Virtual reality on upper limb kinesiophobia in post-stroke

Realidade virtual sobre kinesiofobia de membros superiores no pós-AVC

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Abstract

Introduction: Kinesiophobia, the fear of movement due to perceived pain or re-injury, is a significant barrier to rehabilitation and recovery, particularly for stroke patients. This case study examines the impact of kinesiophobia on rehabilitation in a stroke survivor with left-sided weak-ness and limited shoulder range of motion. **Objective:** To explore the efficacy of a virtual reality-based intervention on kinesiophobia, shoulder range of motion and pain management in a post-stroke patient using the Reach Shoulder Health app. **Methods:** A 54-year-old male with hypertension and type 2 diabetes experienced left-sided weakness following a non-haemorrhagic infarct in the right middle cerebral artery space. Limited shoulder range of motion was observed, particularly during voluntary movements, linked to kinesiophobia and left shoulder pain. A virtual reality-based app, Reach Shoulder Health, featuring the Oculus Quest and Star Beam games, was used for 25-minute sessions, five days a week, over three weeks. The effectiveness of intervention was evaluated using the Tampa Scale of Kinesiophobia, Visual Analogue Scale, and goniometer. **Results:** Post-intervention, the patient showed a marked reduction in kinesiophobia, a significant improvement in shoulder range of motion, and a noticeable decrease in pain intensity, demonstrating the positive effects of the virtual reality intervention. **Conclusion:** This case study demonstrates the potential of virtual reality as an effective tool for reducing kinesiophobia and improving rehabilitation outcomes in stroke patients. The integration of immersive technologies could offer substantial benefits for patients with rehabilitation challenges.

Keywords: Immersive games. Fear-avoidance. Graded exposure. Rehabilitation.

Resumo

Introdução: *Cinesiofobia, o medo de se movimentar devido à dor percebida ou ao risco de nova lesão, é uma barreira significativa à reabilitação e à recuperação, especialmente em pacientes pós-acidente vascular cerebral (AVC). Este estudo de caso examina o impacto da cinesiofobia na reabilitação de um sobrevivente de AVC com fraqueza do lado esquerdo e amplitude de movimento limitada no ombro.* ***Objetivo:*** *Explorar a eficácia de uma intervenção baseada em realidade virtual na cinesiofobia, amplitude de movimento do ombro e manejo da dor em um paciente pós-AVC utilizando o aplicativo Reach Shoulder Health.* ***Métodos:*** *Um homem de 54 anos, hipertenso e com diabetes tipo 2, apresentou fraqueza do lado esquerdo após um infarto não hemorrágico na artéria cerebral média direita. Observou-se limitação da amplitude de movimento do ombro, especialmente durante movimentos voluntários, associada à cinesiofobia e dor no ombro esquerdo. Um aplicativo baseado em realidade virtual, Reach Shoulder Health, com os jogos Oculus Quest e Star Beam, foi utilizado em sessões de 25 minutos, cinco dias por semana, durante três semanas. A eficácia da intervenção foi avaliada por meio da Escala de Cinesiofobia de Tampa, Escala Visual Analógica e goniômetro.* ***Resultados:*** *Após a intervenção, o paciente apresentou uma redução significativa na cinesiofobia, melhora notável na amplitude de movimento do ombro e diminuição perceptível na intensidade da dor, demonstrando os efeitos positivos da intervenção com realidade virtual.* ***Conclusão:*** *Este estudo de caso demonstra o potencial da realidade virtual como uma ferramenta eficaz para reduzir a cinesiofobia e melhorar os resultados da reabilitação em pacientes com AVC. A integração de tecnologias imersivas pode oferecer benefícios substanciais para pacientes com desafios na reabilitação.*

Palavras-chave: *Jogos imersivos. Evitação por medo. Exposição graduada. Reabilitação.*

