International Journal of Basic and Applied Sciences, 14 (6) (2025) 21-28

International Journal of Basic and Applied Sciences

Website: www.sciencepubco.com/index.php/IJBAS
https://doi.org/10.14419/xp6hfk23
Research paper

Virtual Reality and Applications in The Rehabilitation of Shoulder Musculoskeletal Disorders: A Narrative Review

Om Wadhokar [1] *, Seema Saini [2], Tushar Palekar [2], Sakshi Yede [3], Vanshika Tandon [3], Jayantika Bhardwaj [3]

[1] Assistant Professor, Department of Musculoskeletal Sciences, Dr. D.Y. Patil College of Physiotherapy, Dr. D.Y. Patil Vidyapeeth, Pimpri, Pune, Maharashtra, India, Ph.D Scholar, Department of Public Health, Jawaharlal Nehru Medical College, Datta Meghe Institute of Higher Education and Research, Sawangi(M), Wardha, Maharashtra, India.
[2] Professor, Department of Musculoskeletal Sciences, Dr. D.Y. Patil College of Physiotherapy, Dr. D.Y. Patil Vidyapeeth, Pimpri, Pune, Maharashtra, India
[3] Resident, Department of Musculoskeletal Sciences, Dr. D.Y. Patil College of Physiotherapy, Dr. D.Y. Patil Vidyapeeth, Pimpri, Pune, Maharashtra, India
**Corresponding author E-mail: Seema.saini@dpu.edu.in*

Received: June 9, 2025, Accepted: September 10, 2025, Published: October 2, 2025

Abstract

Background: Shoulder musculoskeletal disorders (MSDs) can significantly impair daily activities and quality of life. Traditional rehabilitation, while effective, requires considerable time, effort, and resources. Virtual reality (VR) has emerged as a novel tool, offering immersive, engaging, and interactive rehabilitation experiences that can improve motivation and outcomes.
Objective: This review explores the effectiveness, benefits, challenges, and future potential of VR-based rehabilitation in treating shoulder MSDs.
Methods: A narrative review was conducted by searching Google Scholar, PubMed, PEDro, Web of Science, and Scopus. MeSH terms such as "Virtual Reality," "Shoulder Rehabilitation," and "Musculoskeletal Disorders" were used. Inclusion criteria focused on studies evaluating VR's impact on shoulder MSDs through experimental designs, case studies, or randomized controlled trials (RCTs). Studies involving non-shoulder conditions or neurological disorders were excluded.
Results: Studies demonstrated that VR-based rehabilitation improved range of motion (ROM), pain reduction, and patient engagement. Gamification elements boosted motivation and adherence compared to traditional therapies. Combining VR with conventional approaches resulted in faster recovery, especially in conditions like frozen shoulder and subacromial impingement.
Conclusion: VR offers promising benefits in managing shoulder MSDs by enhancing patient engagement and recovery. While preliminary evidence supports its use as a complementary tool to traditional therapy, further research is needed to assess its cost-effectiveness, long-term viability, and integration into clinical practice.

Keywords: *Virtual Reality, Shoulder Rehabilitation, Musculoskeletal Disorders, Shoulder Pain, Shoulder Dysfunction, and Physical Therapy, Review Article.*

1. Introduction

Common and incapacitating, shoulder musculoskeletal diseases can have a major negative influence on a person's quality of life. The greatest number of years spent disabled is caused by musculoskeletal illnesses as a category of conditions (1)Musculoskeletal shoulder issues are a prevalent pain complaint within this category. Approximately 4% to 47% of the population may experience shoulder pain in a year, and over 30% of adults over 65 will experience shoulder pain every day(2). Any loss of shoulder function is linked to a significant impact on day-to-day functioning since the shoulder is involved in a variety of activities, including pulling, pushing, carrying, lifting, throwing, and placing(3) .
Traditional rehabilitation methods can alleviate shoulder pain and enhance function, but they often demand significant time, effort, and financial resources. In rehabilitation, VR represents a valid and reliable tool for joint and functional (4). In recent years, virtual reality (VR) and augmented reality (AR) have introduced innovative approaches in managing various musculoskeletal conditions. These technologies offer immersive, personalized, and interactive rehabilitation experiences, boosting patient motivation, engagement, and outcomes (5). Post-surgical rehabilitation plays a very crucial role in optimizing recovery and restoring function to enhance performance and independence in activities of daily living. VR has become progressively popular for orthopedic rehabilitation in both clinical and home environments (6).

Its benefits include improved patient motivation, faster progress, and the ability to refine movement strategies through real-time feedback from the activities (7).In particular, the most important benefit of Virtual reality in rehabilitation is its ability to give users instant feedback on whether they are performing the right actions(8). In terms of motivation and rehabilitation intensity, several benefits of virtual rehabilitation can be proposed. Through gamification—the process of incorporating game design features and ideas into something (like a task) to encourage participation—and increased enjoyment, virtual reality (VR) can inspire patients to participate. Rehabilitation through VR describes an assistive health technology that is used to recover motor or sensory skills lost due to an accident or illness through a virtual but interactive environment(9). With less direct therapist supervision, a low-cost virtual rehabilitation system can be employed as a tele- or home-based rehabilitation tool in addition to being an adjuvant therapy to traditional rehabilitation(10). With motion sensors and virtual reality (VR) devices, patients' progress can be digitally tracked and functionally assessed during rehabilitation (11).

