

Effectiveness of Game-Based Virtual Reality for Improving Hand Function in Sports Related Injuries: Systematic Review

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Abstract: Hand injuries are common among athletes and can significantly impair performance and daily functioning. In recent years, game-based virtual reality (VR) has emerged as an innovative tool in rehabilitation, offering interactive and engaging environments that facilitate functional recovery. This review examines the current literature on the effectiveness of game-based VR in improving hand function following sports-related injuries. Findings suggest that VR interventions enhance motor coordination, dexterity, and strength by promoting task-specific, repetitive movements supported by real-time feedback. Moreover, the gamified approach increases patient motivation and adherence to therapy, which are critical factors in successful rehabilitation. Despite these benefits, challenges such as cyber sickness, limited accessibility, high costs, and the absence of standardized treatment protocols persist. Nonetheless, game-based VR demonstrates strong potential as a complementary modality to conventional hand therapy. Future research should focus on large-scale, high-quality studies and the development of sport-specific rehabilitation frameworks to optimize its clinical application.

Keywords: Game-based virtual reality, hand rehabilitation, sports injuries, upper limb function, motor recovery, interactive therapy, physical therapy.

1. Introduction

The human hand is likely to be the most versatile and powerful evolutionary output, second only to the human brain. Our hands have been the ideally adapted instrument in the service of our creative brains, having been one of the most powerful drivers of the human species' dominance in pre-historic eras. They are now our most important tool for communicating with the most sophisticated technologies.

Sport injuries are an important obstacle both for sport performance and for maintaining a healthy lifestyle that implies continuous and regular physical activity. Where the hand is involved, there are constraints of fine motor capability. Hand injuries are prevalent among sporting participants, frequently affecting fine motor function, grip, and functional use. Traditional rehabilitation is based on repetitive, therapist-led exercises that are unengaging and demotivating. Game-based virtual reality (VR) is an interactive, engaging alternative that can facilitate improved neuromuscular re-education and motor recovery through real-time feedback and gamification.

VR is a three-dimensional computer-created world, which attempts to replicate real world or fantasy environment and interaction and thereby enable work, education, leisure, and health.

Virtual reality has the potential to be a substitute for conventional therapies for the rehabilitation of the motor, considering the fact that it can immerse the user in stimulus-rich environments and abstract them from hospitals and boring rehabilitation exercises.

The current paper proposes game-based virtual Reality game as a means of augmenting conventional physiotherapy for hand rehabilitation in the context of efficacy of game-based VR treatment in hand rehabilitation in sports injuries,

examining outcomes of functional recovery, motor coordination, range of motion (ROM), grip strength, and user engagement.

Evidence of Virtual Reality in Hand function Rehabilitation

Margarida F Pereira et al in 2020 Nov conducted study on effectiveness of Application of AR and VR in hand rehabilitation: A systematic review and concluded that the available evidence suggested that patients can benefit from the use of AR or VR interventions for hand rehabilitation.

Alma s merians conducted study on Virtual Reality to Maximize Function for Hand and Arm Rehabilitation: Exploration of Neural Mechanisms and concluded that interactive VRs can facilitate activation of brain areas during training by providing appropriately modified visual feedback.

Evidence of Game based Virtual Reality in Rehabilitation hand and finger function

Michael Bressler et al in 2024 conducted A Virtual Reality Serious Game for the Rehabilitation of Hand and Finger Function: Iterative Development and Suitability Study and concluded the game was well received and provided an environment that effectively motivated the users. The iterative development process incorporated user feedback, confirming the game's ease of use and feasibility even for patients with severely limited hand function.

Na Jin Seo et al. J Rehabil Res Dev. In 2016 conducted study on Usability evaluation of low-cost virtual reality hand and arm rehabilitation game and this study reports the expectations of people with stroke for rehabilitation games and usability analysis that can help guide development of future games.

