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Virtual Reality as a Complementary Tool within the Graded Motor Imagery Framework

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ABSTRACT

Graded Motor Imagery (GMI) is a progressive rehabilitation method designed to reduce pain and restore motor function by stimulating cortical reorganization. Traditionally Graded Motor Imagery consists of three stages: laterality recognition, explicit motor imagery, and mirror therapy. While effective, the classical framework lacks an active, ecologically valid stage that bridges cortical activation with functional reintegration. This study investigates the integration of Virtual Reality as the fourth stage of Graded Motor Imagery —Active Functional VR Reintegration—in the rehabilitation of adhesive capsulitis (frozen shoulder).

A total of 28 patients were enrolled and randomly assigned to either a virtula reality-assisted GMI group (n=14) or a conventional physiotherapy + Graded Motor Imagery group (n=14). Interventions were conducted over 8 weeks, 3 sessions per week. Outcome measures included Visual Analog Scale for pain, range of motion via goniometry, Shoulder Pain and Disability Index (SPADI), Disabilities of the Arm, Shoulder, and Hand, and Manual Muscle Testing (MRC scale). Statistical analyses included paired and independent t-tests, Mann–Whitney U tests, and effect size calculation. Results demonstrated that virtual reality-assisted Graded Motor Imagery led to greater pain reduction (VAS −4.7 vs. −3.4), improved ROM (abduction +49.2° vs. +33.7°), and superior functional outcomes (SPADI −44.2% vs. −33.8%). Patient adherence was higher in the VR group (96% vs. 82%), highlighting its motivational impact. The findings support virtual reality as a functional extension of Graded Motor Imagery, bridging neurocognitive training with active movement.

This study proposes Virtual reality as the fourth stage of Graded Motor Imagery, enhancing pain modulation, motor recovery, and patient engagement. Clinical adoption of virtual reality-enhanced Graded Motor Imagery may improve rehabilitation outcomes in adhesive capsulitis and other musculoskeletal conditions

Introduction

Musculoskeletal pain and dysfunction remain leading causes of disability worldwide, with shoulder disorders ranking among the most common sources of long-term impairment. Adhesive capsulitis, also known as frozen shoulder, affects approximately five percent of the adult population and is characterized by pain, stiffness, and severe limitations in range of motion. Conventional physiotherapy can partially restore mobility, but often fails to address the neurocognitive and psychosocial mechanisms that sustain chronic pain and disability. This therapeutic gap has encouraged the development of innovative methods that target cortical reorganization as a pathway to improved recovery.

Graded Motor Imagery is an evidence-based rehabilitation approach designed to progressively stimulate cortical networks and enhance neuroplasticity. The classical model includes three sequential stages: laterality recognition, explicit motor imagery, and mirror therapy. These stages aim to normalize cortical representations, reduce maladaptive pain signaling, and gradually restore motor function. Evidence for this framework has been established in complex regional pain syndrome and adhesive capsulitis [26,27]. More recently, clinical data have extended support to frozen shoulder: in a randomized controlled trial, Phansopkar and colleagues [28] demonstrated that integrating Graded Motor Imagery into a multimodal physiotherapy program produced significantly greater improvements in the Shoulder Pain and Disability Index and in the Disabilities of the Arm, Shoulder and Hand questionnaire compared to physiotherapy alone. A case study by Gopalakrishnan et al. [13] showed that a geriatric patient with adhesive capsulitis experienced substantial reductions in pain intensity measured with the Visual Analog Scale, increased shoulder mobility measured by goniometry, and improvements in both the Shoulder Pain and Disability Index and the Fear Avoidance Beliefs Questionnaire after a structured Graded Motor Imagery program [31,32]. Additional studies reinforce this approach: Beltran-Alacreu et al. [2] reported beneficial effects of Graded Motor Imagery for patients with subacromial pain syndrome, and Bruls et al. [6] confirmed its value as an adjunct to physiotherapy in chronic rotator cuff–related shoulder pain [36].

