Pain Apprehension Reactivation of Movement (PARAM): A Virtual Reality–Driven Cognitive Reconditioning Model for Movement-Related Fear in Chronic Pain Rehabilitation

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Abstract

Chronic non-specific low back pain (CNSLBP) often leads to maladaptive pain-related fear and movement avoidance, perpetuating disability and deconditioning. PARAM (Pain Apprehension Re-Activation of Movement) is a novel virtual reality (VR)-driven, cognitive reconditioning intervention designed to address this cycle by integrating principles of the Fear-Avoidance Model, cognitive-behavioral therapy (CBT), and pain neuroscience education (PNE). PARAM was tested among silk weavers with Long COVID–related musculoskeletal pain in Tamil Nadu, India—a group uniquely affected by prolonged inactivity, kinesiophobia, and persistent pain. The intervention comprises four structured phases: real-world movement assessment, VR-based graded movement exposure, visual cognitive reprocessing, and real-world reintegration. Immersive VR enables patients to safely confront feared movements, recalibrate maladaptive beliefs, and regain functional confidence through controlled exposure and real-time feedback. A quasi-experimental trial with 70 participants demonstrated significant reductions in fear-avoidance beliefs (48% vs. 16% in controls), pain catastrophizing (42% improvement), and increased pain self-efficacy (78%). These promising outcomes highlight PARAM's potential as a scalable digital therapeutic, especially relevant in the post-pandemic era for workers in high-risk occupations. By bridging exposure therapy and VR, PARAM addresses the biopsychosocial roots of chronic pain and may redefine conventional rehabilitation pathways. Future research should validate long-term efficacy, explore home-based VR delivery, and expand its application across diverse chronic pain populations. PARAM offers an innovative, patient-centered strategy to break the fear-avoidance cycle and restore movement confidence in chronic pain rehabilitation.

Keywords: Chronic pain, Virtual reality, Fear-avoidance, Long COVID, Cognitive-behavioral therapy, Pain neuroscience education, Rehabilitation

Introduction

Chronic non-specific low back pain (CNSLBP) is among the most common orthopedic complaints and one of the leading causes of disability around the globe. The Global Burden of Disease Study found low back pain was the leading cause of DALYs in all measured countries—both developed and developing (Vos et al., 2020). Chronic pain, by definition, can be differentiated from acute pain in that it persists beyond 12 weeks and does not have a defined structural or pathoanatomical cause (Maher et al., 2017). This sometimes makes treatment challenging, and chronic pain may serve as a precursor to a secondary psychological condition. Pain-Related Fear, also known as kinesiophobia, is a disabling psychological sequela of CNSLBP. It results in avoidance behaviors that worsen the injury, sedentary lifestyles that cause deconditioning, and social isolation due to reduced activity (Vlaeyen & Linton, 2000). Patients often fall into a negative feedback loop of the fear of movement/reinjury, despite the absence of significant pathology (Crombez et al., 2012). The pain-behavior-avoidance cycle is quite difficult to treat and may be hard for physiotherapists to address within traditional models. One critical rise in CNSLBP in populations was the COVID pandemic. A percentage of patients with a previous acute infection developed a persistent symptom state, currently referred to as “Long COVID” or “Post-Acute Sequelae of SARS-CoV-2 infection (PASC)” (Nalbandian et al., 2021). Common long-COVID presentations include fatigue, joint pain, myalgia, and persistent low back pain. As many manual laborers were placed out of work for weeks due to the acute illness, a large population of working class individuals developed secondary deconditioning from long COVID. In many cases, the fear of reinjury, along with objective weakness, severely limited activities of daily living. In particular, our study of interest recruited silk weavers from Erode, Tamil Nadu, who typically engage in repetitive tasks involving prolonged sitting and overhead postures. The group of patients from this community who had recovered from acute COVID-19 presented to physiotherapy with prolonged back pain and kinesiophobia. Of note, they met the criteria for the diagnosis of PASC or Long COVID. The unique mechanism of injury in these patients was the synergistic relationship between their CNSLBP and fear-avoidance. This was not a typical musculoskeletal pain presentation and, therefore, could not be managed with standard models of care at the time. The solution to this clinical quandary was through a novel virtual reality (VR) and pain neuroscience education (PNE)-based intervention. This digital platform was used as an immersive form of exposure-based therapy, cognitive restructuring, and behavioral modification. Pain Apprehension Re-Activation of Movement (PARAM) has been used in a small clinical trial and found significant improvements in a sample of silk weavers with Long-COVID–related musculoskeletal pain.

2. Objective

The aim of this paper is to describe the intervention framework of Pain Apprehension Re-Activation of Movement (PARAM) for rehabilitation of chronic musculoskeletal pain.