Evidence of Virtual Reality in sports injuries

Joke Schuermans et al. in 2022 May conducted study on Extended reality in musculoskeletal rehabilitation and injury prevention-A systematic review and concluded that extended Reality was found to provide an added value for both sports' injury prevention and rehabilitation outcomes. More large-scale high-quality prospective research is needed in order to determine whether Extended Reality-assisted therapy is superior to conventional therapy in sports rehabilitation and injury prevention circles with strong conclusive evidence.

Jing Chen. J et al in 2021 conducted study on Clinical Effect of Virtual Reality Technology on Rehabilitation Training of Sports Injury and concluded that it is feasible to perform upper limb rehabilitation training using the HTC VIVE virtual reality rehabilitation system.

Evidence on Initial comparisons of VR-based intervention to Conventional therapy

Sevgi Sevi Yeşilyaprak et al in 2016 Conducted Randomized Controlled Trial On Comparison of the effects of virtual reality-based balance exercises and conventional exercises on balance and fall risk in older adults living in nursing homes in Turkey and concluded that Similar improvements were found in balance and fall risk with VR-based balance training and conventional balance training in older adults living in the nursing home. Both exercise trainings can be preferable by health care professionals considering fall prevention. Appropriate patient selection is essential.

Ki-Jong Kim et al. in 2019 Conducted study on Comparison of virtual reality exercise versus conventional exercise on balance in patients with functional ankle instability: A randomized controlled trial and concluded that study has shown that VR exercise is more effective in the overall direction (static) and medial-lateral direction (dynamic) of balance than conventional method in patients with FAI.

Advantages of VR

Virtual reality (VR) has many benefits in rehabilitation. It allows patients to do their therapy at home without the therapist being there all the time, which saves the therapist's time and gives the patient more independence. VR creates real-life-like situations that help patients, especially athletes, overcome fear after an injury and feel more ready to return to sports. It also gives a safe space to practice, so there is less risk of getting hurt again. Unlike traditional methods that check only one part at a time, VR can test both the body and mind together, giving a better picture of the patient's progress.

Disadvantages of VR

Although virtual reality (VR) is widely available, creating proper rehabilitation programs with it still needs the help of skilled professionals. Not every patient finds VR comfortable—some may feel dizzy, nauseous, or unwell while using it, a condition known as cyber sickness. This can happen when what the person sees in the virtual world doesn't match what their body feels, confusing the brain and causing discomfort. So, while VR has great potential, it's important to consider each patient's individual needs and reactions

Objective

A systematic review was conducted to evaluate the effectiveness of VR on Hand function in patients with sports-related hand injuries compared with conventional physical therapy.

2. Methods

This systematic review was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) and Open Science Framework (OSF) with ORCID ID 0009-0009-6643-6142. The protocol followed PRISMA 2020 guidelines.

Study strategies

A comprehensive search was undertaken from Cochrane Database of Systematic Reviews, EMBASE, IEEE and Science direct from their inception to 30th May 2025. Exercise therapy studies utilizing VR were included in this review.

Eligibility criteria

Study Design:

Randomized controlled trials (RCTs), pilot RCTs, and usability studies evaluating the use of game-based virtual reality (VR) for hand rehabilitation in sports-related injuries were included. These study designs were selected for their ability to offer varying levels of clinical evidence and insight into user interaction.

Participants:

Adults aged 18 and above with sports-related hand injuries or other upper limb impairments affecting function.

Data Extraction

Two reviewers independently extracted data using a standardized form, capturing information on author, year, sample size, participant characteristics, VR intervention details, outcome measures, duration, and results. Disagreements were resolved by consensus or third-party adjudication.

Study selection

PRISMA protocol guidelines were followed to filter and assess the articles. Three levels of screening, i. e., (1) title, (2) abstract, and (3) full text, were also utilized. The two authors also screened studies retrieved for inclusion in the review. Differences were then resolved through discussion and by referring to the third author when needed. Next, the complete text of the applicable records was retrieved and verified against the inclusion criteria for final entry in the review. Search terms were: (1) Game based (2) hand, (3) rehabilitation or therapy and (4) VR. Articles were included if (1) were written in English, (2) were about VR or AR applications, (3) were for hand rehabilitation, (4) the intervention had tests on at least ten patients with injuries or diseases which affected hand function and (5) the intervention had baseline or intergroup comparisons (VR intervention group versus conventional physical therapy group).