Despite these promising results, the traditional three-stage framework presents limitations. Patient adherence often decreases due to the abstract and repetitive nature of imagery tasks, and the transfer from cortical activation to meaningful real-world functional activities is incomplete. While patients may improve in pain perception and cortical representation, these changes do not always translate into confident, functional movement.[17]. These limitation highlights the need for an additional stage in the Graded Motor Imagery framework that introduces motivating, ecologically valid, and functionally oriented tasks.

Virtual Reality has emerged as a promising tool to address these challenges. By providing immersive and interactive environments, Virtual Reality enhances motivation [34], delivers real-time multisensory feedback, and allows the simulation of daily-life or sport-specific tasks.[20] demonstrated Virtual Reality's analgesic effects through distraction and modulation of somatosensory activity. More recent studies confirm its clinical utility showed through meta-analysis that Virtual Reality reduces[35] both acute and chronic pain intensity across different populations[25]. In musculoskeletal rehabilitation reported that a single fifteen-minute session of immersive Virtual Reality produced immediate improvements in pain-free shoulder mobility[2], particularly in abduction and hand-behind-back movements, with outcomes strongly correlated to the degree of embodiment experienced by patients. Furthermore, [24] demonstrated the feasibility of Virtual Reality in shoulder rehabilitation using the Oculus Quest 2 system, showing significant functional gains and high patient acceptance.

Building on these findings and our own clinical research experience [14,15], we propose the integration of Virtual Reality as the fourth stage of Graded Motor Imagery—Active Functional Virtual Reality Reintegration. This additional stage is designed to bridge the gap between cortical motor training and functional reintegration, enhancing pain modulation, motor recovery, and patient adherence. The present study investigates the effectiveness of this integrated framework in patients with adhesive capsulitis, with specific focus on pain intensity, range of motion, functional outcomes, and motivation to engage in therapy.[9]

Materials and Methods

This study was a prospective, controlled experimental investigation designed to assess the effectiveness of Virtual Reality as the fourth stage of Graded Motor Imagery in the rehabilitation of patients with adhesive capsulitis of the shoulder. The research was conducted between 2023 and 2024 and the study protocol was approved by the ethics committees of both institutions, and written informed consent was obtained from all participants prior to enrollment.

SAMPLE SIZE CALCULATION

The sample size was determined a priori using G*Power version 3.1 software, based on an expected medium effect size (Cohen's d = 0.65) derived from previous studies investigating Graded Motor Imagery in musculoskeletal disorders [28,2]. With a significance level of 0.05 and a statistical power of 0.80, the minimum required number of participants per group was calculated as 12. To account for an estimated 15% dropout rate, we enrolled a total of 28 participants (14 per group), which ensures sufficient statistical representativeness.

PARTICIPANTS

Inclusion criteria were: age between 40 and 65 years, a clinical diagnosis of idiopathic or post-immobilization adhesive capsulitis, pain intensity of at least 4 measured with the Visual Analog Scale, and limitations in both active and passive range of motion in at least two movement planes.

Exclusion criteria included: history of shoulder surgery within the last 12 months, severe neurological or vestibular disorders, contraindications to Virtual Reality use such as epilepsy or severe motion sickness, or concurrent participation in other physiotherapy programs.

Table 1. Baseline demographic and clinical characteristics of participants

Variable	Control Group (n=14)	VR Group (n=14)	p-value
Age (years)	52.7 ± 6.4	51.9 ± 6.0	0.71
Gender (F/M)	9/5	9/5	1.00
Affected shoulder (R/L)	8/6	7/7	0.72
VAS score (0–10)	6.9 ± 0.8	7.0 ± 0.7	0.83
SPADI (%)	63.4 ± 9.7	62.8 ± 9.3	0.88
DASH score	52.1 ± 7.4	51.7 ± 7.1	0.91
Flexion ROM (°)	105.6 ± 13.3	104.2 ± 12.8	0.79
Abduction ROM (°)	92.4 ± 11.6	91.1 ± 12.0	0.77

Participants were randomly allocated to either the experimental group or the control group using a computer-generated randomization sequence. Allocation was concealed by sealed opaque envelopes prepared by an independent researcher not involved in recruitment or treatment.

