable short-term analgesic benefit, independent of any cumulative training effect.

In contrast, the VIGOR trial (van der Veen et al., 2026) illustrates a distinct and complementary mechanism, namely graded exposure to feared movements through gamified, immersive VR. The finding that improvements in pain and disability were mediated by reductions in patients' expectations of pain and harm, rather than by objectively measured increases in lumbar range of motion, is a notable and somewhat counter-intuitive result. It suggests that the primary therapeutic action of exposure-based VR programmes for CLBP with high kinesiophobia may operate predominantly through cognitive and psychological pathways, altering maladaptive beliefs about the dangerousness of movement, rather than through a purely biomechanical pathway of restored physical capacity (van der Veen et al., 2026).

The trial conducted by Yilmaz Yelvar et al. (2017), evaluating physiotherapy integrated with virtual walking, extends these findings to the domain of kinesiophobia and physical performance. The significant between-group advantage observed for the Tampa Scale of Kinesiophobia, the Timed Up-and-Go test, and the six-minute walk test suggests that VR-integrated physiotherapy may confer functional performance benefits beyond self-reported pain and disability scores alone. Notably, however, quality-of-life outcomes measured via the Nottingham Health Profile did not differ significantly between groups in this trial, indicating that improvements in pain, fear, and physical performance do not necessarily generalise to broader, patient-perceived quality of life within a short two-week intervention window.

A similar pattern of outcome-specific, rather than globally uniform, benefit was observed in the pilot trial by Alsobayel et al. (2025). Although fully immersive VR exercise produced a statistically significant reduction in pain relative to conventional exercise, no significant between-group difference was observed for fear-avoidance beliefs or disability-related outcomes. This dissociation between pain and disability/psychological outcomes, also apparent to a lesser extent in other included trials, underscores an important conceptual point: pain intensity, physical disability, and pain-related fear are related but partially independent constructs, and an intervention that effectively reduces one does not automatically produce proportionate improvement in the others. This has direct implications for outcome selection in future VR trials, which should ideally report a core outcome set spanning pain, function, and psychological domains rather than relying on a single primary endpoint.

The feasibility trial of a VR dodgeball intervention (Thomas et al., 2016) provides an important reminder that not all early-phase VR research in CLBP is designed, or adequately powered, to answer questions of clinical efficacy. This trial's primary contribution was to establish that an immersive, movement-based VR exergame using principles of graded exposure could be delivered safely and was tolerated well by patients with CLBP and significant fear-avoidance behaviour, without provoking adverse events such as motion sickness or symptom exacerbation. Such

feasibility and safety data are a necessary precursor to the design of adequately powered efficacy trials and should not be conflated with, or over-interpreted as, definitive evidence of clinical effectiveness.

Considering the included trials collectively, a distinction can be drawn between two broad categories of VR intervention represented in this review: (1) behavioural-skills and cognitive-behavioural VR programmes that incorporate pain education, relaxation, and biofeedback delivered through immersive, home-based headsets (exemplified by Garcia et al., 2021), and (2) movement- and exercise-based VR programmes, whether immersive or non-immersive, that embed therapeutic exercise within gamified environments (exemplified by Afzal et al., 2022; van der Veen et al., 2026; Alsobayel et al., 2025; Matheve, Bogaerts and Timmermans, 2020; Yilmaz Yelvar et al., 2017; Thomas et al., 2016). Both categories demonstrated benefit relative to their respective comparators, suggesting that VR may exert therapeutic effects through multiple, non-mutually exclusive pathways, including cognitive-behavioural skill acquisition, movement-based graded exposure, and attention-based distraction analgesia.

The durability of treatment effects represents one of the most clinically important, and most unevenly reported, considerations arising from this review. The EaseVRx trial (Garcia et al., 2021) is distinguished from the other included trials by the availability of long-term follow-up data, with subsequent publications from the same research group reporting maintained superiority of VR over sham VR for pain intensity and interference at three, six, and twelve months post-treatment. In contrast, most of the other included trials assessed outcomes only immediately post-treatment or after a very short intervention period, leaving the durability of their observed effects largely unknown. This asymmetry in the availability of long-term data likely also explains, at least in part, the divergent conclusion reached by Li et al. (2024), whose meta-analysis found that significant short-term (immediate) benefits of VR training were not maintained when outcomes were re-assessed at three to six months across the broader pool of twenty trials, most of which lacked long-term follow-up entirely.

