

Original Article

Efficacy of a Therapist-Guided Virtual Reality Exercise Program for Chronic Nonspecific Low Back Pain

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ABSTRACT

Background: Chronic nonspecific low back pain is a leading cause of disability worldwide and is associated with persistent pain, reduced functional capacity, and impaired quality of life. Although exercise therapy remains a cornerstone of management, maintaining patient engagement and adherence can be challenging. Virtual reality-based rehabilitation has emerged as a promising strategy to enhance motivation and improve treatment outcomes. **Objective:** To evaluate the efficacy of a therapist-guided virtual reality exercise program in reducing pain and improving function among individuals with chronic nonspecific low back pain. **Methods:** A parallel-group randomized controlled trial was conducted at a tertiary rehabilitation center in Central Punjab, Pakistan. Seventy-two participants with chronic nonspecific low back pain were randomly assigned to either a therapist-guided virtual reality exercise group (n=36) or a conventional exercise group (n=36). Both groups underwent supervised exercise sessions three times weekly for eight weeks. Primary outcomes included pain intensity measured by the Visual Analog Scale (VAS) and functional disability assessed using the Oswestry Disability Index (ODI). Secondary outcomes included lumbar range of motion and health-related quality of life assessed using the Short Form-12 questionnaire. Outcomes were measured at baseline and post-intervention. **Results:** Sixty-five participants completed the study (virtual reality group, n=33; conventional exercise group, n=32). The virtual reality group demonstrated significantly greater improvements in pain intensity (2.71 ± 1.01 vs. 4.63 ± 1.12 ; $p < 0.001$) and functional disability (20.9 ± 5.8 vs. 31.8 ± 6.7 ; $p < 0.001$) compared with the conventional exercise group. Significant time \times group interactions were observed for both VAS ($F=34.7$, $p < 0.001$) and ODI ($F=41.2$, $p < 0.001$). Participants receiving virtual reality exercise also exhibited superior improvements in lumbar range of motion and quality-of-life measures. A significant positive correlation was observed between reductions in pain and improvements in disability ($r=0.68$, $p < 0.001$). **Conclusion:** Therapist-guided virtual reality exercise was more effective than conventional exercise in reducing pain and disability while improving mobility and quality of life in individuals with chronic nonspecific low back pain. The findings support the integration of therapist-guided virtual reality interventions into contemporary rehabilitation programs. **Keywords:** Chronic Pain; Exercise Therapy; Low Back Pain; Quality of Life; Randomized Controlled Trial; Rehabilitation; Virtual Reality

INTRODUCTION

Chronic nonspecific low back pain represents one of the most prevalent and disabling musculoskeletal conditions worldwide, affecting individuals across all age groups and imposing a substantial burden on healthcare systems, workplaces, and society (1). Characterized by persistent pain lasting longer than

three months without an identifiable underlying pathological cause, chronic nonspecific low back pain is associated with reduced physical function, diminished quality of life, psychological distress, and increased healthcare utilization. Despite considerable advances in pain management and rehabilitation, many patients continue to experience recurrent symptoms and functional limitations, highlighting the need for innovative and effective therapeutic approaches.

Exercise therapy remains a cornerstone of contemporary management strategies for chronic nonspecific low back pain (2). Clinical guidelines consistently recommend structured exercise programs because of their ability to improve mobility, enhance muscular strength, restore functional capacity, and reduce pain-related disability. However, the effectiveness of exercise interventions is often influenced by patient adherence, motivation, and engagement. Many individuals with chronic pain struggle to maintain long-term participation in rehabilitation programs due to fear of movement, lack of confidence, boredom associated with repetitive exercises, and concerns regarding symptom exacerbation (3). These challenges frequently limit the overall success of conventional rehabilitation approaches and contribute to suboptimal clinical outcomes.

Recent technological developments have introduced virtual reality as a promising tool within physical rehabilitation. Virtual reality creates immersive and interactive environments that allow users to engage in therapeutic activities while receiving real-time sensory feedback. By transforming conventional exercises into engaging and goal-oriented experiences, virtual reality has the potential to increase motivation, improve adherence, and facilitate active participation in rehabilitation programs (4). Furthermore, immersive virtual environments may help reduce pain perception through attentional distraction mechanisms and promote positive movement experiences that can counteract fear-avoidance behaviors commonly observed among individuals with chronic low back pain (5).