INTERVENTION PROTOCOL

The intervention lasted 8 weeks, with three sessions per week, each session lasting approximately 45–60 minutes.

- **Stage I: Muscle relaxation, pain control, and laterality recognition** – breathing exercises, gentle range of motion activities, and computerized laterality tasks.
- **Stage II: Explicit motor imagery** – guided visualization of shoulder movements and daily tasks.
- **Stage III: Mirror therapy** – visual illusion of movement using mirror or video feedback.
- **Stage IV: Active Functional Virtual Reality Reintegration** – immersive Virtual Reality tasks simulating activities of daily living and sport-specific movements, including reaching, lifting, and throwing, with real-time biofeedback and progressively graded challenges.

The control group performed the same program but without Virtual Reality immersion in Stage IV, instead using conventional functional exercises in the real environment.

OUTCOME MEASURES

Participants were evaluated at three time points: baseline, week 4, and week 8. Pain intensity was assessed using the Visual Analog Scale, providing a continuous measure of subjective pain perception. Shoulder mobility was evaluated through goniometric assessment of flexion, abduction, external rotation, and internal rotation, allowing for objective quantification of joint range of motion. Functional status was measured using two validated instruments: the Shoulder Pain and Disability Index, which captures shoulder-specific pain and functional limitations, and the Disabilities of the Arm, Shoulder and Hand questionnaire, which evaluates broader upper limb disability. In addition, rotator cuff muscle strength was assessed with the Medical Research Council scale, offering a standardized measure of muscle performance across the main planes of shoulder movement.

STATISTICAL ANALYSIS

Data analysis was conducted using SPSS version 26.0. Normality was tested with the Shapiro–Wilk test. For between-group comparisons, either the independent samples t-test or the Mann–Whitney U test was applied. Within-group changes were assessed using the paired t-test or the Wilcoxon signed-rank test. The level of significance was set at $p < 0.05$. Effect sizes were calculated using Cohen's d to quantify the magnitude of improvement in pain, mobility, and functional outcomes.

Results

PARTICIPANT CHARACTERISTICS

A total of 28 participants (18 females, 10 males; mean age 52.3 ± 6.1 years) completed the study. Demographic and baseline clinical characteristics were comparable between the experimental VR group (n=14) and the control group (n=14) (Table 1).

All baseline variables showed no statistically significant difference between groups ($p > 0.05$), indicating homogeneity. Pain Reduction (VAS). Pain intensity decreased significantly in both groups across the eight-week intervention, but the improvements were consistently greater in participants who underwent Virtual Reality–assisted Graded Motor Imagery. In this group, mean scores on the Visual Analog Scale declined from 7.0 at baseline to 2.3 at week 8, corresponding to an average reduction of 4.7 points ($p < 0.001$). In the control group, pain scores decreased from 6.9 to 3.5, representing an average reduction of 3.4 points ($p < 0.01$). The between-group comparison revealed a statistically significant difference in favor of the Virtual Reality group, with an effect size (Cohen's d = 0.71) indicative of a moderate to strong clinical impact.

The magnitude of pain reduction observed in the Virtual Reality group is clinically relevant, as improvements greater than two points on the Visual Analog Scale are generally considered meaningful for patients with musculoskeletal pain. Beyond statistical differences, the ability of Virtual Reality to achieve nearly a five-point reduction highlights its potential as a superior analgesic adjunct to conventional rehabilitation. These results are consistent with previous evidence suggesting that immersive environments modulate pain perception through mechanisms of attentional distraction, altered cortical processing, and enhanced sensorimotor integration [2].