Several aspects of upper limb rehabilitation require careful evaluation to properly customise treatment plans. To assess various aspects of upper limb recovery, several evaluation instruments have been developed. Rehabilitation of the upper limbs includes a variety of techniques adapted to the requirements of stroke and injury patients (12). To improve range of motion, motor abilities, and everyday life activities, occupational and physical therapies offer structured exercises. VR creates immersive 3D worlds for rehabilitative exercises through interactive simulation with computer software and hardware (13). VR systems are divided into three levels of immersion: semi-immersive (using screens or headsets for partial immersion), non-immersive (enabling simultaneous virtual and real environments), and fully immersive (totally blocking real-world awareness) (14).

This route can substitute fun games or activities that are extremely adaptable to the patient's personal interests and preferences for tedious required exercises. Using VR in conjunction with tracking technology to track gestures would not only boost motivation but also make it possible to quantify actions. Employing supplementary metrics to assess patients' overall quality of life will, in turn, enable medical practitioners to track the patients' recuperation (15).

In order to enhance motor function, virtual reality (VR) combines 3D visualisations with movement tracking technology to provide real-time engagement in simulated worlds. VR systems can "assist patients in engaging in intensive, repetitive, and task-oriented practice using new technologies to promote neuroplasticity and recovery," claim Bui et al. (2021) (16). Because of this feature, virtual reality is especially well-suited to treating disorders like shoulder MSDs, where healing requires constant mobility and muscle-strengthening activities. Furthermore, through adaptive feedback mechanisms and the decrease of compensatory movements—which are frequently harmful to long-term recovery—VR-based rehabilitation systems “can guide users to complete training actions and improve the rehabilitation effect,” according to Xiao et al. (2022)(17).

By producing repetitive, interesting, and task-specific workouts that can be tailored to each user's needs, VR-based rehabilitation systems have been demonstrated to promote improvements in motor control and musculoskeletal recovery(18)(19). Kurashina et al. (2023) state that physical therapy after anaesthesia significantly improved range of motion (ROM), whereas patients with frozen shoulder, for example, had limited ROM because of discomfort and muscle contraction. (17). This emphasises how crucial pain management and range of motion restoration are to musculoskeletal rehabilitation, two areas in which virtual reality may offer substantial benefits by providing adaptive training that overcomes these constraints.

Furthermore, Merians et al. (2009) highlight that by enabling patients to participate in virtual environments that mimic real-world tasks, VR can support functional neuroplasticity, which is essential for motor recovery. Because these devices accommodate patients with different levels of disability and offer haptic input and anti-gravity support, they are especially helpful in upper extremity rehabilitation (18). By guaranteeing that workouts are both rigorous and customised to each patient's demands, these elements could improve patient results in shoulder rehabilitation.

Despite its potential, little is known about how VR can be incorporated into therapeutic practice for shoulder MSDs, especially when it comes to long-term efficacy and clinical results. The effective use of VR technologies for rehabilitation, particularly in the field of neurological conditions, has already been demonstrated in several reviews(20)(21). On the other hand, there are very few articles regarding the rehabilitation of musculoskeletal disorders (22)(23).

The purpose of this study is to summarise the available data on virtual reality applications in shoulder musculoskeletal rehabilitation, examining the advantages, difficulties, and potential future developments of this field. This review aims to explore the application of VR in the rehabilitation of shoulder MSDs, examining the current evidence on its effectiveness, potential benefits, and future directions in clinical practice.

2. Methodology

This narrative review aimed to investigate the available data about the use of virtual reality (VR) in the treatment of musculoskeletal disorders (MSDs) of the shoulder. Google Scholar, PubMed, PEDro, Web of Science, and Scopus were among the major electronic databases that were extensively screened in order to do this.

3. Search strategy

The search strategy aimed to locate pertinent studies available in English. The following MeSH terms were used: "Virtual Reality," "Shoulder Rehabilitation," "Musculoskeletal Disorders," "Shoulder Pain," "Shoulder Dysfunction," and "Physical Therapy." Boolean operators AND and OR were applied to combine terms and refine the search results.

4. Inclusion Criteria

1. Studies focused on utilizing virtual reality for treating musculoskeletal conditions of the shoulder.
2. Studies that assessed the effectiveness, results, or workings of VR-based therapies for MSDs of the shoulder.

3. Case studies, experimental studies, and randomised controlled trials (RCTs). Original research articles in full text that were published in English were included.

5. Exclusion Criteria

- Any study that concentrated on musculoskeletal disorders affecting joints other than the shoulder joint.
- If the study population has any neurological conditions.
- Full-text articles were not available.

6. Study Selection and Data Extraction

The titles and abstracts were found and screened during the search. Full-text articles were then obtained and evaluated for relevance according to the inclusion and exclusion criteria. Any disagreements in selecting studies were resolved through consensus discussions.

The following data were gathered from each included study: author, year of publication, Aims and objectives, intervention, sample size, outcome measures, conclusion, and key findings. The data were qualitatively synthesized to identify themes and trends across the studies.

