VIRTUAL REALITY GRADED EXPOSURE THERAPY FOR CHRONIC LOW BACK PAIN: A FEASIBILITY AND ACCEPTABILITY STUDY

By

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https://doi.org/10.26634/javr.2.2.21649

Date Received: 13/02/2025 *Date Revised: 15/02/2025* *Date Accepted: 17/02/2025*

ABSTRACT

Chronic low back pain (CLBP) is a leading cause of disability worldwide, with traditional graded exposure therapy (GET) frequently limited by high costs and patient attrition. This pilot study examines the feasibility and acceptability of a virtual reality (VR) dodgeball game designed for CLBP rehabilitation. The game integrates graded activity, biofeedback, and gamification principles, tailored to individual patients' range of motion using full-body tracking. The study involved evaluations by three pain rehabilitation experts, two CLBP patients, and 16 healthy participants. Results demonstrated high feasibility in clinical settings, with patients reporting high acceptability, describing the game as fun and engaging, and noting increased movement without exacerbating pain. While these preliminary findings are promising, further research with larger cohorts is necessary to validate efficacy.

Keywords: Virtual Reality, Biofeedback, Gamification, VR Therapy, Clinical Evaluation, Pain Rehabilitation.

INTRODUCTION

Chronic low back pain (CLBP) is a primary cause of disability globally, severely affecting both quality of life and productivity (Hartvigsen et al., 2018). In Venezuela, CLBP accounts for approximately 10% of primary care visits, translating to billions of dollars in lost productivity annually (Flachs et al., 2015). Despite its widespread occurrence, non-specific chronic low back pain (CLBP) pain without a clear anatomical cause continues to pose a clinical challenge, typically managed through Graded Exposure Therapy (GET). This approach aims to reduce fear-avoidance behaviors by gradually reintroducing movement and activity (Ferreira et al., 2018; Foster et al., 2018). However, GET is associated with significant limitations, including high dropout rates and resource-intensive implementation (Bailey et al., 2010; Steiner et al., 2020).

Recently, Virtual Reality (VR) has emerged as a promising rehabilitation tool, providing immersive, interactive environments that promote movement through gamification, biofeedback, and real-time performance tracking (Jin et al., 2016; Mahrer & Gold, 2009; Pourmand et al., 2017). VR applications in physical therapy have demonstrated increased adherence, motivation, and functional improvement across various musculoskeletal conditions (Li et al., 2024; Goudman et al., 2022).

This study evaluates a novel VR dodgeball game designed to motivate movement while tracking lumbar kinematics in individuals with CLBP. By integrating real-time biofeedback, adaptive difficulty, and gamified elements, this intervention seeks to address key barriers associated with traditional GET. The primary objectives of this study are to assess the feasibility, usability, and patient acceptability of the VR-based intervention, providing foundational evidence for its potential clinical application.

1. Literature Review

1.1 Chronic Low Back Pain and Fear-Avoidance Behaviours

Chronic low back pain was a persistent musculoskeletal condition affecting millions worldwide. It was frequently associated with significant disability, decreased physical activity, and psychological distress (Hartvigsen et al., 2018). The fear-avoidance model explained how pain-related fear led to activity restriction, reinforcing physical deconditioning and pain persistence (Vlaeyen & Linton, 2012). Traditional rehabilitation strategies focused on overcoming these behaviors through gradual exposure to feared movements, known as Graded Exposure Therapy (GET) (Lee et al., 2015).

While GET demonstrated effectiveness in reducing pain-related fear, its implementation was challenged by high attrition rates and patient disengagement (Bailey et al., 2010). Patients often perceived traditional rehabilitation exercises as monotonous and struggled to adhere to long-term treatment plans. Additionally, GET required close supervision by healthcare professionals, increasing costs and limiting accessibility (Goudman et al., 2022).

1.2 Virtual Reality in Rehabilitation

Virtual Reality (VR) gained recognition as an effective rehabilitation tool, leveraging immersive environments to facilitate movement and pain desensitization. VR enabled graded exposure by incorporating interactive tasks that encouraged movement while minimizing pain perception (Jones et al., 2016). Studies indicated that VR-based rehabilitation enhanced motivation, engagement, and treatment adherence compared to traditional physiotherapy methods (Li et al., 2024).

Recent systematic reviews suggested that VR interventions could effectively improve mobility, reduce pain sensitivity, and enhance overall functional outcomes in patients with musculoskeletal conditions (Goudman et al., 2022; Li et al., 2024). By integrating gamification elements such as score tracking, real-time feedback, and adaptive difficulty, VR interventions enhanced intrinsic motivation and encouraged repeated participation.

