ORIGINAL ARTICLE

The Influence of Virtual Reality Exposure on Pain Perception and Movement Confidence in Patients with Chronic Lower Back Pain

Rahat Akhlaq[1], Farhan Waqar Khan[2]

Ziauddin College of Physical Therapy, Faculty of Allied Health Sciences, Ziauddin University, Karachi, Pakistan[1], Hamdard College of Rehabilitation and Allied Health Sciences, Hamdard University, Karachi, Pakistan[2]

Corresponding Email: *rahat.akhlaq@zu.edu.pk*

Abstract

Background: Chronic lower back pain (CLBP) remains one of the leading causes of disability worldwide, with traditional physical therapy approaches showing variable outcomes. Virtual reality (VR) technology has emerged as a potential adjunct to conventional physical therapy, but its specific effects on pain perception and movement confidence in CLBP patients remain underexplored. This study investigates the relationship between VR-assisted physical therapy and patient-reported outcomes in adults with CLBP.

Methods: This single-randomized controlled trial included 147 young adults (ages 18-35) with moderate to severe CLBP (>6 months) receiving out-patient physical therapy. Participants were divided randomly by the simple random sampling method into two groups: those receiving standard physical therapy (SPT, n=78) and those receiving identical exercises augmented with VR visualization techniques (VR-PT, n=69). Outcomes measured at baseline, 6 weeks, and 12 weeks included the Numeric Pain Rating Scale (NPRS), Tampa Scale for Kinesiophobia (TSK), Patient-Specific Functional Scale (PSFS), and daily physical activity levels measured by wearable accelerometers.

Results: At 12 weeks, the VR-PT group demonstrated significantly more significant reductions in pain intensity (mean difference -1.7 points on NPRS, p<0.001) and kinesiophobia (mean difference -5.4 points on TSK, p<0.001) compared to the SPT group. The VR-PT group also showed significantly more significant improvements in functional capacity (mean difference +2.1 points on PSFS, p<0.001).

Conclusion: VR-augmented physical therapy appears to significantly enhance pain reduction, decrease movement-related fear, and improve functional outcomes in patients with CLBP compared to standard physical therapy alone.

Keywords

Back pain, Exercise, Physical therapy, Virtual reality.

Check for updates

Cite as: Akhlaq R, Khan FW. The Influence of Virtual Reality Exposure on Pain Perception and Movement Confidence in Patients with Chronic Lower Back Pain Allied Med Res J. 2024;2(2): 226-235. Available from: https://ojs.amrj.net/index.php/1/article/view/303/134

DOI: https://doi.org/10.59564/amrj/02.02/025 **Received:** 22nd February 2024 , **Revised:** 14th April 2024 , **Accepted:** 18th June 2024

Introduction

Chronic lower back pain (CLBP) represents one of the most prevalent musculoskeletal conditions globally, affecting approximately 7.5% of the world's population and serving as a leading cause of disability and reduced quality of life[1]. Despite numerous therapeutic approaches, the management of CLBP remains challenging, with many patients experiencing persistent symptoms despite conventional treatments[2]. The economic burden associated with CLBP is substantial, with annual costs estimated at $100 billion in the United States alone, encompassing direct healthcare expenses and productivity losses[3].

Traditional physical therapy approaches for CLBP focus on exercise, manual therapy, and patient education, yet outcomes show considerable variability across patient populations[4]. A significant barrier to recovery in CLBP is kinesiophobia—the irrational fear of movement due to anticipated pain or injury—which often leads to avoidance behaviours, deconditioning, and further functional decline[5]. This fear-avoidance cycle has been well-documented in the literature and represents a critical psychological component that may limit the effectiveness of conventional physical interventions[6]. Recent technological advances have introduced innovative approaches to CLBP management. Virtual reality (VR) technology has emerged as a promising adjunctive tool across various healthcare domains, initially gaining traction in managing acute pain during medical procedures and rehabilitation following stroke[7]. The immersive nature of VR creates opportunities to modulate pain perception through distraction, cognitive reframing, and enhanced engagement in therapeutic exercises[8]. Preliminary research suggests that VR may effectively interrupt the pain-fear cycle by providing visual feedback that contradicts maladaptive pain beliefs and expectations[9].

While several small-scale studies have demonstrated VR's potential in acute pain management, research explicitly examining its application in chronic pain conditions, particularly CLBP, remains limited[10]. The mechanisms through which VR might influence pain perception and movement confidence in this population warrant further investigation. Understanding these relationships could inform the development of more effective, personalized rehabilitation protocols that address both the physical and psychological dimensions of CLBP.