7. Results

- In a 2017 study, Nihan Ozunlu Pekyavas et al. explored the short-term effects of virtual reality (VR) exergaming compared to traditional home exercise programs for individuals with scapular dyskinesis and subacromial impingement syndrome (SAIS). The study involved 30 participants, divided into two groups: 15 underwent a VR exergaming intervention, while the other 15 followed a conventional home exercise routine. The VR program included interactive activities such as boxing, bowling, tennis, and bilateral shoulder elevation, guided by a virtual avatar. Over six weeks, both groups were evaluated using outcome measures like the Shoulder Pain and Disability Index (SPADI) for functional impairment, the Visual Analogue Scale (VAS) for pain intensity, and the Neer and Hawkins tests for shoulder impingement. The results indicated that the VR group showed greater improvements in shoulder function, scapular control, and pain reduction compared to the home exercise group. Participants in the VR program also reported higher motivation and engagement, likely due to the immersive nature of the virtual environment. The findings suggest that VR exergaming may offer a more effective short-term approach for managing SAIS symptoms and enhancing functional recovery.(24)
- In a July 2022 pilot study, Isabella Schwartz et al. examined the impact of a controlled virtual kinematic intervention on individuals with traumatic stiff shoulders. The research aimed to assess improvements in pain relief, impairment levels, and both active and passive range of motion (ROM) using virtual feedback. Thirteen participants were divided into two groups: one received altered feedback (n = 7), while the other did not. Over six weeks, shoulder flexion and abduction were measured using a goniometer, and outcomes were evaluated with the Visual Analogue Scale (VAS) for pain and the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire for function. Results showed that participants receiving manipulated feedback demonstrated greater improvements in both active and passive ROM compared to the control group. They also reported better DASH scores and greater pain reduction, indicating superior functional outcomes. The study concluded that virtual kinematic interventions with controlled feedback may offer an effective treatment strategy for managing traumatic stiff shoulder.(25)
- An experimental study explored the use of immersive virtual reality (VR) to improve the range of motion (ROM) and reduce pain in individuals with movement-related shoulder pain. The study aimed to determine whether adopting a virtual avatar with enhanced shoulder movements could positively influence patients' mobility and pain levels. In the VR environment, participants' shoulder movements were either accurately mirrored or altered to appear more mobile than they were.

Key outcome measures included changes in active range of motion (AROM), pain levels assessed with the Visual Analogue Scale (VAS), and self-reported function using standardized questionnaires. The results showed that participants with the altered virtual embodiment experienced greater improvements in ROM compared to those who only saw mirrored movements. Additionally, the manipulated group reported reduced pain and increased confidence in shoulder movement, suggesting that the perception of enhanced mobility had beneficial psychological and physical effects. The study concluded that virtual embodiment could be a promising treatment for shoulder pain by improving ROM and alleviating discomfort and anxiety associated with movement.(26)

- A June 2022 study by Shrutika Wankhade et al. evaluated the effectiveness of virtual reality (VR)-assisted physical therapy as a complement to conventional treatment for patients with frozen shoulder. The research aimed to determine if integrating VR with traditional therapy could enhance recovery by improving range of motion (ROM), reducing pain, and restoring functional ability. Participants were divided into two groups: one received only traditional therapy, while the other combined it with VR-based exercises involving interactive, movement-focused tasks targeting the shoulder joint. Key outcome measures included ROM, pain levels (measured with the Visual Analogue Scale, VAS), and functional performance (assessed using the Shoulder Pain and Disability Index, SPADI). The results showed that patients in the VR-assisted group experienced faster pain relief and greater ROM improvements compared to those receiving traditional therapy alone. They also reported higher motivation and engagement, contributing to better adherence to the rehabilitation program. The study concluded that incorporating VR into standard physiotherapy offers a promising supplemental strategy to improve clinical outcomes for individuals with frozen shoulder.(27)
- A study compared the effectiveness of game-based virtual reality (VR) training with conventional physiotherapy in treating patients with frozen shoulder. The objective was to assess improvements in functional ability, pain reduction, and range of motion (ROM). Participants were divided into two groups: one underwent traditional physiotherapy, while the other participated in VR-based training featuring gamified activities, such as mobility challenges and virtual sports, to engage the shoulder joint. Both groups showed improvements in ROM, pain levels (measured by the Visual Analogue Scale, VAS), and functional performance (assessed by the Shoulder Pain and Disability Index, SPADI). However, the VR group experienced faster pain relief and greater mobility gains. Additionally, patients in the VR group reported higher satisfaction and motivation, contributing to better adherence to the rehabilitation program. The study concluded that game-based VR training can serve as an effective alternative or complement to conventional physiotherapy, particularly by enhancing patient engagement throughout the recovery process (28).
- A case report examined the impact of combining virtual reality (VR) exergaming with conventional physiotherapy for a patient with stage 2 frozen shoulder, characterized by severe pain and restricted range of motion (ROM). The intervention included traditional

mobility-focused exercises alongside VR-based activities, such as movement games and virtual sports, to engage the shoulder joint. Outcome measures included the Visual Analogue Scale (VAS) for pain, the Shoulder Pain and Disability Index (SPADI), and ROM assessments. The results demonstrated that the combined approach improved shoulder function, reduced pain, and increased ROM more quickly than traditional therapy alone. The immersive and engaging nature of VR exergaming also enhanced the patient's motivation and adherence to the rehabilitation program, contributing to better outcomes. The report concluded that VR exergaming is a valuable supplement to conventional physiotherapy for frozen shoulder, particularly by addressing both the psychological and motivational aspects of recovery.(29)