In the context of chronic pain, VR had been shown to modulate pain perception through distraction mechanisms and neuroplasticity (Hoffman et al., 2020). Pain reduction was achieved by shifting cognitive focus away from discomfort and toward engaging virtual tasks. These findings suggested that VR-based GET interventions might have offered a more effective and engaging alternative to traditional approaches (Nijs et al., 2017).

1.3 Motion Tracking and Biofeedback in VR Rehabilitation

Advancements in motion capture technology enabled the precise tracking of body movements in VR environments, allowing for real-time biofeedback (Clark et al., 2020). Biofeedback mechanisms helped patients visualize movement performance, facilitating motor learning and reinforcing correct movement patterns (Toledo-Peral et al., 2022).

The HTC Vive system, used in this study, employed infrared tracking for full-body motion capture, enabling clinicians to monitor patient performance with high accuracy. Real-time lumbar kinematics tracking allowed for personalized adjustments to exercise difficulty, ensuring that movements remained within the patient's comfort range while promoting gradual exposure to previously avoided actions (Aristidou & Lasenby, 2011).

Recent studies highlighted the benefits of biofeedback-driven VR interventions in rehabilitation. For instance, Brea-Gomez et al. (2021) demonstrated that real-time movement tracking and feedback significantly improved functional recovery in patients with lower back pain. Similarly, Toledo-Peral et al. (2022) found that biofeedback-enhanced VR exercises led to greater pain reduction and mobility gains than conventional physical therapy.

Given these technological advancements, integrating motion tracking and biofeedback into VR-based GET could enhance therapeutic outcomes by providing immediate feedback and facilitating adaptive exercise progression.

2. Methods

2.1 Participants

The participants in this study consisted of:

- Three pain rehabilitation experts, including two physiotherapists and one researcher.
- Two CLBP patients, with 11 and 25 years of illness.
- Sixteen healthy participants, comprising graduate and undergraduate students.

2.2 VR System and Game Design

The VR system used in this study was based on HTC Vive full-body tracking, with the game requiring players to dodge, catch, and throw virtual balls, integrating biofeedback and real-time movement tracking. A clinician user interface was also developed for data tracking and patient monitoring, as shown in Figure 1. Additionally, the VR system in use is shown in Figure 2, illustrating how the system functions during gameplay.

2.2.1 Key Features

- *Graded Activity:* The frequency of enemy spawns and the placement of balls were adjusted based on the patient's range of motion.
- *Biofeedback:* Real-time monitoring of lumbar kinematics was conducted.
- *Gamification:* Points were awarded for exceeding baseline movement.

Figure 1. Clinician User Interface

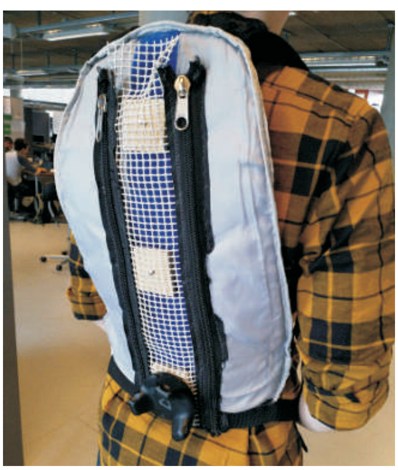

Figure 2. VR System

2.3 Evaluation Metrics

- *Feasibility:* Assessed through expert interviews and SUS scores.
- *Acceptability:* Evaluated based on patient feedback using the Game Experience Survey (GES).
- *Usability:* Measured through SUS scores from healthy participants.
- *Simulator Sickness:* Assessed using the Simplified SSQ (Kennedy et al., 1993).

3. Results

The results of this pilot study provide critical insights into the feasibility, acceptability, and usability of the VR-GET system for chronic low back pain rehabilitation. Data from expert evaluations, patient feedback, and healthy participant testing indicate that the system demonstrates strong potential for clinical implementation and user engagement.

3.1 Feasibility

The system's feasibility was evaluated through expert interviews and System Usability Scale (SUS) scores. All three pain rehabilitation experts strongly agreed that the system was clinically viable, highlighting its potential to improve patient engagement compared to traditional GET interventions.

3.1.1 Key Expert Insights

- The VR-GET system has high clinical applicability and could be effectively integrated into rehabilitation programs.
- The gamified nature of the intervention makes it more engaging than traditional GET, potentially reducing attrition rates.
- Automated difficulty adjustments and real-time biofeedback were viewed as strong advantages, allowing clinicians to tailor therapy based on patient progress.

3.1.2 Quantitative Findings

- Table 1 shows the SUS scores for both experts and healthy participants were evaluated to assess the system's usability.
- Experts particularly praised the intuitive interface, biofeedback integration, and calibration system for tailoring movement therapy.

