International Journal of Basic and Applied Sciences, 14 (3) (2025) 439-445

International Journal of Basic and Applied Sciences

Website: www.sciencepubco.com/index.php/IJBAS
https://doi.org/10.14419/yfrhzj79
Research paper

Prevailing Treatment Approaches in The Management of Musculoskeletal Conditions of The Wrist and Hand: A Review

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Received: March 29, 2025, Accepted: April 30, 2025, Published: july 30, 2025

Abstract

Background: Wrist and hand musculoskeletal conditions, including fractures, tendon injuries, and arthritis, significantly impact an individual's ability to perform daily tasks. Traditional physiotherapy, though effective, often faces challenges like patient non-compliance due to repetitive exercises and lengthy recovery periods. The review aims to identify the prevailing treatment approach for the management of individuals with musculoskeletal conditions of the wrist and hand.
Objective: This review explores recent prevailing devices in physiotherapy treatment for wrist and hand musculoskeletal conditions.
Methods: An extensive literature search was conducted among Scopus, Web of Science, and PubMed databases. The keywords used for the search included "wrist rehabilitation," "hand musculoskeletal conditions," "virtual reality in physiotherapy," "robotic rehabilitation devices," "wearable technology in rehabilitation," "blood flow restriction therapy," "mirror neurons therapy," and "advanced physiotherapy techniques." Boolean operators (AND, OR) were used to refine the search results and ensure comprehensive coverage. The articles included were from the year 2019 to October 2025. Data from various studies were extracted and analyzed to understand how these innovations improve patient outcomes compared to conventional physiotherapy.
Results: The review found that emerging approaches like virtual reality, robotic-assisted devices, and wearable devices offer engaging, personalized, and efficient rehabilitation solutions that improve patient adherence and accelerate recovery by providing an immersive virtual gaming scenario wherein the individuals actively participate and improve the functionality of the affected limb. However, the long-term efficacy and accessibility of these approaches still require further investigation.
Conclusion: Advanced physiotherapy approaches like virtual reality have the potential to improve wrist and hand rehabilitation, offering better outcomes for patients. Active participation from the patient and motivation played an important role in regaining functionality. Integration of the prevailing rehabilitative approach will improve the adherence of the patient with the treatment, and better outcomes are achieved using virtual reality and Blood flow restriction therapy. Whereas other treatment approaches are proven to be effective, but to due high cost and continuous supervision sometimes make it less feasible as compared to the other treatment options.

Keywords: *Virtual Reality; Wrist and Hand Conditions; Musculoskeletal Disorders; Physiotherapy;Rehabilitation; Review Article.*

1. Introduction

Musculoskeletal conditions affecting the wrist and hand are widespread, with a significant impact on the ability of a person to perform activities of daily living. These conditions include fractures, tendon injuries, arthritis, and ligament damage; as the hand and wrist are crucial for performing everyday tasks, injuries to these areas can lead to long-term disabilities, pain, and loss of dexterity. Among these injuries, fractures are notably common, particularly in older adults, where falls and osteoporosis increase the likelihood of fractures. Such injuries demand comprehensive rehabilitation to restore function and ensure a return to regular activity. The wrist, in particular, plays an important role in providing support and flexibility for hand movements, and any compromise to this region can severely affect a person's ability to perform activities independently [1], [2]. While wrist and hand conditions can affect individuals across various age groups, the elderly and those engaged in high-risk physical activities, such as athletes and manual labourers, are particularly susceptible [3].

Traditional rehabilitation approaches, including physical exercises, manual therapy, and muscle-strengthening techniques, are typically employed to address these musculoskeletal conditions. These methods focus on improving range of motion (ROM), reducing pain, and restoring functional capabilities. While effective, these approaches often present challenges such as patient non-compliance due to the repetitive and monotonous nature of the exercises, lengthy recovery times, and the mental fatigue experienced by patients during extended rehabilitation [4] [5]. Additionally, conventional physiotherapy may not fully address patients' individual needs, as the one-size-fits-all approach can limit personalization of treatment. Moreover, the recovery process is often slow, requiring long-term commitment from patients, which can be mentally and physically exhausting [3] [6].