- The paper by Won Kee Chang et al. outlines the protocol for a single-center randomized controlled trial investigating the effectiveness of a digital healthcare system for post-operative rehabilitation following rotator cuff repair. The study aims to compare two groups: one using a home-based digital system with augmented reality (AR) for guided exercises, and the other following a traditional rehabilitation approach with in-person physical therapist supervision. The digital group will utilize an Xbox Kinect 3D depth camera system with software to track movements and ensure correct exercise performance. Rehabilitation will occur in three phases: 1. On-brace phase (up to 6 weeks post-op): Includes low-intensity and upper-limb mobilization exercises. 2. Off-brace phase (6–9 weeks): Focuses on passive range of motion (ROM) exercises and scapular stabilization. 3. Active mobilization phase (9–12 weeks): Introduces active ROM and advanced shoulder stabilization exercises. The primary outcome will be measured using the Simple Shoulder Test (SST), which assesses functional improvement. Secondary measures include other functional assessments and pain scores. To promote adherence and ensure safety, both groups will have the option to request additional educational sessions with therapists as needed.(30)

Table 1: Comparison of the studies

Title, Author & Date	Aims & Objectives	Intervention(Sample size, Outcome measure, Study duration)	Conclusion	Remark
Comparison of virtual reality exergaming and home exercise programs in patients with subacromial impingement syndrome and scapular dyskinesis: Short-term effect NihanOzunluPekyavas and Nevin Ergun(24) April 2017	To compare the short-term effects of a home exercise program and virtual reality exergaming in patients with subacromial impingement syndrome (SAIS).	N=30 -Group A- 15 (Home Exercise Program) -Group B- 15 (Virtual Reality Exergaming Program) -Virtual Reality Exergaming Program includes Exercise training of bilateral shoulder elevation, boxing, bowling, and tennis games, accompanied by an avatar. -Visual Analogue Scale, Neer and Hawkins Tests, Scapular Retraction Test, Scapular Assistance Test, Lateral Scapular Slide Test, and Shoulder Pain and Disability Index. -6 weeks	Virtual reality exergaming programs were found to be more effective than home exercise programs in the short term in subjects with SAIS.	The study focuses on short-term outcomes (6 weeks of treatment and 1 month follow-up). Further research could explore the long-term efficacy of virtual reality exergaming compared to home exercises over the long term.
Positive Effect of Manipulated Virtual Kinematic Intervention in Individuals with Traumatic Stiff Shoulder: A Pilot Study Isabella Schwartz, et al.(25) July 2022	To test the effect of manipulated virtual kinematic intervention on measures of active and passive range of motion (ROM), pain, and disability level in individuals with traumatic stiff shoulder.	N=13 -Group A- 6 (non-manipulated feedback group) -Group B-7 (manipulated feedback group) -A goniometer was used to measure the active and passive ROM of the shoulder (flexion and abduction), a visual analogue scale (VAS) was used to record shoulder pain, and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was administered. - 6 weeks	Manipulated virtual kinematic intervention might be beneficial in individuals with a traumatic stiff shoulder.	Manipulated virtual kinematics should be further tested for other populations with orthopedic injuries, such as elbow and knee injuries, and can be done in a larger sample size.
Virtual embodiment for improving range of motion in patients with movement-related shoulder pain: an experimental study MercèÁlvarez de la CampaCrespo, et al.(26) Sept 2023	To investigate whether a single session of an embodiment-based immersive VR training program influences the pain-free range of motion in patients with shoulder pain.	N=21 Kinovea video analysis software to measure pain-free active movement, QuickDASH, and TSK-11 questionnaires -one time (15-minute session) with 1 week follow-up	Virtual embodiment may be a useful therapeutic tool to help improve the range of motion in patients with movement-related shoulder pain in the short term, which in turn could expedite rehabilitation and recovery in these conditions.	There is a lack of evidence on the long-term effects of virtual embodiment interventions for improving shoulder pain and range of motion. It also emphasizes the need for further research with larger sample sizes, control groups, and longer follow-ups to better understand the mechanisms driving the observed benefits and to assess the potential cumulative effects of repeated VR interventions
Effect of virtual reality-aided physical therapy an adjunct to traditional therapy in frozen shoulder patients Shrutika Wankhade, et al.(27) June 2022	To compare the efficacy of virtual reality headset-assisted physiotherapy to traditional physical therapy in frozen shoulder patients.	N=50 - Group A 25 (Conventional therapy, including Maitland's mobilization)	In patients with frozen shoulder, a virtual reality headset, i.e., Oculus-assisted physical therapy, is	Participants with conditions like diabetes, rheumatoid arthritis, or those with a post-surgical history were excluded. However, excluding