Furthermore, patients in the Virtual Reality group reported not only less pain intensity but also reduced fear of movement during therapy sessions, which likely contributed to greater engagement and willingness to participate actively in rehabilitation exercises. This motivational effect, coupled with the immersive feedback of Virtual Reality, may have amplified the analgesic benefits and accelerated the desensitization process. In contrast, although the control group achieved meaningful improvements, the lower magnitude of change suggests that traditional physiotherapy combined with the classical three-stage Graded Motor Imagery may not provide the same degree of cortical and psychological modulation as the Virtual Reality–enhanced model.

Between-group difference at week 8: p = 0.03 (Cohen's d = 0.71, moderate effect size)
Range of Motion (ROM). Functional mobility improved in both groups, but VR-assisted GMI achieved superior gains in all planes (Table 2).

Table 2. Change in shoulder ROM (degrees) after 8 weeks

Motion	Control (Baseline → Week 8)	Δ°	VR Group (Baseline → Week 8)	Δ°	p-value
Flexion	105.6 → 138.4	+32.8	104.2 → 150.7	+46.5	0.04
Abduction	92.4 → 126.1	+33.7	91.1 → 140.3	+49.2	0.03
External rotation	22.5 → 38.2	+15.7	23.0 → 45.8	+22.8	0.05
Internal rotation	35.2 → 47.3	+12.1	34.9 → 53.7	+18.8	0.04

The largest effect was observed in abduction and flexion, critical for daily activities.

Functional Outcomes (SPADI and DASH). Both SPADI and DASH scores showed clinically significant improvements in the VR group:

- SPADI: 62.8 → 18.6 (Δ = −44.2; p < 0.001)
- DASH: 51.7 → 15.9 (Δ = −35.8; p < 0.001)

Compared to the control group:

- SPADI reduction: Δ = −33.8 (p = 0.02)
- DASH reduction: Δ = −28.4 (p = 0.03)

This confirms that functional reintegration was faster and more complete with VR-assisted training.
Muscle Strength (MRC Scale)

- VR group: Mean improvement of +1.2 grades across rotator cuff muscles
- Control group: Mean improvement of +0.8 grades
- Between-group difference: p = 0.04

Patient Feedback and Compliance

- VR group compliance: 96% attendance
- Control group compliance: 82% attendance
- Self-reported motivation: significantly higher in VR group (p < 0.01)

Patients in the VR group reported greater engagement and reduced perceived effort, supporting the hypothesis that immersive environments enhance neurocognitive involvement and adherence.

VR as stage IV of GMI led to superior pain reduction, faster ROM recovery, and better functional outcomes. Patient motivation and adherence were higher in the VR group. These results validate the integration of VR as the functional reintegration stage in the GMI framework.

Discussion

The present study demonstrates that Virtual Reality (VR), when integrated as the fourth stage of the Graded Motor Imagery (GMI) framework, provides superior clinical outcomes in the rehabilitation of patients with adhesive capsulitis (frozen shoulder) compared to conventional physiotherapy combined with standard GMI. Our findings reveal that VR not only enhances pain modulation and range of motion (ROM) but also significantly improves functional recovery and patient adherence, confirming its potential as a complementary neurorehabilitation tool.

Integration of VR within the GMI Framework

The classical GMI model, originally conceptualized for complex regional pain syndrome and chronic musculoskeletal pain, involves three sequential stages [26,27,22]

- Laterality recognition (implicit motor imagery)
- Explicit motor imagery
- Mirror therapy

These stages aim to normalize cortical representations, reduce pain through graded exposure, and progressively restore motor function. However, one limitation of the classical approach is the absence of an active, ecologically valid stage that transitions patients from cognitive motor training to functional reintegration.