Level of immersion emerged as a plausible, though not definitively established, moderator of treatment response within this review. The trials employing fully immersive, head-mounted-display VR generally reported larger or more consistent effects on pain intensity (Garcia et al., 2021; Alsobayel et al., 2025), potentially reflecting the greater degree of sensory immersion and consequent attentional capture achieved by these systems relative to non-immersive, screen-based alternatives. However, the non-immersive trials included in this review (Afzal et al., 2022; Yilmaz Yelvar et al., 2017; Matheve, Bogaerts and Timmermans, 2020) also demonstrated statistically significant benefits, and offer practical advantages in terms of lower cost, easier integration into a supervised clinic environment, and reduced risk of cybersickness, suggesting that immersion level alone should not be the sole determinant of platform selection in clinical practice.

The heterogeneity of comparator conditions, intervention duration, and outcome measures across the included trials precluded formal meta-analytic pooling within this review and is a recurring limitation across the wider VR-for-CLBP literature, as previously highlighted by Li et al. (2024). This heterogeneity likely reflects the nascent and rapidly evolving state of VR technology applied to chronic pain, with different research groups independently developing bespoke hardware-software combinations rather than converging on a small number of standardised, well-characterised interventions. Greater standardisation of intervention reporting, ideally following frameworks such as the Template for Intervention Description and Replication (TIDieR) checklist, together with the adoption of a core outcome set for CLBP trials, would substantially improve the comparability and pooled interpretability of future VR trials.

From a clinical and health-systems perspective, the findings of this review suggest that VR-based physiotherapy holds particular promise as a means of increasing patient engagement with prescribed exercise, extending access to structured pain self-management skills into the home environment, and providing an alternative or adjunctive analgesic strategy in a clinical landscape increasingly seeking to reduce reliance on pharmacological pain management, including opioids (Garcia et al., 2021). Nonetheless, the relatively modest sample sizes, short follow-up periods, and methodological heterogeneity characterising much of the current evidence base mean that these findings should, for now, be regarded as promising rather than conclusive, and should not be interpreted as justifying wholesale replacement of established, evidence-based physiotherapy approaches.

Several limitations of the included trials, and of this review itself, warrant explicit acknowledgement. At the level of the primary studies, blinding of participants to VR versus non-VR conditions is inherently difficult, raising the possibility of performance and detection bias in trials without an active sham comparator; several included trials also had modest sample sizes, limiting statistical power to detect between-group differences in secondary outcomes. At the level of this review, restriction to English-language, peer-reviewed publications may have excluded relevant trials published in other languages or in the grey literature, and the narrative, rather than fully quantitative meta-analytic, approach to synthesis, while appropriate given the observed heterogeneity, limits the precision with which an overall pooled effect size can be reported.

Future research priorities emerging from this review include the conduct of adequately powered, multi-centre randomized controlled trials with active comparators and outcome assessment extending beyond twelve months; direct head-to-head comparisons of immersive versus non-immersive VR platforms; economic evaluations to establish the cost-effectiveness of VR-based physiotherapy relative to conventional care, particularly given the upfront hardware

costs associated with immersive systems; and mechanistic studies further delineating the relative contributions of distraction, graded exposure, and cognitive-behavioural skill acquisition to observed clinical benefit. Trials should also report a standardised, multi-domain outcome set encompassing pain, disability, kinesiophobia, and quality of life, given the evidence from this review that improvement across these domains does not necessarily co-occur within the same intervention.

5. CONCLUSION

In conclusion, this systematic review of seven randomized controlled trials involving 641 participants indicates that virtual reality-based physiotherapy, whether delivered as an immersive, home-based behavioural-skills programme or as an adjunct to conventional exercise therapy, is associated with statistically significant and, in several trials, clinically meaningful reductions in pain intensity among adults with chronic lower back pain, with more variable and outcome-specific evidence for disability, kinesiophobia, and quality-of-life measures. The strongest and most durable evidence currently available relates to a single, well-powered, sham-controlled trial of an immersive behavioural-skills VR programme, with benefits maintained to twelve months, while the remaining evidence base is characterised by smaller trials, shorter follow-up periods, and considerable heterogeneity in VR platforms and comparator conditions. Virtual reality-based physiotherapy therefore represents a promising, though not yet definitively established, adjunct to conventional physiotherapy for chronic low back pain, and larger, longer-term, and more methodologically standardised trials are required before firm clinical practice recommendations can be made.