  "*The system offers an interactive, low-cost alternative that could keep patients engaged compared to standard physiotherapy.*" — Expert Reviewer

3.2 Acceptability

Patient acceptability was evaluated using the Game Experience Survey (GES) and semi-structured interviews. The two CLBP patients who participated gave overwhelmingly positive feedback regarding the system's comfort, engagement, and motivational aspects.

3.2.1 Key Findings from Patient Feedback

- *Engaging and Motivating:* The game was described as fun and challenging in a good way by patients.
- *No Pain Exacerbation:* An increase in back pain was not reported by either patient after gameplay.
- *Encourages Movement:* Baseline lumbar motion was exceeded during gameplay, indicating increased activity levels.

3.2.2 Quantitative Findings

The Game Experience Survey (GES) ratings provided insights into the system's usability and patient experience. Participants rated the ease of use at 4 out of 5, indicating that the system was generally user-friendly. The comfort level was also rated 4 out of 5, suggesting that the VR experience was well-tolerated. Additionally, willingness to continue using the system received the highest rating of 5 out of 5, highlighting strong patient engagement and motivation for continued use.

"*I didn't even think about my pain while playing. It kept me moving in a way that normal exercises don't.*" — Patient B

Group	Mean SUS Score	Min	Max	Std. Dev
Healthy Participants	81.72	62.5	97.5	8.88
Experts	80.83	77.5	85	3.82

Table 1. SUS Scores

3.3 Movement Metrics

Both CLBP patients exceeded baseline lumbar motion while playing. This suggests that the game successfully encouraged movement without increasing discomfort.

3.4 Simulator Sickness

The Simulator Sickness Questionnaire (SSQ) results, shown in Table 2, indicated that minor symptoms, such as sweating, were reported. However, these symptoms were attributed to physical activity rather than VR sickness, suggesting that the VR system did not induce significant discomfort or motion-related issues.

4. Discussion

The findings from this pilot study highlight the feasibility, acceptability, and usability of Virtual Reality Graded Exposure Therapy (VR-GET) for chronic low back pain (CLBP) rehabilitation. This discusses how VR-based GET compares to traditional approaches, explores the impact of patient engagement and adherence, and outlines limitations and future directions.

4.1 Comparison to Traditional GET

Traditional Graded Exposure Therapy (GET) has been widely used for managing chronic musculoskeletal pain, aiming to gradually reintroduce movement while reducing fear-avoidance behaviors (Bailey et al., 2010). Despite its effectiveness, traditional GET often suffers from high dropout rates, primarily due to:

- *Low Patient Engagement:* Exercises are frequently found to be repetitive and are unable to maintain patient motivation over time.
- *Resource-Intensive Treatment:* Frequent supervision by healthcare professionals is required, making long-term therapy costly and difficult to sustain.

Symptom	Percentage of Participants Reporting
Sweating	50%
Fatigue	20%
Eye Strain	10%
No Discomfort	40%

Table 2. Simulator Sickness Questionnaire (SSQ) Results

- *Unclear Adherence Timelines:* Progress is typically struggled to be tracked by many patients, leading to inconsistent participation.

4.1.1 Addressing the Challenges with VR-GET

The VR-GET approach introduced in this study provides a highly immersive, interactive, and gamified alternative to traditional GET, as shown in Table 3.

4.2 Patient Engagement and Adherence

Sustained patient engagement is a critical factor in rehabilitation success. Traditional rehabilitation exercises can feel monotonous and isolating, whereas VR-based therapy transforms rehabilitation into an interactive and immersive experience.

4.2.1 Gamification: A Key Driver of Adherence

Gamification is widely acknowledged as an effective strategy for enhancing adherence in rehabilitation programs. The VR dodgeball game developed in this study integrates essential gamification principles, which include:

- *Real-time feedback:* Instant feedback on movements is provided to patients.
- *Scoring System:* Points are awarded for exceeding baseline movement, encouraging progression.
- *Adaptive Challenges:* Difficulty is automatically adjusted based on performance, preventing boredom or frustration.
- *Engaging Visuals and Environment:* A relaxing tropical island setting is used, contrasting with clinical environments to make therapy more enjoyable.

4.2.2 Patient Feedback on Engagement

- *"I didn't feel like I was doing therapy—it was just fun!"*

Challenge in Traditional GET	VR-GET Solution
High dropout rates due to low motivation.	OpeGamification encourages continued participation by making therapy engaging.
Supervised sessions are resource-intensive.	Patients can engage in self-guided rehabilitation with minimal clinician supervision.
Lack of progress tracking discourages adherence.	Real-time biofeedback and movement tracking enhance patient awareness of improvements.
Fear-avoidance behaviors limit movement.	VR distracts from pain perception, reducing movement anxiety.