Our study proposes VR as the fourth stage of GMI—Active Functional VR Reintegration, which provides:

- Immersive, interactive movement tasks simulating daily or sport-specific activities
- Real-time visual and proprioceptive feedback enhancing neuroplasticity
- A motivational environment that sustains patient engagement throughout rehabilitation

This paradigm shift is supported by our results, where patients in the VR group achieved greater improvements in pain, ROM, and functional scores, with superior adherence (96% vs. 82%).

Pain Modulation and Neuroplastic Mechanisms
Our findings align with previous studies highlighting VR as a powerful modulator of pain perception. Immersive environments may downregulate somatosensory cortex hyperactivity and facilitate central desensitization, thereby reducing the intensity of perceived pain [17,18,19]
In our cohort:

- VAS decreased by 67% in the VR group vs. 49% in the control group
- The effect size (Cohen's d = 0.71) indicates a moderate-to-strong clinical effect

The analgesic effect of VR is consistent with distraction-based mechanisms and sensorimotor reorganization, both critical in the management of adhesive capsulitis, where pain-related fear and motor inhibition often perpetuate functional limitations.

Functional Recovery and Motor Reintegration
The superior improvements in SPADI (−44.2%) and DASH (−35.8%) scores in the VR group indicate that patients not only regained ROM but also translated motor gains into daily functional activities. VR provides contextualized motor tasks—such as reaching, lifting, or throwing—within a safe and controlled virtual environment, which accelerates motor relearning and confidence in movement.

From a neurocognitive perspective, the progressive transition from visualized to embodied movement in VR mirrors the graded exposure principle of GMI, but enhances it by adding ecological validity and functional challenge. This supports the hypothesis that VR completes the GMI framework by closing the gap between cortical activation and real-world performance.

Clinical Implications
The integration of VR into physiotherapy protocols presents several practical advantages:
Enhanced patient motivation and adherence, addressing a key challenge in long-term rehabilitation. Safe functional training with real-time feedback, allowing early exposure to complex tasks. Potential for home-based telerehabilitation, expanding access to high-quality therapy. Personalization of exercise intensity based on pain tolerance and functional capacity

Clinicians adopting this model should carefully stage the intervention, ensuring that VR is introduced after motor imagery and mirror therapy, when patients are cognitively and physically ready for active, task-oriented movement.

Study Limitations

While our study provides compelling evidence for VR as the fourth stage of GMI, some limitations must be acknowledged:

- Sample size (n=28) was relatively small, limiting generalizability
- Follow-up was restricted to 8 weeks; long-term retention of motor gains remains to be assessed
- Cost and accessibility of VR equipment may limit immediate large-scale implementation

Future studies should focus on:

- Multicenter randomized trials with larger cohorts
- Long-term outcomes including motor learning retention and return-to-activity rates
- Integration of wearable sensors and biofeedback to optimize individualized therapy
- Exploration of telerehabilitation models leveraging VR for home-based programs

Our study validates that Virtual Reality enhances the GMI framework, providing a bridge between neurocognitive training and functional reintegration. By acting as the fourth stage of GMI, VR not only accelerates pain reduction and ROM restoration but also enhances patient engagement, positioning it as a valuable complementary tool in modern physiotherapy for adhesive capsulitis

Conclusion

This study provides original evidence that Virtual Reality can serve as the fourth stage of the Graded Motor Imagery framework in the rehabilitation of adhesive capsulitis of the shoulder. Compared with conventional physiotherapy combined with Graded Motor Imagery alone, the Virtual Reality–assisted intervention achieved superior clinical results. Pain reduction was more pronounced, with a 67 percent decrease in Visual Analog Scale scores compared to 49 percent in the control group, while improvements in range of motion were greatest in flexion and abduction—movements that are essential for daily activities.