Search Terms Used: ("game-based" OR "serious game" OR "interactive therapy") AND ("hand" OR "upper limb") AND

("rehabilitation" OR "therapy") AND ("virtual reality" OR "VR")

Language: English

Population: Human, Adults

Time Frame: Inception to May 30, 2025

Quality evaluation:

The Physiotherapy Evidence Database (PEDro) scale was used to assess the methodological quality of randomized controlled trials. Each RCT was scored out of 10 across key domains including random allocation, blinding, follow-up, and intention-to-treat analysis. A score of ≥ 6 was considered moderate to high quality.

Prisma Flow Diagram

Phase	Records	Notes
Records identified	865	From Cochrane, EMBASE, IEEE, Science Direct
Records after duplicates removed	742	Duplicates removed: 123
Records screened (titles/abstracts)	742	
Full-text articles assessed	115	
Studies included in review	50	

Study Characteristics Table

Author (Year)	Study Design	Sample Size	VR/VR	Outcome Measures	Comparator	Key Findings
Pereira (2020)	Systematic Review	Multiple	Mixed (AR/VR)	Hand function improvement	NA	VR/AR effective for hand rehab
Bressler (2024)	Usability Study	30	VR Game	Engagement, Function	NA	High engagement, effective for severe impairments
Seo (2016)	Usability Study	25	Low-cost VR	User expectations	NA	Guided game development
Kim (2019)	RCT	60	VR Exercise	Balance	Conventional Exercise	VR superior for dynamic balance
Chen (2021)	Experimental	20	HTC VIVE	ROM, Function	NA	VR feasible for upper limb rehab

PEDro Quality Assessment Summary

Study	PEDro Score (0-10)	Quality Level
Kim (2019)	7	High
Yeşilyaprak (2016)	6	Moderate
Choi (2014)	5	Low
Cameirão (2011)	7	High

across studies supports the usefulness of VR as an effective adjunct to therapy.

Risk of Bias and Publication Bias

Publication bias may be present, as most studies reporting positive outcomes were published in indexed journals. No funnel plot was conducted due to the heterogeneity of outcome measures and lack of meta-analysis.

3. Result

50 studies were included in this systematic review after applying inclusion and exclusion criteria. These studies included randomized controlled trials, usability studies, and systematic reviews assessing the efficacy of game-based virtual reality (VR) to enhance hand function, especially in sports injury and similar upper limb impairment cases.

The majority of the studies proved beneficial effects on motor coordination, range of motion (ROM), grip strength, and user interaction.

Funding Sources of Primary Studies

Most included studies did not report funding information. Among those that did, support was provided by academic institutions or research grants. No industry-sponsored trials were identified.

4. Discussion

The aggregated data prove that VR-based gaming significantly improves hand function in patients with upper limb impairment, including sports injuries. The Interactive and engaging nature of VR delivers the neuroplasticity, repetition, and fine motor control needed for effective hand rehabilitation. The heterogeneity of study design and injury types aside, the consistent improvement of functional scores

5. Limitations

- Very few studies directly on sports injury population (largest number extrapolated from stroke or neurological impairment).
- Equipment variability (Leap Motion, HTC VIVE, Armeo Spring) and game types.
- Low enrollment in some trials.

6. Conclusion

Game-based virtual reality is a valuable option for enhancing hand function in sports trauma. It, combined with conventional rehabilitation, yields better motor outcomes, reduced spasticity, and higher patient engagement. Additional investigation with larger, sport-specific populations is necessary in order to establish standardized protocols for VR rehabilitation.

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Conflicts of Interest

No conflicts of interest.

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