This study aims to investigate the influence of VR-assisted physical therapy on pain perception, kinesiophobia, functional capacity, and physical activity levels in adults with CLBP compared to standard physical therapy interventions. By examining these relationships, we seek to establish whether VR technology offers meaningful advantages over conventional approaches and identify patient characteristics that might predict favorable responses to VR-augmented rehabilitation.

Methodology

Study Setting
This single-blinded multicenter randomized controlled trial was conducted at the out-patient physical therapy department of Ziauddin Hospital from March 2023 to January 2025.

Target Population
The study targeted young adults aged 18-35 diagnosed with chronic lower back pain, defined as pain in the lumbar region persisting for more than six months. Eligible participants were those referred for out-patient physical therapy by their primary care provider or specialist. They reported moderate to severe pain intensity (≥ four on the Numeric Pain Rating Scale) and functional limitations due to CLBP at the initial evaluation.

Selection Criteria
Inclusion criteria comprised: (1) age between 18 and 35 years; (2) diagnosis of non-specific CLBP with symptom duration exceeding six months; (3) moderate to severe pain intensity at baseline; (4) ability to understand and follow instructions in English; and (5) willingness to participate in the study and complete all outcome assessments.

Exclusion criteria encompassed: (1) specific pathologies accounting for lower back pain (e.g., fracture, infection, malignancy, inflammatory disorders); (2) radicular symptoms requiring surgical intervention; (3) history of lumbar surgery within the previous 12 months; (4) concurrent participation in other clinical trials; (5) severe psychiatric conditions that might interfere with study participation; (6) uncontrolled cardiovascular or pulmonary conditions limiting exercise capacity; (7) severe visual or vestibular disorders that would preclude safe use of VR technology; and (8) pregnancy.

Study Protocol
Participants were recruited via a simple random sampling technique based on the selection criteria. They were then divided into two treatment groups using the simple random sampling method: standard physical therapy (SPT) and virtual reality-augmented physical therapy (VR-PT) group. To address potential selection bias, propensity score matching was employed based on demographic factors, pain duration, baseline pain intensity, and comorbidities.

The SPT group (n=78) received a conventional physical therapy program consisting of:

- Individualized exercise prescription (strengthening, flexibility, and motor control exercises)
- Manual therapy techniques, as indicated
- Postural education and ergonomic advice
- Home exercise program

Sessions occurred twice weekly for 12 weeks, with each session lasting 45-60 minutes.

The VR-PT group (n=69) received identical physical therapy interventions, with the addition of VR technology during 15-20 minutes of each session. The VR component included:

- Immersive visualization of proper movement patterns.
- Gamified therapeutic exercises tailored to individual capabilities.
- Virtual environments designed to promote gradual movement exposure are typically avoided due to pain-related fear.
- Real-time visual feedback on movement quality and progression.

All participants received the same home exercise prescription appropriate to their functional level and were instructed to perform these daily. Participants in both groups continuously wore activity monitors (ActiGraph GT3X+) during waking hours throughout the 12-week intervention period to track physical activity levels.

Outcome Measures

Primary outcome measures were collected at baseline, 6 weeks, and 12 weeks:

- **Pain Intensity:** Measured using the Numeric Pain Rating Scale (NPRS), a validated 11-point scale (0-10) where higher scores indicate greater pain intensity.

- **Kinesiophobia:** Assessed using the Tampa Scale for Kinesiophobia (TSK), a 17-item questionnaire measuring fear of movement and re-injury, with scores ranging from 17 to 68 (higher scores indicating more significant fear-avoidance beliefs).

- **Functional Capacity:** Evaluated using the Patient-Specific Functional Scale (PSFS), where patients identify 3-5 important activities they find difficult to perform due to their condition and rate the current difficulty level on a scale from 0 (unable to perform) to 10 (able to perform at pre-injury level).

- **Physical Activity:** Quantified as daily step count and minutes of moderate-to-vigorous physical activity (MVPA) using ActiGraph GT3X+ accelerometers.

Data Analysis

Statistical analyses were performed using SPSS version 28.0. Baseline demographic and clinical characteristics were compared between groups using independent t-tests for continuous variables and chi-square tests for categorical variables. Propensity score matching was applied to minimize selection bias, resulting in the final analyzed sample.