REFERENCES

1. Afzal, M. W., Ahmad, A., Bandpei, M. A. M., Gilani, S. A., Hanif, A., & Waqas, M. S. (2022). Effects of virtual reality exercises and routine physical therapy on pain intensity and functional disability in patients with chronic low back pain. *Journal of the Pakistan Medical Association*, 72(3), 413–417.
2. Afzal, M. W., Ahmad, A., Hanif, H. M. B., Chaudhary, N., & Gilani, S. A. (2023). Effects of virtual reality exercises on chronic low back pain: Quasi-experimental study. *JMIR Rehabilitation and Assistive Technologies*, 10, e43985.
3. Alsobayel, H., Almufaireej, K., Alimam, D., Alduaij, H., Shaheen, A., & Al-Khalifa, H. (2025). Effects of a fully immersive virtual reality exercise game on fear of movement, pain, and disability in people with chronic non-specific low back pain: A pilot randomized controlled trial. *Healthcare*, 13(16), 2641.
4. Darnall, B. D., Krishnamurthy, P., Tsuei, J., & Minor, J. D. (2020). Self-administered skills-based virtual reality intervention for chronic pain: Randomized controlled pilot study. *JMIR Formative Research*, 4(7), e17293.
5. Garcia, L. M., Birkhead, B. J., Krishnamurthy, P., Sackman, J., Mackey, I. G., Louis, R. G., Salmasi, V., Maddox, T., & Darnall, B. D. (2021). An 8-week self-administered at-home behavioral skills-based virtual reality program for chronic low back pain: Double-blind, randomized, placebo-controlled trial conducted during COVID-19. *Journal of Medical Internet Research*, 23(2), e26292.
6. Garcia, L. M., Darnall, B. D., Krishnamurthy, P., Mackey, I. G., Sackman, J., Louis, R. G., Maddox, T., & Birkhead, B. J. (2022). Three-month follow-up results of a double-blind, randomized placebo-controlled trial of 8-week self-administered at-home behavioral skills-based virtual reality (VR) for chronic low back pain. *Journal of Pain*, 23(5), 822–840.
7. GBD 2021 Low Back Pain Collaborators. (2023). Global, regional, and national burden of low back pain, 1990–2020, its attributable risk factors, and projections to 2050: A systematic analysis of the Global Burden of Disease Study 2021. *The Lancet Rheumatology*, 5(6), e316–e329.
8. Li, R., Li, Y., Kong, Y., Li, H., Hu, D., Fu, C., & Wei, Q. (2024). Virtual reality-based training in chronic low back pain: Systematic review and meta-analysis of randomized controlled trials. *Journal of Medical Internet Research*, 26, e45406.
9. Maddox, T., Garcia, H., Ffrench, K., Maddox, R., Adair, T., Sparks, C., Oldstone, L., Sackman, J., & Darnall, B. D. (2022). Durability of the treatment effects of an 8-week self-administered home-based virtual reality program for chronic low back pain: 6-month follow-up study of a randomized clinical trial. *Journal of Medical Internet Research*, 24(5), e37480.
10. Maddox, T., Oldstone, L., Sackman, J., Maddox, R., Adair, T., Ffrench, K., Sparks, C., & Darnall, B. D. (2024). Twelve-month results for a randomized sham-controlled effectiveness trial of an in-home skills-based virtual reality program for chronic low back pain. *Pain Reports*, 9(5), e1182.
11. Matheve, T., Bogaerts, K., & Timmermans, A. (2020). Virtual reality distraction induces hypoalgesia in patients with chronic low back pain: A randomized controlled trial. *Journal of NeuroEngineering and Rehabilitation*, 17(1), 55.
12. Thomas, J. S., France, C. R., Applegate, M. E., Leitkam, S. T., & Walkowski, S. (2016). Feasibility and safety of a virtual reality dodgeball intervention for chronic low back pain: A randomized clinical trial. *The Journal of Pain*, 17(12), 1302–1317.

13. van der Veen, S. M., Stamenkovic, A., France, C. R., Robinson, A., Sabo, R., Abtahi, F., & Thomas, J. S. (2026). The effects of Virtual Immersive Gaming to Optimize Recovery (VIGOR) in low back pain: A Phase II randomized controlled trial. *Healthcare*, 14(2), 142.
14. Yilmaz Yelvar, G. D., Çırak, Y., Dalkılıç, M., Parlak Demir, Y., Guner, Z., & Boydak, A. (2017). Is physiotherapy integrated virtual walking effective on pain, function, and kinesiophobia in patients with non-specific low-back pain? Randomised controlled trial. *European Spine Journal*, 26(2), 538–545.