Functional recovery was also accelerated in the Virtual Reality group, as demonstrated by greater gains in the Shoulder Pain and Disability Index and the Disabilities of the Arm, Shoulder and Hand questionnaire. These improvements translated into faster reintegration into daily tasks. In addition, adherence and patient motivation were higher in the Virtual Reality group, with a compliance rate of 96 percent, underscoring the motivational advantage of immersive, interactive environments.

From a neurofunctional perspective, Virtual Reality facilitates sensorimotor integration and bridges the gap between cortical activation and real-world performance, thereby strengthening its role as the stage of Active Functional Virtual Reality Reintegration within the Graded Motor Imagery framework. Clinically, these findings support the adoption of Virtual Reality–enhanced Graded Motor Imagery as a complementary, evidence-based approach in physiotherapy for complex shoulder pathologies. Future research should investigate long-term outcomes, explore scalable delivery models, and assess home-based applications to help establish Virtual Reality as a standard tool in musculoskeletal rehabilitation.

References

1. Álvarez de la Campa Crespo M, Donegan T, Amestoy-Alonso B, Just A, Combalía A, Sanchez-Vives MV. Virtual embodiment for improving range of motion in patients with movement-related shoulder pain: an experimental study. J Orthop Surg Res. 2023.
2. Beltran-Alacreu H, Plaza-Manzano G, López-de-Uralde-Villanueva I, et al. Graded motor imagery for subacromial pain syndrome: randomized trial results. J Clin Med. 2025.
3. Bowering KJ, O'Connell NE, Tabor A, Catley MJ, Leake HB, Moseley GL, Stanton TR. The effects of graded motor imagery and its components on chronic pain: a systematic review and meta-analysis. J Pain. 2013;14(1):3-13.
4. Brady N, McCreesh K, Kieran O, Lewis J. Physiotherapists' beliefs and perspectives on immersive virtual reality for musculoskeletal shoulder pain. PLoS One. 2023.
5. Breckenridge JD, McAuley JH, Moseley GL, Ginn K, Wallwork SB, Hodges PW, Stanton TR. Motor imagery performance and tactile spatial acuity are altered in unilateral frozen shoulder. Int J Environ Res Public Health. 2020;17(21):7872.
6. Bruls R, [others]. Graded motor imagery as adjunct to physiotherapy in chronic rotator cuff–related shoulder pain: randomized trial. BMC Musculoskelet Disord. 2025.
7. Carnevale A, Mannocchi I, Hadj Sassi MS, Carli M, De Luca G, Longo UG, Denaro V, Schena E. Virtual reality for shoulder rehabilitation: accuracy evaluation of Oculus Quest 2. Sensors. 2022;22(15):5511.
8. Carnevale A, Mannocchi I, Hadj Sassi MS, Carli M, De Luca G, Longo UG, Denaro V, Schena E. Performance evaluation of an immersive virtual reality application for rehabilitation after arthroscopic rotator cuff repair. Bioengineering. 2023;10(10):1158.
9. Chaplin E, Hewston P, Petz W, Patterson KK. Clinical applications of virtual reality in musculoskeletal rehabilitation: a PRISMA-ScR review. Healthcare (Basel). 2023;11(24):3178.
10. Daf A, Patil DS. Virtual reality adjunct versus conventional physiotherapy in proximal humerus fractures: randomized controlled trial. Cureus. 2024.
11. Effects of AR-based telerehabilitation in adhesive capsulitis: randomized results. Ann Phys Rehabil Med. 2025.
12. Effects of virtual reality exercise on pain, joint motion, and quality of life in frozen shoulder. Physiother Theory Pract. 2024.
13. Gopalakrishnan R, [others]. Graded motor imagery in adhesive capsulitis: geriatric case study. Int J Allied Med Sci Clin Res. 2024.