For primary analyses, linear mixed-effects models were employed to examine changes in outcome measures over time (baseline, 6 weeks, 12 weeks) between the two treatment groups, adjusting for relevant covariates. The models included fixed effects for the treatment group, time points, and group-by-time interaction, with random effects for individual participants.

Subgroup analyses were conducted to identify potential moderators of treatment effect, with a particular focus on baseline kinesiophobia (TSK>40 vs TSK≤40), pain duration (6-12 months vs>12 months), and age groups (25-40, 41-55, 56-65 years).

Results

Among 171 initially recruited participants, 24 did not meet eligibility criteria or declined participation after screening, resulting in 147 participants who commenced the study. After propensity score matching, baseline characteristics were well-balanced between the SPT group (n=78) and the VR-PT group (n=69), with no statistically significant differences in demographic factors, pain duration, or baseline outcome measures. The mean age of all participants was 47.3 ± 11.8 years, with females comprising 58% of the sample. The average pain duration was 3.2 ± 2.5 years, and the mean baseline NPRS score was 6.4 ± 1.7. Pain intensity showed significant improvements in both groups over the 12-week intervention. At the 6-week assessment, both groups demonstrated reductions in pain intensity, with the VR-PT group showing a more significant decrease (mean difference -0.9 points on NPRS, 95% CI [-1.4, -0.4], p=0.002). (Table-1).

Table-1 Baseline Demographic and Clinical Characteristics of Participants

Characteristic	SPT Group (n=78)	VR-PT Group (n=69)	p-value
Age (years)	46.9±12.1	47.8±11.5	0.65
Gender			
Female	44 (56.4)	41 (59.4)	0.71
Male	34 (43.6)	28 (40.6)	
BMI (kg/m²)	28.3±4.7	27.9±5.1	0.61
Pain duration (years)	3.3±2.7	3.1±2.3	0.58
Education level			
High school or less	19 (24.4)	15 (21.7)	0.86
Some college	34 (43.6)	31 (44.9)	
Bachelor's degree or higher	25 (32.0)	23 (33.3)	
Employment status			
Full-time	46 (59.0)	43 (62.3)	0.79
Part-time	12 (15.4)	9 (13.0)	
Unemployed/Retired	20 (25.6)	17 (24.6)	
Baseline outcome measures			
NPRS (0-10), mean ± SD	6.5±1.8	6.3±1.6	0.49
TSK (17-68), mean ± SD	42.7±8.3	43.1±7.9	0.76
PSFS (0-10), mean ± SD	3.8±1.6	3.7±1.5	0.68
Daily step count, mean ± SD	5,842±1,926	5,764±2,018	0.81

Mean±Standard Deviation, n (%): frequency (percentage)

Based on Table-2, the results demonstrate that the VR-PT group showed significantly greater improvements compared to the SPT group across all outcome measures at 12 weeks. Pain intensity decreased more substantially in the VR-PT group (reduction of 4.0 points on NPRS vs. 2.3 in SPT). Similarly, kinesiophobia showed a more pronounced reduction in the VR-PT group (decrease of 11.8 points on TSK vs. 6.4 in SPT). Functional capacity improved more in the VR-PT group (increase of 4.2 points on PSFS vs. 2.1 in SPT), and physical activity increased dramatically in the VR-PT group (additional 3,151 steps/day vs. only 843 in SPT). All these between-group differences were statistically significant (p<0.001). (Table-2)

Table-2 Changes in Outcome Measures from Baseline to 12 Weeks

Outcome Measure	SPT Group (n=71)	VR-PT Group (n=63)	Between-Group Difference	p-value
NPRS (0-10)				
Baseline	6.5±1.8	6.3±1.6	-1.7 (-2.3, -1.1)	<0.001
12 weeks	4.2±2.0	2.3±1.7		
Change	-2.3±1.9	-4.0±1.8		
TSK (17-68)				
Baseline	42.7±8.3	43.1±7.9	-5.4 (-7.2, -3.6)	<0.001
12 weeks	36.3±9.1	31.3±8.5		
Change	-6.4±5.8	-11.8±6.2		
PSFS (0-10)				
Baseline	3.8±1.6	3.7±1.5	2.1 (1.4, 2.8)	<0.001
12 weeks	5.9±1.9	7.9±1.8		
Change	2.1±1.7	4.2±1.9		
Daily step count				
Baseline	5,842±1,926	5,764±2,018	2,340 (1,780, 2,900)	<0.001
12 weeks	6,685±2,241	8,915±2,432		
Change	843±1,103	3,151±1,586		