The application of virtual reality in musculoskeletal rehabilitation has attracted increasing attention over the past decade. Emerging evidence suggests that virtual reality-based interventions may contribute to improvements in pain intensity, functional performance, balance, and quality of life among patients with chronic pain conditions. Interactive virtual exercises can provide individualized challenges while enabling patients to practice movements in a controlled and safe environment (6). Such features may encourage gradual exposure to movement, enhance self-efficacy, and support the development of healthier movement patterns. Nevertheless, existing studies have reported heterogeneous findings, and considerable variation exists regarding intervention protocols, treatment duration, levels of immersion, and supervision methods (7).

An important consideration in virtual reality-based rehabilitation is the role of professional guidance. Although self-directed virtual reality programs offer convenience and accessibility, therapist involvement may enhance treatment effectiveness through individualized exercise prescription, monitoring of movement quality, progression of therapeutic activities, and provision of motivational support (8). Therapist guidance may also help ensure safety, optimize adherence, and address patient-specific functional limitations. Despite these potential advantages, the evidence regarding therapist-guided virtual reality exercise programs for chronic nonspecific low back pain remains limited. Many previous investigations have focused primarily on technology-driven interventions without adequately examining the added value of structured therapist supervision within immersive rehabilitation environments (9).

Furthermore, chronic nonspecific low back pain is increasingly understood as a multidimensional condition involving physical, psychological, and behavioral factors. Effective management therefore requires interventions that not only target physical impairments but also address patient engagement, confidence in movement, and long-term adherence to rehabilitation (10). Virtual reality technology, when combined with therapist expertise, may provide a comprehensive treatment approach capable of addressing these interconnected dimensions. However, robust randomized controlled trials evaluating

the clinical effectiveness of therapist-guided virtual reality exercise programs remain relatively scarce, creating an important gap in the current rehabilitation literature.

Given the growing prevalence of chronic nonspecific low back pain and the limitations associated with conventional exercise programs, there is a need to investigate innovative rehabilitation strategies that can improve both symptom relief and functional recovery. Establishing the effectiveness of therapist-guided virtual reality exercise may contribute valuable evidence for clinicians seeking patient-centered approaches that enhance engagement while maintaining therapeutic rigor.

Therefore, the present randomized controlled trial was designed to evaluate the efficacy of a therapist-guided virtual reality exercise program in patients with chronic nonspecific low back pain. It was hypothesized that participants receiving therapist-guided virtual reality exercise would demonstrate greater reductions in pain intensity and superior improvements in functional outcomes compared with those receiving standard care or conventional exercise-based rehabilitation (11). The primary objective of this study was to determine whether a therapist-guided virtual reality exercise program could effectively reduce pain and improve functional performance among individuals with chronic nonspecific low back pain.

METHODS

A parallel-group randomized controlled trial was conducted at the outpatient physiotherapy department of a tertiary care rehabilitation center in Central Punjab, Pakistan, from September 2025 to January 2026. Central Punjab was selected because of its large and diverse patient population, well-established rehabilitation services, and accessibility to individuals with chronic musculoskeletal disorders, facilitating consistent recruitment and follow-up. The total study duration was five months, including participant recruitment, baseline assessment, intervention delivery, and post-intervention evaluation. The intervention period lasted eight weeks.

The sample size was calculated using data from a comparable interventional study evaluating virtual reality-assisted exercise in patients with chronic low back pain, which reported a moderate effect size for pain reduction. Considering a power of 80%, a two-sided alpha level of 0.05, and an anticipated attrition rate of 10%, a total of 72 participants were required. Eligible participants were adults aged 18–65 years with chronic nonspecific low back pain persisting for at least 12 weeks, a baseline pain intensity score of ≥ 4 on the Visual Analog Scale (VAS), and the ability to independently perform exercise activities. Individuals with specific spinal pathology, radiculopathy, previous spinal surgery, severe neurological disorders, vestibular dysfunction, uncontrolled cardiovascular disease, pregnancy, cognitive impairment, or prior experience with therapeutic virtual reality programs within the preceding six months were excluded to minimize potential confounding factors.