Table 3. Challenges in Traditional GET and Solutions Offered by VR-GET

- *"I found myself moving without thinking about my pain."*
- *"This is so much better than just doing exercises at home."*

4.2.3 Quantitative Findings

The Game Experience Survey (GES) ratings provided valuable insights into user experience with the VR-GET system. Participants rated the ease of use at 4 out of 5, indicating that the system was largely user-friendly. The willingness to continue using the system received the highest rating of 5 out of 5, suggesting strong motivation to continue engaging with the therapy. Additionally, engagement was also rated 5 out of 5, demonstrating that the system was highly engaging and successful in maintaining patient involvement throughout the sessions.

4.3 Limitations and Future Directions

While this pilot study provides promising evidence for the feasibility of VR-GET, certain limitations must be addressed in future research.

4.3.1 Small Sample Size

- This study only included two CLBP patients.
- Future research should involve a larger, more diverse sample to generalize the findings and evaluate the system's effectiveness across various patient demographics.

4.3.2 Novelty Bias

- Patients may be initially excited about using VR, but engagement may decline over time.
- Future research should include a longitudinal study of 6 to 12 months to assess long-term adherence rates and sustained benefits.

4.3.3 Hardware and Accessibility Challenges

- VR systems require setup, which may limit accessibility for home use.
- HTC Vive trackers and external sensors need calibration, potentially reducing usability for elderly or less tech-savvy patients.
- Future research should investigate wireless and standalone VR systems, such as Meta Quest, to facilitate home-based rehabilitation.

4.3.4 Need for Personalization

- While this system adapts to lumbar motion, it does not yet personalize exercise regimens for individual rehabilitation needs.
- Future research should implement machine learning algorithms to customize therapy based on real-time user performance.

4.4 Future Research Priorities

Based on the findings and limitations identified, future research should prioritize:

- *Expanding Clinical Trials:* Multi-center studies are being conducted with at least 100+ CLBP patients.
- *Measuring Long-Term Adherence:* Patient engagement is being tracked over 6–12 months to assess sustained motivation levels.
- *Comparative Studies:* VR-GET is being compared to traditional GET using randomized controlled trials (RCTs).
- *Exploring Home-Based VR Therapy:* Standalone VR devices are being investigated for at-home rehabilitation programs.
- *AI-Powered Personalization:* AI-driven adaptive therapy models are being developed based on real-time motion tracking data.

4.5 Summary of Key Discussion Points

Table 4 shows the key discussion points, highlighting the findings related to various aspects of VR-GET, including its comparison to traditional rehabilitation, patient engagement, sample size limitations, novelty bias, hardware limitations, and the potential for AI-based personalization in therapy.

Discussion Area	Findings
Comparison to Traditional GET	VR-GET offers higher engagement and less patient dropout compared to traditional rehabilitation.
Patient Engagement	Gamification and biofeedback increase motivation and adherence to therapy.
Small Sample Size	Requires larger cohort studies to confirm efficacy.
Novelty Bias	Long-term studies needed to assess sustained engagement.
Hardware Limitations	Future research should explore wireless VR for home-based therapy.
Personalization	AI-based adaptive therapy models could enhance patient outcomes.

Table 4. Key Discussion Areas and Findings

Conclusion

This study highlights the feasibility, usability, and acceptability of a novel VR dodgeball game as a rehabilitation tool for chronic low back pain. The integration of gamified graded exposure, real-time biofeedback, and adaptive movement tracking offers a promising alternative to traditional physiotherapy approaches.

Findings from this pilot study suggest that VR-based GET can enhance patient engagement, reduce fear-avoidance behaviors, and promote increased movement without exacerbating pain. High usability scores from both experts and participants indicate that the system is intuitive and well-suited for clinical application. Patient feedback further supports the acceptability of the intervention, with participants describing the experience as fun, motivating, and engaging.

Despite these promising results, several limitations must be addressed in future research. The small sample size of CLBP patients limits the generalizability of findings, necessitating larger clinical trials to validate efficacy. Additionally, long-term adherence remains a key consideration, as novelty effects may diminish over time. Future studies should explore extended intervention durations to assess sustained engagement and functional improvements. Additionally, advancements in wireless and standalone VR systems, such as Meta Quest, could enhance accessibility, enabling more effective home-based rehabilitation solutions.

By leveraging gamification, biofeedback, and immersive VR environments, VR-GET represents a transformative approach to chronic pain rehabilitation. Future research should focus on refining personalization algorithms, expanding clinical trials, and exploring at-home applications to maximize therapeutic impact. If validated in larger studies, VR-GET could significantly improve adherence rates, reduce healthcare costs, and offer a more engaging alternative to traditional rehabilitation for individuals with chronic low back pain.

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