Introduction

Kinesiophobia is a severe and irrational fear of physical movement and activity, driven by an amplified perception of vulnerability of pain or re-injury. This condition process a significant barrier to physical rehabilitation and psychological well-being, impending participation in essential therapeutic intervention and routine daily activities, thereby exacerbating overall health challenges.[1]

Recent research suggests that impairments, pain and disability do not exhibit a direct correlation; rather they are shaped by a complex interplay of cognitive, perceptual, psychophysiological and motor-environmental factors.[2] The causative mechanisms of kinesiophobia are twofold: past experiences of pain or trauma and social learning or observation, which can lead to a perpetuation of fear-avoidance behaviors.[3]

Kinesiophobia arises from central sensitization, where the nervous system amplifies pain signals, making pain feel stronger and more chronic. This alters brain regions like the amygdala and insula, increasing fear and anxiety about movement. Avoiding movement leads to muscle deconditioning, worsening pain and reinforcing the cycle of pain, fear, and avoidance. Neurobiological studies have demonstrated that the brain's plasticity and adaptability enable previous traumatic or threatening experiences to accelerate future responses to threats, thereby reinforcing the phobic response.[4]

A focused neurological deficiency brought on by a reduced blood flow to a particular area of the brain is known as a stroke. It ranks as the fourth most common cause of mortality worldwide and the fifth most common cause of disability. The incidence rate of stroke in India is 152 per 100,000 people.[5] Kinesiophobia significantly affects stroke patients with hemiplegia, with 47.9% experiencing it. Pain, a history of falls, anxiety, despair, and low exercise self-efficacy are all influencing variables, under-scoring the necessity of focused intervention techniques.[6]

In individuals with kinesiophobia, painful experiences are perceived as threats, fostering the belief that exercise induces pain and heightens the risk of re-injury. This leads to avoidance behaviors and withdrawal from activities that may result in discomfort or perceived harm.[7] Kinesiophobia can significantly impact stroke rehabilitation by limiting participation in therapy and exercises due to fear, anxiety, and stress. This reluctance slows progress, reduces motivation, and leads to muscle atrophy, joint stiffness, and decreases cardiovascular fitness. These physical consequences, combined with psychological barriers, increase the risk of secondary health issues and make motor recovery more challenging.[8] A multidisciplinary approach combined with physical therapy would be best to treat kinesiophobia. Therapies like virtual reality (VR), cognitive behavioral therapy, graded exposure, acceptance and commitment therapy, pain education programs and mindful-based stress reeducation are used.[9]

VR is one of the developing technologies that is used to treat stroke and other neurological conditions. VR has been shown to be effective in managing pain through mechanisms like distraction and neuroplastic adaptation.[10,11] VR game-based training emerges as an effective intervention for stroke rehabilitation especially on kinesiophobia.[12] It immerses users in computer generated environment that gives real world experiences. By providing a safe and controlled environment, VR can distract users from pain or anxiety during movement, allowing them to focus on tasks within the virtual environment and reducing the intensity of perceived pain and mental barriers associated with fear of movement. As it is programmed to give interactive exercises to patients, it helps in overcoming kinesiophobia by better participation.[13]

Tampa Scale of Kinesiophobia (TSK) consists of 17 items that measure fear-avoidance beliefs related to physical activity and re-injury. Respondents assess each item on a four-point Likert scale ranging from "strongly disagree" to "strongly agree," with higher scores reflecting a greater fear of movement.[14,15]

By using immersive VR technology, the intervention aims to break through these psychological barriers, encouraging patients to move more freely and confidently. At the same time, VR activities support motor recovery and help patients regain the ability to perform daily tasks. This study highlights the potential of VR as an innovative and engaging tool in stroke rehabilitation not just to improve physical outcomes, but also to ease the psychological challenges that often come with recovery.

Case report

A 54-year-old male presented to Saveetha Medical College and Hospital, Chennai, India, on September 10, 2024, with a sudden onset of weakness in his left upper and lower limbs. His medical history includes 11 years of systemic hypertension and 10 years of type 2 diabetes mellitus (Table 1).