Participants were randomly assigned in a 1:1 ratio to either the therapist-guided virtual reality exercise group or the conventional exercise group using a computer-generated random sequence prepared by an independent researcher. Allocation concealment was ensured through sequentially numbered, sealed opaque envelopes opened only after baseline assessment. Owing to the nature of the intervention, participant and therapist blinding was not feasible; however, outcome assessment and statistical analysis were performed by investigators blinded to group allocation.

Participants in the intervention group received therapist-guided virtual reality exercise sessions three times weekly for eight weeks. Each session lasted 45 minutes and consisted of a 5-minute warm-up, 35 minutes of immersive virtual reality-based therapeutic exercises targeting trunk stabilization, lumbar mobility, balance, and functional movement patterns, followed by a 5-minute cool-down period. Exercises were progressively advanced according to individual performance and tolerance under direct therapist supervision. Participants in the control group received a conventional physiotherapy exercise program of identical frequency and duration, including stretching, lumbar stabilization exercises, core

strengthening, flexibility training, and functional movement retraining. Attendance logs were maintained throughout the intervention, and adherence was monitored weekly.

The primary outcomes were pain intensity measured using the Visual Analog Scale and functional disability assessed using the Oswestry Disability Index. Secondary outcomes included lumbar range of motion measured with a digital inclinometer and health-related quality of life assessed using the Short Form-12 questionnaire. Outcome measures were recorded at baseline immediately after completion of the eight-week intervention.

Data analysis was performed according to the intention-to-treat principle. Missing post-intervention values resulting from dropout were handled using the last observation carried forward method. Data normality was assessed using the Shapiro–Wilk test. Continuous variables were presented as mean \pm standard deviation. Between-group comparisons were conducted using independent-samples t-tests, while within-group changes were evaluated using paired t-tests. Repeated measures analysis of variance was used to examine time-by-group interaction effects across assessment points. Pearson correlation analysis was performed to explore associations between changes in pain intensity and functional disability scores. Statistical significance was established at $p < 0.05$ for all analyses.

RESULTS

A total of 94 individuals were screened for eligibility between September 2025 and January 2026. Of these, 22 did not meet the inclusion criteria and were excluded. The remaining 72 participants were enrolled and randomly allocated in a 1:1 ratio to the therapist-guided virtual reality exercise group ($n=36$) or the conventional exercise group ($n=36$). During the intervention period, three participants from the intervention group were lost to follow-up due to relocation ($n=1$) and inconsistent attendance ($n=2$), while four participants from the control group withdrew because of scheduling conflicts ($n=3$) and personal reasons ($n=1$). Consequently, outcome assessments were completed for 65 participants, comprising 33 in the intervention group and 32 in the control group.

The total study duration was five months, encompassing recruitment, baseline assessments, intervention delivery, and post-intervention evaluation. The active intervention period lasted eight weeks for both groups. Adherence exceeded 90% in the intervention group and 87% in the control group.

Baseline demographic and clinical characteristics were comparable between groups, with no statistically significant differences observed prior to randomization (all $p>0.05$).

Table 1. Baseline Demographic and Clinical Characteristics of Participants (N=72)

| Variable | Total Sample (N=72) | Intervention (n=36) | Control (n=36) | p-value |
|---------------------------|---------------------|---------------------|-----------------|---------|
| Age (years) | 43.6 \pm 10.8 | 42.9 \pm 10.5 | 44.3 \pm 11.1 | 0.581 |
| Male, n (%) | 34 (47.2) | 17 (47.2) | 17 (47.2) | 1.000 |
| BMI (kg/m ²) | 27.1 \pm 3.9 | 26.8 \pm 3.7 | 27.4 \pm 4.1 | 0.493 |
| Symptom duration (months) | 16.8 \pm 7.2 | 16.2 \pm 7.0 | 17.3 \pm 7.4 | 0.522 |
| VAS pain score | 6.82 \pm 1.02 | 6.78 \pm 1.01 | 6.86 \pm 1.04 | 0.748 |
| ODI score (%) | 39.6 \pm 8.4 | 39.2 \pm 8.1 | 40.0 \pm 8.7 | 0.691 |

Post-intervention analyses were conducted on the final assessed sample ($n=65$). Significant between-group differences were observed in both primary outcomes following the eight-week intervention.