		- Group B 25 (virtual reality (Oculus) aided physical therapy and Maitland's mobilization) -Numerical Pain Rating Scale (NPRS), Shoulder Range of Motion (ROM) using goniometry, and the Shoulder Pain Disability Index (SPADI) scale. - 2 weeks	more beneficial than traditional physical therapy, according to the findings of this study.	these patients leaves a gap in clinical evidence, as many patients undergoing rehabilitation will have diabetes or other chronic conditions. This limits the **generalizability of** the findings from the current study.
Effect of game-based virtual reality training versus conventional physiotherapy in periarthritis of the shoulder Sharmila. S, et al.(28) 2022	To find out the effect of game-based Virtual Reality training versus conventional Physiotherapy in Periarthritis of the Shoulder.	N=30 - Group A 15 (40 mins of game-based virtual reality training using X-box Kinect 360 wireless sensor) - Group B 15 (40 mins of conventional therapy capsular stretching exercise, Codman's Exercise, towel stretch, wand exercise, cog wheel exercise, pulley exercise, finger ladder exercise, and elastic band exercise.) -SPADI scale (Shoulder Pain and Disability Index). NPRS Scale (Numerical Pain Rating Scale) Goniometer for shoulder ROM -4 weeks	The 4-week program of Game-based Virtual Reality training was equally effective in reducing pain and improving range of motion and upper limb function in people with Periarthritis of the shoulder.	The study only included participants in stage 2, missing insights from other stages. Testing the interventions on patients across all stages of periarthritis to understand differential impacts.
Impact Of Virtual Reality Exergaming and Conventional Physiotherapy in Stage 2 Frozen Shoulder Patient: A Case Report Mubashshirah Firdaus Ansari Et Al.(29) October 2022	To check the effect of Virtual Reality and Conventional Physiotherapy on patients with Frozen Shoulder.	Virtual Reality and Conventional Physiotherapy for pain reduction, increasing functional independence, and reduction in fear of avoidance and improvement in sleep pattern and quality. -Disability index scale (SPADI), Range of Motion (ROM) measured by Universal Goniometer, Kinesiophobia was measured through the Tampa Scale of Kinesiophobia (TAMPA), and sleeping routine through the Pittsburgh Sleep Quality Index (PSQI). - 4 weeks	Four weeks of intervention, thrice a day in a week, showed marked improvement in pain, ROM, fear of avoidance, and sleep quality through Virtual Reality exergaming and Conventional Physiotherapy in a Frozen shoulder patient.	Adding experimental groups to compare multiple rehabilitation methods could provide deeper insights into the best treatment strategies. Larger studies, including randomized controlled trials (RCTs), can be done to validate the results across a broader population.
Post-operative rehabilitation using a digital healthcare system in patients who had undergone rotator cuff repair: protocol for a single-center randomized controlled trial Won Kee Chang, et al.(30) Aug 2022	To increase the efficacy of the rehabilitation program and raise patients' compliance levels by developing a post-op rehabilitation-oriented digital healthcare system and applying it to patients who had undergone rotator cuff repair.	N=115 - Group A- 58 (Digital group) - Group B- 57 (Conventional group) -Simple Shoulder Test (SST), Pain at rest and action (NRS), ROM of affected shoulder, MMT of affected shoulder, Grip strength (JAMAR dynamometer), DASH score, SPADI score, Quality of Life: EQ-5D-5L - 12 weeks	The study concludes that integrating an augmented reality (AR)-based digital healthcare system into post-operative rehabilitation may enhance patient outcomes for individuals recovering from rotator cuff repair. Specifically, the AR system is expected to improve patient compliance and the efficacy of rehabilitation by providing tailored, phase-specific exercises and real-time feedback.	The AR-based system is only used during the off-brace and active mobilization phases (weeks 6–12), leaving the potential impact on the initial phase unexplored. Future studies could evaluate the effects of AR from the immediate post-operative period.

8. Discussion

The recent advances in physiotherapy for wrist and hand musculoskeletal conditions have introduced promising new technologies that aim to improve both the effectiveness and the patient experience during rehabilitation. Techniques such as virtual reality (VR), robotic-assisted devices, wearable technologies, blood flow restriction (BFR) therapy, and mirror neuron therapy offer innovative solutions to long-standing challenges in traditional physiotherapy, such as low patient adherence and prolonged recovery times. These technologies not only make

rehabilitation more engaging for patients but also allow for more personalized, data-driven treatment plans that can adapt to the needs of individual patients.[1] [2] [7].

Despite the promise of these emerging techniques, further research is needed to fully understand their long-term benefits and potential drawbacks. Studies focusing on the usability, accessibility, and cost-effectiveness of these technologies across diverse patient populations are essential to validate their widespread application in clinical settings. Additionally, comparative studies that assess the efficacy of these innovations relative to conventional therapies are crucial for determining their place within standard rehabilitation protocols. [19] [25]

Overall, the integration of these advanced techniques represents a significant step forward in the field of physiotherapy, with the potential to improve patient outcomes, enhance the rehabilitation process, and ultimately, restore function more effectively. Below is a table summarizing the recent studies reviewed for this research. (Table 2) As the use of technology in healthcare continues to rise, these innovations are likely to play an increasingly important role in the treatment of musculoskeletal conditions, improving the quality of life for patients worldwide.