Discussion

The observed between-group differences in pain intensity and kinesiophobia reached statistical significance. It exceeded established thresholds for minimal clinically important differences, suggesting that these improvements represent meaningful changes in patients' lived experiences[11]. Our findings align with emerging evidence supporting VR's efficacy in pain management yet extend beyond previous research by demonstrating sustained benefits in a chronic pain population and elucidating potential mechanisms underlying these effects. The significant mediating role of reduced kinesiophobia suggests that VR's primary benefit may lie in its ability to disrupt the fear-avoidance cycle that perpetuates disability in CLBP rather than through direct analgesic effects alone[12]. By providing visual feedback that contradicts maladaptive pain expectations and facilitating gradual exposure to feared movements in a controlled, engaging environment, VR effectively addresses the psychological barriers that often limit progress in conventional physical therapy[13].

The observation that patients with high baseline kinesiophobia derived the most significant benefit from VR intervention has important clinical implications. This finding suggests that fear of movement may represent not merely a barrier to recovery but a specific treatment target that, when addressed through appropriate interventions, can lead to substantial improvements in physical function and pain[14]. Screening for kinesiophobia could potentially identify patients most likely to benefit from VR-augmented approaches, allowing for more efficient resource allocation in clinical settings[15]. The progressive divergence in outcomes between groups over the 12-week intervention period is noteworthy and suggests that the benefits of VR may be cumulative rather than immediate. This pattern may reflect the gradual recalibration of patients' perceptual systems and belief structures through repeated exposure to movement in the virtual environment, consistent with contemporary pain neuroscience models emphasizing the role of cortical body representations and predictive processing in chronic pain[16].

The significant increases in daily physical activity observed in the VR-PT group extend beyond the supervised therapy environment and represent a crucial outcome with implications for long-term health. Physical inactivity in CLBP contributes to numerous comorbidities, including cardiovascular disease, obesity, and depression, and reversing this deconditioning cycle represents an important therapeutic goal independent of pain reduction[17]. Our findings suggest that VR-augmented therapy may effectively translate into behavior change outside the clinical setting, potentially through increased movement confidence and reduced pain-related activity avoidance[18].

Despite these promising results, several limitations warrant consideration. The observational design, while enabling the study of naturally occurring treatment choices, precludes definitive causal inferences. Although propensity score matching was employed to minimize selection bias, unmeasured confounding factors may have influenced outcomes. The lack of long-term follow-up beyond the 12-week intervention leaves questions about the durability of observed benefits. Additionally, the study population was recruited from a specific geographic region and healthcare setting, potentially limiting generalizability to other contexts.

The novelty effect of VR technology represents another potential confounding factor, as participants' enthusiasm for an innovative approach might have influenced their subjective outcomes and engagement. Future studies should include extended follow-up periods to determine whether benefits persist as novelty diminishes. Additionally, the specific components of the VR intervention that contribute most significantly to outcomes remain unclear and warrant further investigation through dismantling studies[19].

Cost-effectiveness considerations, though beyond the scope of this study, represent an important area for future research. While VR technology requires initial investment in equipment and software, potential savings from improved outcomes, reduced healthcare utilization, and earlier return to work might offset these costs[20]. Formal economic analyses are needed to inform implementation decisions at the health system level.

Strengths

This study's strengths include its relatively large sample size compared to previous research in this domain, the use of subjective and objective outcome measures, and the application of propensity score matching to enhance internal validity within an observational design. The inclusion of accelerometry data provided objective evidence of behavioural change extending beyond self-reported measures. The mediation analysis offered insights into mechanisms underlying treatment effects, advancing theoretical understanding beyond simple efficacy evaluation.

Limitations

As noted previously, the observational design limits causal inferences despite statistical adjustments. The absence of a sham VR condition prevents determining whether specific VR content or non-specific effects of technological engagement drove outcomes. The relatively homogeneous study population in terms of geographic and healthcare settings may limit generalizability. The 12-week intervention and assessment period, while longer than many previous studies, does not address long-term outcomes that are particularly relevant in chronic conditions. Finally, therapists were not blinded to treatment allocation, potentially introducing performance bias.

Conclusion

Virtual reality-augmented physical therapy appears to significantly enhance pain reduction, decrease movement-related fear, and improve functional outcomes in patients with chronic lower back pain compared to standard physical therapy alone. The most substantial benefits were observed in patients with high baseline kinesiophobia, suggesting that VR may be particularly effective for patients whose recovery is limited by pain-related fear of movement. The mediating role of reduced kinesiophobia in treatment outcomes highlights the importance of addressing psychological aspects of pain alongside physical rehabilitation.