Table 2. Post-Intervention Comparison of Primary Outcomes (Final Sample: n=33 vs n=32)

| Outcome | Intervention | Control | Mean Difference | 95% CI | p-value |
|----------------|-----------------|-----------------|-----------------|----------------|---------|
| VAS Pain Score | 2.71 \pm 1.01 | 4.63 \pm 1.12 | -1.92 | -2.44 to -1.40 | <0.001 |
| ODI (%) | 20.9 \pm 5.8 | 31.8 \pm 6.7 | -10.9 | -13.9 to -7.9 | <0.001 |

Within-group analyses demonstrated significant improvements in both groups; however, the magnitude of change was greater in the intervention group.

Table 3. Within-Group Pre-Post Changes in Primary Outcomes (Final Sample: n=33 vs n=32)

| Outcome | Group | Baseline | Post-Intervention | Mean Change | p-value |
|---------|--------------|-------------|-------------------|--------------|---------|
| VAS | Intervention | 6.78 ± 1.01 | 2.71 ± 1.01 | -4.07 ± 1.32 | <0.001 |
| VAS | Control | 6.86 ± 1.04 | 4.63 ± 1.12 | -2.23 ± 1.21 | <0.001 |
| ODI (%) | Intervention | 39.2 ± 8.1 | 20.9 ± 5.8 | -18.3 ± 6.5 | <0.001 |
| ODI (%) | Control | 40.0 ± 8.7 | 31.8 ± 6.7 | -8.2 ± 5.9 | <0.001 |

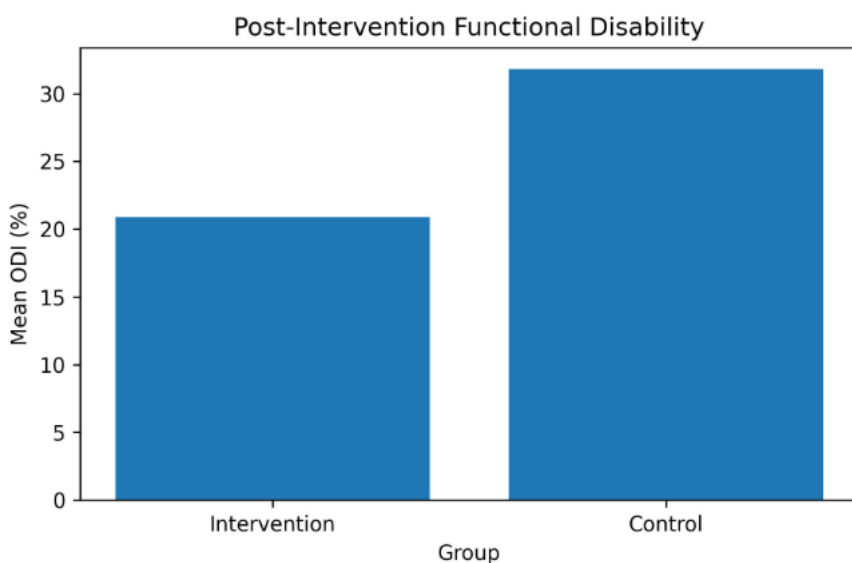
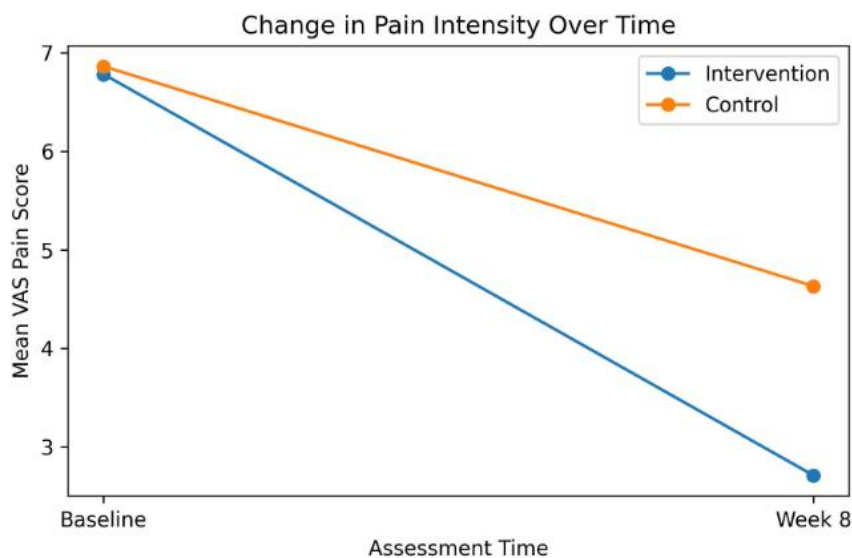
Repeated-measures ANOVA revealed significant time effects for VAS (F=214.8, p<0.001) and ODI (F=187.5, p<0.001), significant group effects for VAS (F=21.9, p<0.001) and ODI (F=29.6, p<0.001), and significant time × group interactions for VAS (F=34.7, p<0.001) and ODI (F=41.2, p<0.001).