Integrating the above-mentioned treatment approach in the management of the patient in our outpatient department provides real-time visual feedback to the patient, which can be used to motivate the patient to perform better with each repetition. This incentive feedback provides adherence of the patient to the treatment, which will improve the functional outcome of the patient in terms of providing a speedy recovery.

This review was limited by variability in study designs, small sample sizes, and a lack of standardized intervention protocols across included studies. Meta-analysis was not performed, and the potential for publication bias exists. Furthermore, only adult populations were considered, limiting generalizability to pediatric and geriatric groups.

The existing literature provides insight into the above-mentioned devices for the short term, whereas studies need to be conducted to assess the long-term effect of virtual reality and other treatments to establish a higher level of evidence in the efficient management of patients. Research can be done to explore the effect of virtual reality in the paediatric population as well as in the geriatric population, which provides an innovative approach and speedy recovery for the patient. Table 3 below summarizes all the articles included in the study for wrist and hand rehabilitation.

Table 2: Comparison of the efficacy of the studies

Study	Treatments	Effectiveness (Recovery Time, ROM Improvement)	Ease of Use	Patient Adherence	Cost
Nihan Ozunlu Pekyavas et al. (2017)	VR exergaming vs. traditional home exercises	The VR group showed superior ROM improvement, better scapular control, and faster pain reduction	Moderately easy; avatar guidance helpful	High – due to immersive, engaging format	Moderate – requires VR equipment but can be home-based
Isabella Schwartz et al. (2022)	Virtual kinematic feedback (altered vs. non-altered)	The altered feedback group had better ROM gains and DASH scores	Simple feedback-based system; easy to use	High – due to perceived improvement and reduced pain	Low to Moderate – tech needs are minimal
Immersive VR Avatar Study	Altered vs. mirrored shoulder movement in VR	The altered movement group had better ROM, less pain, and higher confidence	Easy if familiar with VR; setup may be complex for some	High psychological benefits increased motivation	Moderate – VR headset and software required
Shrutika Wankhade et al. (2022)	VR-assisted therapy vs. traditional therapy	The VR group had faster pain relief and superior ROM	VR tasks were interactive and intuitive	High–gamified tasks boosted engagement	Moderate – added VR cost but efficient results
Game-Based VR vs. Conventional Therapy	Gamified VR vs. standard physiotherapy	The VR group had quicker pain relief and better mobility	Very user-friendly; game elements simplify tasks	High – greater enjoyment, better compliance	Moderate – game system needed, but cost-effective
Case Report (Stage 2 Frozen Shoulder)	Combined VR exergaming + conventional PT	Faster pain reduction and ROM recovery than PT alone	Moderate – required both therapy types	Very high – motivation improved due to the fun factor	Low to Moderate – feasible as supplemental treatment
Won Kee Chang et al. Protocol	Home-based digital AR vs. in-person rehab	Effectiveness to be measured (protocol stage); expected benefits in guidance and safety	Depends on user's comfort with tech (AR-based)	Potentially high – remote access supports adherence	Potentially high–AR system with Kinect camera and software

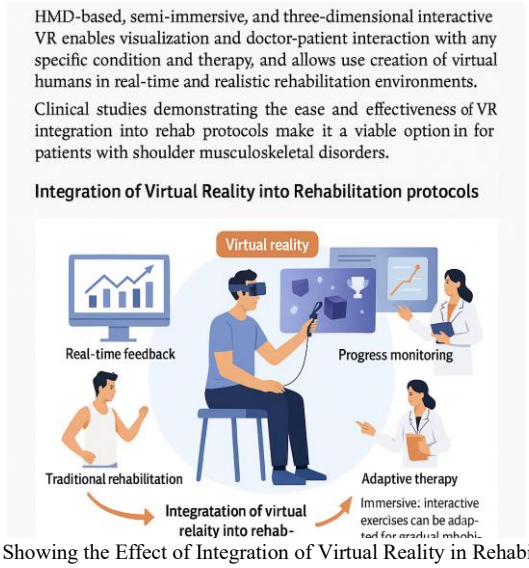

Fig. 1: Showing the Effect of Integration of Virtual Reality in Rehabilitation

9. Conclusion

We conclude that virtual reality and robot-assisted devices have more consistent results, whereas blood flow restriction therapy showed significant improvement in strength even with minimal effort. Extensive studies with a large sample size are required in wearable devices and game-based rehabilitation to gain a clearer idea about the interventions. Overall integration of such newer rehabilitation approaches improves patient adherence and cooperation, and real-time feedback helps the patient to track progress and improve the outcome.

References

[1] Crowe CS, Massenburg BB, Morrison SD, Chang J, Friedrich JB, Abady GG, et al. Global trends of hand and wrist trauma: a systematic analysis of fracture and digit amputation using the Global Burden of Disease 2017 Study. Inj Prev. 2020 Oct;26(Suppl 2):i115–24.

[2] Hidalgo JCC, Vásconez NMP, Bykbaev VER, Muñoz ÁAP, Pinos MEA. Development of a Hand Rehabilitation Therapy System with Soft Robotic Glove. In: Ahram T, Falcão C, editors. Advances in Usability and User Experience [Internet]. Cham: Springer International Publishing; 2020 [cited 2024 Oct 18]. p. 948–58. (Advances in Intelligent Systems and Computing; vol. 972). Available from: https://doi.org/10.1007/978-3-030-19135-1_93.