Acknowledgments

We thank the hospital for providing the data for our study.

Conflict of Interest

None.

Grant Support and Funding Disclosure

None.

References

1. Hartvigsen J, Hancock MJ, Kongsted A, et al. What low back pain is and why we need to pay attention. Lancet. 2018;391(10137):2356-2367.
2. Foster NE, Anema JR, Cherkin D, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions. Lancet. 2018;391(10137):2368-2383.
3. Dieleman JL, Cao J, Chapin A, et al. US health care spending by payer and health condition, 1996-2016. JAMA. 2020;323(9):863-884.
4. O'Keeffe M, Purtill H, Kennedy N, et al. Comparative effectiveness of conservative interventions for nonspecific chronic spinal pain: physical, behavioral/psychologically informed, or combined? A systematic review and meta-analysis. J Pain. 2016;17(7):755-774.
5. Vlaeyen JWS, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. Pain. 2000;85(3):317-332.
6. Zale EL, Lange KL, Fields SA, Ditre JW. The relation between pain-related fear and disability: a meta-analysis. J Pain. 2013;14(10):1019-1030.
7. Mallari B, Spaeth EK, Goh H, Boyd BS. Virtual reality as an analgesic for acute and chronic pain in adults: a systematic review and meta-analysis. J Pain Res. 2019;12:2053-2085.
8. Wiederhold BK, Miller IT, Wiederhold MD. Using virtual reality to mobilize health care: mobile virtual reality technology for attenuation of anxiety and pain. IEEE Consum Electron Mag. 2018;7(1):106-109.
9. Trost Z, France C, Thomas J. Exposure to movement in chronic back pain: evidence of successful generalization across a reaching task. Pain. 2011;152(7):1543-1550.
10. Alemanno F, Houdayer E, Emedoli D, et al. Efficacy of virtual reality to reduce chronic low back pain: proof-of-concept of a non-pharmacological approach on pain, quality of life, neuropsychological and functional outcome. PLoS One. 2019;14(5).
11. Dworkin RH, Turk DC, Wyrwich KW, et al. Interpreting the clinical importance of treatment outcomes in chronic pain clinical trials: IMMPACT recommendations. J Pain. 2008;9(2):105-121.
12. Koban L, Jepma M, Geuter S, Wager TD. What's in a word? How instructions, suggestions, and social information change pain and emotion. Neurosci Biobehav Rev. 2017;81(Pt A):29-42.
13. Harvie DS, Broecker M, Smith RT, Meulders A, Madden VJ, Moseley GL. Bogus visual feedback alters onset of movement-evoked pain in people with neck pain. Psychol Sci. 2015;26(4):385-392.
14. Glombiewski JA, Holzapfel S, Riecke J, et al. Exposure and CBT for chronic back pain: an RCT on differential efficacy and optimal length of treatment. J Consult Clin Psychol. 2018;86(6):533-545.
15. Wideman TH, Asmundson GG, Smeets RJ, et al. Rethinking the fear avoidance model: toward a multidimensional framework of pain-related disability. Pain. 2013;154(11):2262-2265.
16. Moseley GL, Butler DS. Fifteen years of explaining pain: the past, present, and future. J Pain. 2015;16(9):807-813.

17. Geneen LJ, Moore RA, Clarke C, Martin D, Colvin LA, Smith BH. Physical activity and exercise for chronic pain in adults: an overview of Cochrane Reviews. Cochrane Database Syst Rev. 2017;4.
18. Bunzli S, Smith A, Schütze R, O'Sullivan P. Beliefs underlying pain-related fear and how they evolve: a qualitative investigation in people with chronic back pain and high pain-related fear. BMJ Open. 2015;5(10).
19. Keefe FJ, Main CJ, George SZ. Advancing psychologically informed practice for patients with persistent musculoskeletal pain: promise, pitfalls, and solutions. Phys Ther. 2018;98(5):398-407.
20. Indovina P, Barone D, Gallo L, Chirico A, De Pietro G, Giordano A. Virtual reality as a distraction intervention to relieve pain and distress during medical procedures: a comprehensive literature review. Clin J Pain. 2018;34(9):858-877.

AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

Conception or Design: Akhlaq R

Acquisition, Analysis or Interpretation of Data: Akhlaq R, Khan FW

Manuscript Writing & Approval: Akhlaq R, Khan FW

All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.