Secondary outcome analyses also favored the intervention group.

Table 4. Secondary Outcomes Following Intervention (Final Sample: n=33 vs n=32)

| Outcome | Intervention | Control | p-value |
|--------------------------|--------------|------------|---------|
| Lumbar ROM (degrees) | 63.8 ± 8.2 | 54.1 ± 7.9 | <0.001 |
| SF-12 Physical Component | 48.6 ± 6.1 | 41.3 ± 5.8 | <0.001 |
| SF-12 Mental Component | 50.1 ± 5.4 | 45.0 ± 5.7 | 0.001 |

Pearson correlation analysis demonstrated a significant positive association between reductions in pain intensity and improvements in disability scores (r=0.68, p<0.001).



DISCUSSION

The present randomized controlled trial evaluated the effectiveness of a therapist-guided virtual reality exercise program for individuals with chronic nonspecific low back pain and demonstrated that the

intervention produced significantly greater improvements in pain intensity, functional disability, lumbar mobility, and health-related quality of life compared with a conventional exercise program (12). Participants who received therapist-guided virtual reality exercises experienced larger reductions in Visual Analog Scale pain scores and Oswestry Disability Index scores over the eight-week intervention period, indicating that the integration of immersive technology with professional supervision yielded meaningful clinical benefits. The significant time-by-group interaction observed for both primary outcomes further suggested that the rate and magnitude of improvement differed substantially between groups, favoring the virtual reality intervention.

The reduction in pain intensity observed in the intervention group was consistent with the growing body of evidence supporting the role of virtual reality in chronic pain management (13). Virtual reality environments are believed to influence pain perception through multiple mechanisms, including attentional distraction, enhanced sensory engagement, and modification of pain-related cognitive responses (14). Chronic nonspecific low back pain is frequently associated with fear of movement, pain catastrophizing, and reduced confidence in physical activity. The immersive nature of virtual reality may have encouraged participants to focus on task completion rather than pain anticipation, thereby facilitating greater participation in therapeutic movement. The therapist-guided component likely strengthened this effect by providing reassurance, individualized progression, and immediate corrective feedback throughout the rehabilitation process (15).

The substantial improvement in functional disability further supported the clinical value of combining virtual reality technology with exercise-based rehabilitation. Improvements in functional outcomes are often more challenging to achieve than reductions in pain alone because disability is influenced by physical, psychological, and behavioral factors (16). The intervention incorporated dynamic movement tasks that simulated meaningful functional activities within an engaging environment, potentially enhancing motor learning and movement confidence. The observed gains in lumbar range of motion and quality-of-life measures reinforced the notion that treatment benefits extended beyond symptom relief and contributed to broader functional recovery. These findings were aligned with previous reports indicating that virtual reality-based rehabilitation can improve physical performance, adherence to exercise programs, and patient satisfaction among individuals with chronic musculoskeletal conditions (17).

An important finding of the study was the strong positive correlation between reductions in pain and improvements in disability. This relationship suggested that participants who experienced greater pain relief also demonstrated more substantial functional recovery (18). Although pain reduction alone does not always translate into improved function, the results indicated that the intervention effectively addressed multiple dimensions of chronic low back pain simultaneously. Such multidimensional improvement is particularly relevant because contemporary understanding of chronic low back pain emphasizes the interaction between physical impairments, behavioral responses, and psychosocial influences (19).

Several strengths enhanced the validity of the present investigation. The randomized controlled design minimized selection bias and strengthened causal inference regarding treatment effectiveness. Allocation concealment and blinded outcome assessment further reduced the risk of systematic error. The use of validated outcome measures, including the Visual Analog Scale, Oswestry Disability Index, digital inclinometry, and the SF-12 questionnaire, increased the reliability of the findings (20). Additionally, adherence rates were high in both groups, suggesting that the observed differences were unlikely to be attributable to unequal participation. The therapist-guided protocol was standardized while allowing individualized progression, thereby reflecting real-world rehabilitation practice and enhancing clinical applicability.