[3] Shalal NS, Aboud WS. Smart Robotic Exoskeleton: a 3-DOF for Wrist-forearm Rehabilitation. J Robot Control JRC [Internet]. 2021 [cited 2024 Oct 13];2(6). Available from: https://journal.umy.ac.id/index.php/jrc/article/view/10280. https://doi.org/10.18196/jrc.26125.

[4] Valdes K, Gendernalik E, Hauser J, Tipton M. Use of mobile applications in hand therapy. J Hand Ther. 2020 Apr;33(2):229–34. https://doi.org/10.1016/j.jht.2019.10.003.

[5] Pereira MF, Prahm C, Kolbenschlag J, Oliveira E, Rodrigues NF. A Virtual Reality Serious Game for Hand Rehabilitation Therapy. In: 2020 IEEE 8th International Conference on Serious Games and Applications for Health (SeGAH) [Internet]. Vancouver, BC, Canada: IEEE; 2020 [cited 2024 Oct 13]. p. 1–7. Available from: https://ieeexplore.ieee.org/document/9201789/. https://doi.org/10.1109/SeGAH49190.2020.9201789.

[6] Kulkarni CA. Effect of virtual reality and conventional physiotherapy on rehabilitation of distal radius fracture. J Med Pharm Allied Sci. 2022 Aug 30;11(4):5128–32. https://doi.org/10.55522/jmpas.V11I4.1308.

[7] Sethi A, Ting J, Allen M, Clark W, Weber D. Advances in motion and electromyography based wearable technology for upper extremity function rehabilitation: A review. J Hand Ther. 2020 Apr;33(2):180–7. https://doi.org/10.1016/j.jht.2019.12.021.

[8] Hussain S, Jamwal PK, Van Vliet P, Ghayesh MH. State-of-the-Art Robotic Devices for Wrist Rehabilitation: Design and Control Aspects. IEEE Trans Hum-Mach Syst. 2020 Oct;50(5):361–72. https://doi.org/10.1109/THMS.2020.2976905.

[9] Meijer HAW, Graafland M, Obdeijn MC, Van Dieren S, Goslings JC, Schijven MP. Serious game versus standard care for rehabilitation after distal radius fractures: a protocol for a multicentrerandomised controlled trial. BMJ Open. 2021 Mar;11(3):e042629. https://doi.org/10.1136/bmjopen-2020-042629.

[10] Aguilar-Lazcano CA, Rechy-Ramirez EJ, Hu H, Rios-Figueroa HV, Marin-Hernandez A. Interaction Modalities Used on Serious Games for Upper Limb Rehabilitation: A Systematic Review. Games Health J. 2019 Oct 1;8(5):313–25. https://doi.org/10.1089/g4h.2018.0129.

[11] Waliño-Paniagua CN, Gómez-Calero C, Jiménez-Trujillo MI, Aguirre-Tejedor L, Bermejo-Franco A, Ortiz-Gutiérrez RM, et al. Effects of a Game-Based Virtual Reality Video Capture Training Program Plus Occupational Therapy on Manual Dexterity in Patients with Multiple Sclerosis: A Randomized Controlled Trial. J Healthc Eng. 2019 Apr 22;2019:1–7. https://doi.org/10.1155/2019/9780587.

[12] Arman N, Tarakci E, Tarakci D, Kasapcopur O. Effects of Video Games–Based Task-Oriented Activity Training (Xbox 360 Kinect) on Activity Performance and Participation in Patients With Juvenile Idiopathic Arthritis: A Randomized Clinical Trial. Am J Phys Med Rehabil. 2019 Mar;98(3):174–81. https://doi.org/10.1097/PHM.0000000000001001.

[13] Wu YT, Chen KH, Ban SL, Tung KY, Chen LR. Evaluation of leap motion control for hand rehabilitation in burn patients: An experience in the dust explosion disaster in Formosa Fun Coast. Burns. 2019 Feb;45(1):157–64. https://doi.org/10.1016/j.burns.2018.08.001.

[14] Tarakci E, Arman N, Tarakci D, Kasapcopur O. Leap Motion Controller–based training for upper extremity rehabilitation in children and adolescents with physical disabilities: A randomized controlled trial. J Hand Ther. 2020 Apr;33(2):220-228.e1. https://doi.org/10.1016/j.jht.2019.03.012.

[15] Ayed I, Ghazel A, Jaume-i-Capó A, Moyà-Alcover G, Varona J, Martínez-Bueso P. Vision-based serious games and virtual reality systems for motor rehabilitation: A review geared toward a research methodology. Int J Med Inf. 2019 Nov;131:103909. https://doi.org/10.1016/j.ijmedinf.2019.06.016.

[16] Impact Of Immersive Virtual Reality-Based Rehabilitation On Functional Independence And Health Related Quality Of Life After Distal Radius Fracture: A Study Protocol For A Single Blinded Randomized Control Trial. J Crit Rev [Internet]. 2020 Jun 2 [Cited 2024 Oct 13];7(09). Available from: http://www.jcreview.com/index.php?fulltxt=112217&fulltxtj=197&fulltxtp=197-1591168631.pdf.https://doi.org/10.31838/jcr.07.09.111.