Additionally, the patient has a 25-year history of alcohol consumption and a 15-year history of smoking, although he quit smoking five years ago. Initially, the patient was managed medically for a stroke and subsequently discharged. However, on October 15, 2024, he was readmitted to the hospital due to the development of left shoulder pain and the persistence of weakness in his left upper and lower limbs.

Imaging studies, specifically a magnetic resonance imaging of the brain, revealed an acute non-hemorrhagic infarct in the right middle cerebral artery territory, specifically impacting the high parietal lobe. In response to the findings, the patient was continued on medical management for his hypertension and diabetes. As part of secondary stroke prevention and symptom management, the patient was prescribed Tab Clopidogrel 75 mg, Tab Aspirin 75 mg, Tab Atorvastatin 40 mg, Tab Texfenac P, Tab Ultracet, Tab Neurokind OD, Tab Rantac 150 mg, and Tab Pan D. Following this, he was referred to the Physiotherapy Department for further assessment and management of his left shoulder pain and the ongoing weakness in his left upper and lower limbs.

During the physiotherapy assessment, a reduced range of motion (ROM) in the left shoulder was noted. The problem list based on International Classification of Functioning, Disability and Health (ICF) classification is presented in Table 2. Notably, the restriction was more pronounced during voluntary movements compared to involuntary movements, raising suspicion of kinesiophobia, an excessive fear of movement. This suspicion was further confirmed through the administration of the TSK, which revealed a significant fear of movement in the affected limb. The patient expressed concerns about exacerbating the injury by moving his shoulder, which led to avoidance behavior and a consequent reduction in the use of his left upper limb. This fear-driven behavior has likely contributed to the persistence of weakness and a hindered rehabilitation process, limiting the patient's progress in regaining functional use of his left arm.

Table 1 - Demographic data of participant

Age	54
Gender	Male
Weight	74 kgs
Height	168 cm
Occupation	Electrician
Cognitive status	Intact
Dominant hand	Right
Comorbidities	SHTN for 11 years; T2DM for 10 years

Note: SHTN = systemic hypertension; T2DM = type 2 diabetes mellitus.

Table 2 - Problem list based on International Classification of Functioning, Disability and Health classification

Body structure	Body function	Activity limitation	Participation restriction	Personal factors	Contextual factors
Acute non-hemorrhagic infarct in the right middle cerebral artery territory (high parietal lobe).	1. Limited active range of motion in left shoulder. 2. Reduced strength in left upper and lower limbs.	Difficulty performing voluntary movements of the left upper limb which affects activities of daily living.	Inability to resume work due to fear and weakness.	Positive: Cooperative, some residual function, has family support. Negative: Kinesiophobia, low confidence in movement, history of alcohol use.	The presence of kinesiophobia leading to reduced engagement in rehabilitation.

This study was approved by the Institutional Ethics Committee for Human Research under protocol number 11/12/24/ISRB/FR/SCPT. The procedure was thoroughly explained, and the subject provided consent for treatment, with confidentiality assured.

After obtaining informed consent, a comprehensive medical evaluation was conducted, and sociodemographic, educational, and neurological data were collected. Pre-treatment assessments included the administration of the TSK, which served as the primary outcome measure to evaluate the patient's level of fear related to movement and potential injury. Visual Analogue Scale was assessed for pain, and goniometric measurements were taken for ROM. A three-week rehabilitation program leveraging VR games was meticulously designed and executed. The patient received an introductory session on the VR-based game, including a demonstration and hands-on experience with the device. The immersive VR setup consisted of a headset, two handheld controllers, and a laptop running the VR application (Figure 1).

Figure 1 - Pre-intervention (left) and post-intervention (right) using virtual reality.