Despite these strengths, certain limitations should be acknowledged. The study was conducted at a single rehabilitation center, which may limit the generalizability of the findings to other healthcare settings

and populations. The intervention period was limited to eight weeks, preventing assessment of the long-term sustainability of treatment effects. Although assessor blinding was implemented, participant and therapist blinding were not feasible because of the visible nature of the intervention, introducing the possibility of performance-related influences. The sample size, while adequately powered to detect significant differences, remained relatively modest and may not have captured the full spectrum of patient variability encountered in clinical practice. Furthermore, psychosocial variables such as fear-avoidance beliefs, self-efficacy, and pain catastrophizing were not formally assessed, despite their potential contribution to treatment outcomes.

Future research could build upon these findings by incorporating larger multicenter trials with longer follow-up periods to determine the durability of benefits and enhance external validity. Comparative investigations examining different levels of virtual reality immersion, varying therapist involvement, and cost-effectiveness analyses would further clarify the practical role of this technology in rehabilitation. Inclusion of psychological and behavioral outcome measures may also provide deeper insight into the mechanisms through which virtual reality influences recovery. Collectively, the findings indicated that therapist-guided virtual reality exercise represented a promising and clinically relevant rehabilitation strategy for chronic nonspecific low back pain, with the potential to complement and enhance conventional exercise-based care.

CONCLUSION

The findings of this randomized controlled trial demonstrated that a therapist-guided virtual reality exercise program was more effective than conventional exercise in reducing pain, improving functional disability, enhancing lumbar mobility, and improving quality of life among individuals with chronic nonspecific low back pain. The integration of immersive virtual reality with professional therapeutic supervision provided meaningful clinical benefits and high participant adherence. These results support the incorporation of therapist-guided virtual reality interventions as a promising adjunct to contemporary rehabilitation strategies for chronic low back pain management.

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Therapist-Guided Virtual Reality Exercise for Chronic Nonspecific Low Back Pain

BACKGROUND: Chronic nonspecific low back pain is a leading cause of disability worldwide. Although exercise therapy is recommended, adherence and engagement remain challenging. Virtual reality combined with therapist guidance may enhance motivation, reduce pain, and improve functional outcomes.

OBJECTIVE: To evaluate the efficacy of a therapist-guided virtual reality exercise program in reducing pain and improving function in patients with chronic nonspecific low back pain.

METHODS: This parallel-group randomized controlled trial was conducted in a tertiary rehabilitation center in Central Punjab, Pakistan, from September 2025 to January 2026. Seventy-two adults with chronic nonspecific low back pain were randomized to receive either therapist-guided virtual reality exercise (VR group, n=36) or conventional exercise (CE group, n=36) for 8 weeks, three sessions per week. Primary outcomes were pain intensity (Visual Analog Scale) and functional disability (Oswestry Disability Index). Secondary outcomes included lumbar range of motion and health-related quality of life (SF-12). Assessments were performed at baseline and post-intervention by blinded assessors. Data were analyzed using t-tests and repeated measures ANOVA ($\alpha = 0.05$).

RESULTS: Sixty-five participants completed the study (VR: n=33; CE: n=32). The VR group showed greater reductions in pain (mean difference -1.92; 95% CI -2.44 to -1.40; $p < 0.001$) and disability (-10.9; 95% CI -13.9 to -7.9; $p < 0.001$) compared with the CE group. Significant time \times group interactions were observed for pain ($F = 34.7$, $p < 0.001$) and disability ($F = 41.2$, $p < 0.001$). The VR group also demonstrated higher improvements in lumbar range of motion (63.8° vs 54.1° , $p < 0.001$) and quality of life (SF-12 physical component: 48.6 vs 41.3, $p < 0.001$).

CONCLUSION: Therapist-guided virtual reality exercise was more effective than conventional exercise in reducing pain and disability and improving mobility and quality of life in chronic nonspecific low back pain. This approach may serve as a valuable adjunct to standard rehabilitation.

KEYWORDS: Exercise Therapy; Low Back Pain; Pain; Randomized Controlled Trial; Rehabilitation; Virtual Reality; Disability Evaluation