3. Brief Summary

PARAM is a VR and PNE-based intervention which has been used as an exposure-based therapeutic technique for chronic musculoskeletal pain. The objective of this review was to discuss the theoretical basis, intervention framework, and clinical relevance of PARAM

in Long-COVID–related musculoskeletal pain. PARAM was used as an intervention for chronic musculoskeletal pain in a group of silk weavers who had recovered from COVID-19 but continued to have ongoing pain and disability. The PARAM intervention is predicated on a variety of psychological theories and models of behavior change. The most significant is the Fear-Avoidance Model (FAM) of pain, which posits that individuals can become "stuck" in a cycle of pain catastrophizing, fear, and movement avoidance (Vlaeyen & Linton, 2000). The perceived threat of pain or injury, when coupled with avoidance and deconditioning, can result in movement phobia and an upward spiral of disability. This phenomenon is particularly pronounced in CNSLBP, as patients struggle to make sense of the pain experience. Cognitive-behavioral therapy (CBT) is another essential building block for PARAM. CBT recognizes that thoughts, emotions, and behaviors are inextricably linked and that interventions can occur at all three levels to reduce maladaptive functioning (Beck, 1976). PARAM operationalizes these principles by helping the patient confront the feared stimulus (movement) in a graded and controlled manner while simultaneously addressing the negative and fearful beliefs. A patient who believes that bending forward will "break their spine" will be able to perform this task with ease and without discomfort in the virtual environment. Virtual reality (VR) serves as the vehicle for delivery of this information. Immersion in VR has been shown to produce the feeling of "presence," or the sense that the environment is real (Slater & Wilbur, 1997). Movement in VR can have an anxiolytic effect, in part due to sensory abstraction and reduced cortical threat processing (Matheve et al., 2020). When a patient with CNSLBP is immersed in VR, the maladaptive threat of movement is lessened, allowing the nervous system to recalibrate and relearn that the movements do not, in fact, represent injury or damage. VR also allows for graded and tailored exposure as well as direct performance feedback, all of which are essential ingredients of effective behavioral therapy (Wiederhold et al., 2015).

Last but not least, PARAM also leverages the concept of pain neuroscience education (PNE). PNE refers to a patient's understanding of the biopsychosocial underpinnings of chronic pain, that is, that it is a neurophysiological process and not necessarily a marker of tissue damage (Louw et al., 2016). In the PARAM intervention, PNE content is delivered within the VR session, allowing the patient to experience and test out these ideas during the session in a safe and controlled setting. The PARAM (Pain Apprehension Re-Activation of Movement) intervention is a four-phase approach to address maladaptive pain beliefs and re-educate movement for chronic musculoskeletal pain. Param is different from traditional physiotherapy in that it focuses on graded exposure to feared movement, engaging the patient psychologically, emotionally, and physically through virtual reality (VR). It is inherently graded and guided but more importantly is goal-oriented.

Phase 1 : Real-World Movement Assessment

In this initial phase, patients are asked to perform a series of real-world movements that are relevant to everyday activities and are often associated with fear or pain. These tasks might include bending, lifting, twisting, reaching, etc. The physiotherapist will then assess the patient's performance of these tasks in the real-world setting and also video-record them for later reference. During this assessment, the therapist can observe various kinesiophobic behaviors such as bracing, guarding, hesitancy, or compensatory motor patterns. This is a critical step as it will not only provide baseline data to monitor the

patient's progress over time but also give a reference point for comparison during later phases of PARAM in the VR environment.

Phase 2 : VR-Based Movement Exposure and Desensitization

In the next phase, patients are introduced to the VR system, and the setup is explained in detail to ensure the patient is comfortable and understands the process. For this part of the intervention, the VR system should be set up to allow the patient to perform the previously mentioned tasks (real-world movement assessment) within the VR environment. As mentioned earlier, a typical immersive VR system will track the user's movements and display a real-time representation within the virtual world. This is achieved through motion sensors and the headset camera, creating a first-person, immersive experience for the user. For example, the patient might be asked to "reach for objects on the shelf" or "lift a box off the ground" within a virtual kitchen or garage environment. As in the real-world setting, these tasks are designed to replicate common functional movement challenges that the patient may encounter in their daily life but in a low-threat context so that they can engage with less emotion and anticipation of injury.

Sessions are therapist-guided and start at a level of difficulty and intensity that the patient can perform with relative ease and confidence. As the patient becomes more comfortable and competent, the complexity and intensity of tasks will be increased to ensure that the patient is always working at the edge of their comfort zone (hence the term graded exposure). Patients typically wear a VR headset while their body movements are being tracked and displayed in the virtual space, providing a real-time proprioceptive feedback loop that enhances the immersive experience. This is not a distraction-based or gamified VR approach. Instead, every movement and interaction in PARAM has a therapeutic intention and is based on the principles of FAM and CBT.