The VR-based gaming app, Reach Shoulder Health, was employed for rehabilitation. Two immersive games were employed in this study: Oculus Quest and Star Beam. In Oculus Quest, patients engage in a captivating activity where they must capture fireflies in a jar using one upper limb at a time. Upon successfully catching a predetermined number of fireflies, the game progresses to the next level, prompting patients to switch to the opposite limb. This game is designed to facilitate unilateral upper limb movement.

Star Beam is a bilateral upper limb game that requires patients to match identical star shapes with a laser beam. The gaming session was carried out in standing as there was only mild weakness in the left lower limb. This game demands simultaneous coordination of both upper limbs to achieve the task. Five-minute breaks were provided between games, and the app monitored patient progress.

The games create a controlled environment for the user to explore movement at his own pace, with gradual difficulty levels and rewards to encourage ROM improvement. By diverting attention from discomfort, the exercises became less strenuous, allowing patients to perform movements they might otherwise avoid due to anticipated pain.

The game-based treatment was administered five times a week, with each session lasting 25 minutes, for three weeks, in conjunction with a standardized stroke protocol to strengthen the left upper limb and lower limb and to reduce shoulder pain.

Results

After three weeks of VR rehabilitation, the patient showed significant improvement positively. Post-intervention assessments revealed a significant reduction in kinesiophobia, improved ROM and reduced pain in the left shoulder. The patient's TSK score decreased to 34 from 53, which was the baseline score. Visual Analogue Scale score for pain decreased from 8 to 3 (Figure 2). The ROM on the left shoulder has significantly improved in all motion (Figure 3). Pre- and post-intervention outcome measures are presented in Table 3.

Table 3 - Analysis of pre- and post-physiotherapy intervention

Outcome measure	Pre	Post
Tampa Scale of Kinesiophobia	53	34
Visual Analogue Scale	8	3
Range of motion of left shoulder flexion	50°	120°
Shoulder extension	15°	40°
Shoulder adduction	65°	135°
Shoulder abduction	30°	35°
Shoulder internal rotation	30°	55°
Shoulder external rotation	40°	60°

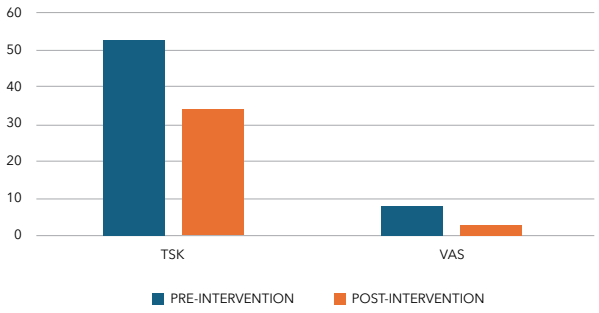

Figure 2 - Pre- and post-measurement of Tampa Scale of Kinesiophobia (TSK) and Visual Analogue Scale (VAS).

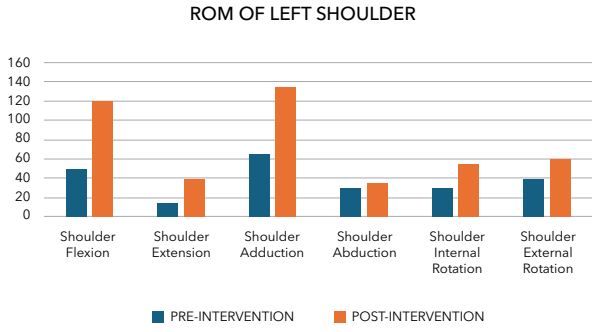

Figure 3 - Pre- and post-measurement of Range of Motion (ROM).

Discussion

The present case report evaluated the efficacy of VR-based games as an intervention for a post-stroke patient, specifically targeting kinesiophobia induced by pain. The intervention, combining VR games such as Star Beam and Oculus Quest with conventional physiotherapy, demonstrated marked improvements in shoulder ROM, reduction in pain, and significant decrease in kinesiophobia scores, such as by TSK. Although the pain was not completely eliminated, its intensity noticeably decreased. The patient showed significant improvements in shoulder ROM, including flexion, extension, abduction, adduction, internal and external rotation. This improvement enhanced the patient's psychological readiness to engage in rehabilitation and actively participate in the recovery process.