14. Gospodin IC, [others]. Virtual reality as a complementary tool within the graded motor imagery framework. EFMS Journal. 2023.
15. Gospodin IC. Virtual Reality as the Fourth Stage within the Graded Motor Imagery Framework. Doctoral thesis. 2025.
16. Grassini S, Laumann K. Virtual reality–assisted nonpharmacological treatments for chronic pain: systematic review and meta-analysis. Int J Environ Res Public Health. 2022;19(7):4071.
17. Gurudut P, Godse AS. Effectiveness of graded motor imagery in subjects with frozen shoulder: a pilot randomized controlled trial. Korean J Pain. 2022;35(2):152-159.
18. Hoffman HG, Richards TL, Coda B, Bills AR, Blough D, Richards AL, Sharar SR. Modulation of thermal pain–related brain activity with virtual reality: evidence from fMRI. NeuroReport. 2004;15(8):1245-1248.
19. Hoffman HG, Sharar SR, Coda B, Everett JJ, Ciol M, Richards T, Patterson DR. Manipulating presence influences the magnitude of virtual reality analgesia. Pain. 2004;111(1-2):162-168.
20. Hoffman HG, Patterson DR, Carrougher GJ, Sharar SR. Virtual reality as an adjunctive nonpharmacologic analgesic for acute burn pain. NeuroRx. 2004.
21. Huang Q, Lin J, Han R, et al. Using virtual reality exposure therapy in pain management: a systematic review and meta-analysis. Value Health. 2022;25(8):1302-1317.
22. Lagueux E, [others]. Graded motor imagery for shoulder pain: clinical perspectives. Clin J Pain. 2012.
23. Longo UG, Carnevale A, Andreoli F, Mannocchi I, Bravi M, Hadj Sassi MS, Santacaterina F, Carli M, Schena E, Denaro V, Papalia R. Immersive virtual reality for shoulder rehabilitation: evaluation of a physical therapy program executed with Oculus Quest 2. BMC Musculoskelet Disord. 2023;24:859.
24. Longo UG, De Salvatore S, Piergentili I, et al. Virtual reality in shoulder rehabilitation: feasibility and outcomes. Muscles Ligaments Tendons J. 2021.
25. 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.
26. Moseley GL. Graded motor imagery is effective for long-standing complex regional pain syndrome: a randomized controlled trial. Pain. 2004;108(1-2):192-198.
27. Moseley GL. Graded motor imagery for pathologic pain: a randomized controlled trial. Neurology. 2006;67(12):2129-2134.
28. Phansopkar P, [others]. Integrating graded motor imagery into multimodal physiotherapy for adhesive capsulitis: randomized controlled trial. J Clin Orthop Trauma. 2024.
29. Rizzo JR, [others]. Manipulated virtual kinematic intervention improves range of motion and pain in stiff shoulder. J Clin Med. 2022.
30. Sawyer EE, McDevitt AW, Louw A, Puentedura EJ. Pain neuroscience education, tactile discrimination, and graded motor imagery in frozen shoulder: a case report. Physiother Theory Pract. 2018;34(8):630-639.
31. Short-term effect of graded motor imagery in chronic shoulder pain syndrome: open-label prospective study. Pain Med. 2020.
32. Sırlan S, [others]. Graded motor imagery as an adjunct to comprehensive physiotherapy in chronic rotator cuff–related shoulder pain: single-blind randomized controlled trial. BMC Musculoskelet Disord. 2025.

33. Tang P, [others]. The efficacy of virtual reality on rehabilitation in musculoskeletal disorders: meta-analysis. J Med Internet Res. 2025.
34. Wei W, Yin X, Zhang Z, et al. Virtual reality exercise for knee osteoarthritis: a systematic review and meta-analysis. Front Physiol. 2024;15:1468164.
35. Yeo SM, Kim MJ, Lim SH, et al. Telerehabilitation using augmented reality for adhesive capsulitis: multicenter randomized controlled trial protocol. BMC Musculoskelet Disord. 2021;22:847.
36. Yasacı Z, [others]. Integration of graded motor imagery training in primary frozen shoulder: randomized clinical trial. In press; 2025.