[17] Pereira MF, Prahm C, Kolbenschlag J, Oliveira E, Rodrigues NF. Application of AR and VR in hand rehabilitation: A systematic review. J Biomed Inform. 2020 Nov;111:103584. https://doi.org/10.1016/j.jbi.2020.103584.

[18] Suero-Pineda A, Oliva-Pascual-Vaca Á, Durán MRP, Sánchez-Laulhé PR, García-Frasquet MÁ, Blanquero J. Effectiveness of a Telerehabilitation Evidence-Based Tablet App for Rehabilitation in Traumatic Bone and Soft Tissue Injuries of the Hand, Wrist, and Fingers. Arch Phys Med Rehabil. 2023 Jun;104(6):932–41. https://doi.org/10.1016/j.apmr.2023.01.016.

[19] Then JW, Shivdas S, Tunku Ahmad Yahaya TS, Ab Razak NI, Choo PT. Gamification in rehabilitation of metacarpal fracture using cost-effective end-user device: A randomized controlled trial. J Hand Ther. 2020 Apr;33(2):235–42. https://doi.org/10.1016/j.jht.2020.03.029.

[20] Rodríguez-Hernández M, Polonio-López B, Corregidor-Sánchez AI, Martín-Conty JL, Mohedano-Moriano A, Criado-Álvarez JJ. Can specific virtual reality combined with conventional rehabilitation improve poststroke hand motor function? A randomized clinical trial. J NeuroEngineeringRehabil. 2023 Apr 4;20(1):38. https://doi.org/10.1186/s12984-023-01170-3.

[21] Rutkowski S, Kiper P, Cacciante L, Cieślik B, Mazurek J, Turolla A, et al. Use of virtual reality-based training in different fields of rehabilitation: A systematic review and meta-analysis. J Rehabil Med. 2020;52(11):jrm00121. https://doi.org/10.2340/16501977-2755.

[22] Fareh R, Elsabe A, Baziyad M, Kawser T, Brahmi B, Rahman MH. Will Your Next Therapist Be a Robot?—A Review of the Advancements in Robotic Upper Extremity Rehabilitation. Sensors. 2023 May 25;23(11):5054. https://doi.org/10.3390/s23115054.

[23] Vo Duy C. Design and development of a wrist rehabilitation device with an interactive game. Results Eng. 2024 Jun;22:102336. https://doi.org/10.1016/j.rineng.2024.102336.

[24] Thakre VM, Phansopkar P. Implementation of a Robotic Hand Glove in the Physiotherapy Treatment of Carpal Tunnel Syndrome Secondary to Volar Barton Fracture: A Case Report. Cureus [Internet]. 2024 Mar 2 [cited 2024 Oct 13]; Available from: https://www.cureus.com/articles/233716-implementation-of-a-robotic-hand-glove-in-the-physiotherapy-treatment-of-carpal-tunnel-syndrome-secondary-to-volar-barton-fracture-a-case-report.https://doi.org/10.7759/cureus.55402.

[25] Aggogeri F, Mikolajczyk T, O'Kane J. Robotics for rehabilitation of hand movement in stroke survivors. Adv Mech Eng. 2019 Apr;11(4):1687814019841921. https://doi.org/10.1177/1687814019841921.

[26] Jimbu D, Cristea AE, Iliescu DM, Oprea D, Iliescu MG, Caraban BM, et al. The importance of advanced technologies in functional rehabilitation of the hand. Balneo PRM Res J. 2024 Mar 31;15(Vol.15, 1):664–664. https://doi.org/10.12680/balneo.2024.664.

[27] Cancio JM, Sgromolo NM, Rhee PC. Blood Flow Restriction Therapy after Closed Treatment of Distal Radius Fractures. J Wrist Surg. 2019 Aug;08(04):288–94. https://doi.org/10.1055/s-0039-1685455.

[28] Fan Y, Bai D, Cheng C, Tian G. The effectiveness and safety of blood flow restriction training for the post-operation treatment of distal radius fracture. Ann Med. 2023 Dec 12;55(2):2240329. https://doi.org/10.1080/07853890.2023.2240329.

[29] Sgromolo NM, Cancio JM, Rhee PC. Safety and Efficacy of Blood Flow Restriction Therapy after Operative Management of Distal Radius Fractures: A Randomized Controlled Study. J Wrist Surg. 2020 Aug;09(04):345–52. https://doi.org/10.1055/s-0040-1712504.

[30] Yun DE, Kim MK. Effects of mirror therapy on muscle activity, muscle tone, pain, and function in patients with mutilating injuries: A randomized controlled trial. Medicine (Baltimore). 2019 Apr;98(17):e15157. https://doi.org/10.1097/MD.0000000000015157.
[31] Tofani M, Santecchia L, Conte A, Berardi A, Galeoto G, Sogos C, et al. Effects of Mirror Neurons-Based Rehabilitation Techniques in Hand Injuries: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2022 May 2;19(9):5526. . https://doi.org/10.3390/ijerph19095526.