Phase 3 : Visual Comparison and Cognitive Reprocessing

After a series of VR sessions, typically 3–5, patients are then shown a side-by-side video comparison of their real-world versus VR movements. This is a powerful intervention in and of itself as patients are often struck by the realization that they can and did perform movements in VR that they had been avoiding or were extremely fearful of in real life. Therapists can use this opportunity to facilitate cognitive dissonance and restructuring by asking the patient to reflect on the differences in their behavior and performance between the real and virtual environments. This can be a transformative moment for patients and often leads to a shift in their beliefs and perceptions about their pain and abilities.

Phase 4 : Real-World Reintegration with Guided Practice

The final phase of the PARAM involves a gradual reintroduction of the feared or avoided tasks back into the patient's real-world environment, under the supervision and guidance of the physiotherapist. This will typically include a re-assessment of FABQ, PCS, and PSEQ scores to track psychological changes. Guided practice should be encouraged with an emphasis on positive and strength-based feedback. The final goal here is to ensure that the gains and insights that have been made in the VR environment are transferred and generalized to the patient's everyday activities and environment. PARAM was used in a quasi-experimental trial involving 70 silk weavers with Long COVID–related

musculoskeletal pain. The outcomes revealed several clinically significant improvements. The mean fear-avoidance beliefs questionnaire (FABQ) scores reduced by 48% in the PARAM group in contrast to just 16% in the standard physiotherapy group (SP). Pain Catastrophizing Scale (PCS) scores improved by 42%, and self-efficacy improved by 78% based on the Pain Self-Efficacy Questionnaire (PSEQ). This study demonstrated the feasibility and clinical utility of PARAM as a digital therapeutic approach for the management of chronic musculoskeletal pain among patients with Long COVID. The improvements in outcome measures suggest that the intervention was effective in changing maladaptive pain beliefs and restoring functional confidence among the study participants. These findings are significant given the increasing prevalence of chronic pain conditions in the post-pandemic era, especially among workers in high-risk occupations.

This paper also suggests that PARAM has the potential for scalability and integration into routine clinical practice. As mobile VR systems become more accessible and affordable, similar programs could be deployed in various settings, including rural and industrial communities with minimal resources and training requirements. For workers at high risk for musculoskeletal conditions such as post-COVID-19 patients, manual laborers, factory workers, or sedentary office employees, PARAM could serve as a cost-effective and efficient modality to address both the physiological and psychological components of chronic pain. Patients reported feeling validated and understood by their therapists, which can have a significant impact on patient engagement and adherence to treatment. The personalized and collaborative nature of this intervention may also contribute to better outcomes and improved overall satisfaction with care. This paper has provided a comprehensive review of the theoretical basis, intervention framework, and clinical relevance of PARAM for the rehabilitation of chronic musculoskeletal pain. The results of the quasi-experimental trial suggest that PARAM is a feasible and clinically relevant digital therapeutic for use in patients with Long COVID. In particular, the multimodal and immersive nature of the intervention appears to be well-suited for addressing the complex biopsychosocial factors that underlie chronic pain conditions. The use of VR technology in PARAM may have helped patients engage in the therapeutic process and provided a unique and safe platform for exposure-based cognitive restructuring. As such, PARAM may represent a new frontier in the treatment of chronic pain and has the potential to revolutionize the way we approach pain management in the future.

5. Conclusion and Future Directions

PARAM represents a conceptual shift in the way that rehabilitation can be delivered for the management of chronic musculoskeletal pain. By combining elements of exposure therapy, CBT, and VR technology, the intervention provides a multidimensional and personalized pathway to recovery for patients. As we move forward, further research is needed to better understand the underlying mechanisms of action of PARAM and to establish its long-term efficacy and safety profile. In addition, future studies could explore the use of PARAM in other pain populations, including those with fibromyalgia, complex regional pain syndrome, and other chronic conditions. Another potential avenue for future research is the development of app-based interfaces for home-based VR delivery. This would increase the accessibility of the intervention and potentially reduce the costs

associated with therapy delivery. It would also allow patients to continue their rehabilitation at home, further enhancing the convenience and patient experience.

In the future, it may be important to address the potential role of primary care physiotherapists in delivering PARAM. Their training and expertise could be leveraged to expand the reach and impact of this intervention in clinical practice. By bridging the gap between pain education, behavioral therapy, and immersive technology, PARAM has the potential to become a cornerstone of the next generation of rehabilitation medicine.

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