Kinesiophobia is particularly prevalent in stroke patients and is positively correlated with age, illness duration and stroke severity.[16,17]

This fear can significantly hinder the rehabilitation process. As kinesiophobia is a key factor contributing to persistent pain and disability, the TSK is recognized as a valuable tool.[18]

Our findings demonstrated reduction in kinesiophobia and pain along with increased ROM aligned with Mukherjee et al.,[19] who reported significant reductions in pain and kinesiophobia following VR training in patients with cervical spondylosis. This further supports the effectiveness of VR in managing both musculoskeletal and psychological pain.[19] Likewise, Nishitha et al.[20] demonstrated that VR based rehabilitation significantly reduced pain levels and functional recovery in patients following total knee arthroplasty. VR technology has shown potential in enhancing upper limb recovery in hemiparetic stroke patients and in reducing kinesiophobia.[21] Notably, when combined with physical exercise VR yields better outcomes in alleviating kinesiophobia than when used in isolation.[22] In addition to decreasing kinesiophobia, VR also facilities improvement in upper limb function.[23]

These findings align with existing literature, suggesting that immersive VR environment enhance motivation, distract from pain, and promote active participation and therapy.[24] According to Laver et al.,[25] VR interventions provide multisensory feedback task-oriented training that facilitates motor recovery in post-stroke patients. In the present case, the engaging, gamified VR environment appeared to reduce fear related avoidance behaviors and encouraged more consistent use of affected upper limb. The mechanism underlying this improvement is the principle of gradual exposure. VR tasks allowed the patient to move the affected shoulder in a controlled, non-threatening environment, thereby reducing anticipatory fear of pain or reinjury.[25] Additionally the repetitive task-specific movements within the VR environment have facilitated neuroplastic changes, further enhancing motor recovery.[26]

Importantly, while the effectiveness of VR in reducing kinesiophobia is well documented in musculoskeletal conditions, there is limited research on its impact in stroke patients. Thus, this study provides preliminary evidence supporting VR's role in stroke-related kinesiophobia management. The patient responded positively to the VR intervention, further suggesting its acceptability and feasibility.

The improvement in TSK score from baseline to post-intervention suggests that VR therapy may be a valuable tool in addressing psychological barriers to rehabilitation. Clinically, this emphasizes the importance of incorporating both physical and cognitive-behavioral strategies when treating stroke survivors with kinesiophobia.

However, this study is limited by its single-subject design and short follow-up period. The results may not be generalized to all stroke patients, particularly those with severe cognitive deficits or poor visual-motor coordination. VR-related side effects, such as motion sickness, were not addressed. Additionally, the absence of a standardized VR protocol may affect replicability. Future studies should include larger randomized trials with standardized VR protocols to improve reliability and clinical relevance. Long-term follow-up and monitoring of side effects are essential. Functional and psychological outcomes should also be evaluated to assess comprehensive benefits.

Conclusion

The findings of this case study suggest that a reduction in kinesiophobia, coupled with a decrease in post-stroke pain, leads to an improvement in shoulder range of motion. The study concludes that VR-based games can serve as an effective intervention for reducing kinesiophobia in post-stroke patients. By engaging patients in immersive, interactive environments, VR therapy not only provides a means of addressing fear but also encourages movement and rehabilitation, fostering greater mobility.

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Authors' contributions

DS was responsible for conceptualization, study design, and manuscript drafting. APYS, for data collection, patient assessment, and intervention. PS, for interpretation and supervision. VJ, for review and manuscript writing. PK, for critical revision of the manuscript and

methodology validation. VS, for the final manuscript review, editing, and approval for submission. All authors approved the final version.

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