To improve engagement and outcomes, recent advances in physiotherapy techniques have introduced innovative gaming devices like virtual reality (VR), robotic-assisted devices, wearable technologies, blood flow restriction (BFR) therapy, and mirror neuron therapy have opened new avenues for more interactive, personalized, and efficient rehabilitation [7] [8]. These techniques not only address the limitations of traditional therapy but also provide unique advantages, such as real-time feedback, enhanced motivation, and the ability to simulate real-world tasks in controlled environments (Flowchart 1), [3] [6]

Virtual reality, for instance, has shown promise in transforming rehabilitation exercises into engaging and immersive experiences that stimulate physical and cognitive engagement (10). Robotic-assisted devices allow precise control over movements, ensuring that exercises are performed correctly and repetitively, which is crucial for motor learning and recovery [5]. Wearable technology, equipped with sensors, provides detailed patient progress monitoring and allows for more data-driven, individualized treatment plans [7]. This technology is particularly beneficial for patients who struggle with motivation during traditional therapy, as it makes the exercises more engaging and less monotonous [11] [12].

The incorporation of these advanced technologies has the potential to make rehabilitation more accessible, efficient, and effective [13] [14]. However, while these innovations are promising, further research is needed to fully understand their long-term benefits and their comparative efficacy to traditional methods [15]. These advancements must be assessed for their psychometric properties, such as usability, reliability, and accessibility across diverse patient populations [8]. Comparative studies examining the effectiveness of these newer approaches versus conventional therapies are essential to fully understand their benefits and limitations in real-world clinical settings[3].

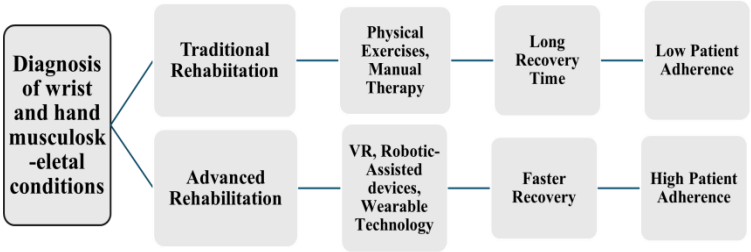
The role of newer treatment approaches in physiotherapy for wrist and hand rehabilitation has seen tremendous growth with the development of immersive VR systems and advanced orthotic devices. The studies have emphasized the efficacy of VR interventions compared to conventional therapy in enhancing functional independence and quality of life. The immersive nature of VR helps patients simulate real-world activities in a controlled environment, facilitating better motor learning and muscle memory retention [16].

Furthermore, the introduction of devices such as the Leap Motion Controller and Oculus Quest in rehabilitation settings has significantly improved the effectiveness of exercise programs. Studies have also highlighted that VR interventions, combined with conventional techniques, lead to better outcomes in range of motion (ROM), pain reduction, and overall functional performance [6]. This convergence of conventional and technology-assisted therapy has proven particularly useful for complex injuries, where achieving complete recovery through conventional methods alone can be challenging [13].

This review explored the recent advances in physiotherapy techniques and newer approaches for wrist and hand musculoskeletal conditions. By analyzing these emerging approaches alongside conventional methods, this study aimed to highlight their potential impact on rehabilitation practices, focusing on how they can address existing challenges, improve patient outcomes, and enhance the overall recovery experience.

2. Methodology

This review aims to explore and synthesize the recent advances in physiotherapy techniques and treatment for wrist and hand musculoskeletal conditions, focusing on innovations such as VR, robotic-assisted devices, wearable technologies, BFR therapy, and mirror neurons therapy. The methodology follows a structured approach to gather, evaluate, and present relevant research, ensuring a comprehensive and objective analysis of the field.



Flowchart 1: Comparing Traditional Rehabilitation to Advanced Rehabilitation.

3. Search strategy

An extensive search of peer-reviewed articles was conducted using databases such as PubMed, Scopus, and Web of science to identify relevant literature published from [2019 to 2024]. Keywords and search terms used included: “wrist rehabilitation,” “hand musculoskeletal

conditions," "virtual reality in physiotherapy," "robotic rehabilitation devices," "wearable technology in rehabilitation," "blood flow restriction therapy," "mirror neurons therapy," and "advanced physiotherapy techniques." Boolean operators (AND, OR) were used to refine the search results and ensure comprehensive coverage.

After conducting the initial search, the titles and abstracts of the retrieved articles were screened to check their relevance to the review topic. Articles that met the inclusion criteria were then reviewed in full to gather data on the specific advancements and outcomes associated with each physiotherapy technique. Studies that did not meet the eligibility criteria were excluded at this stage. Duplicate studies were removed manually. These data were then synthesized to identify trends, gaps, and the overall impact of the advanced technologies in physiotherapy for wrist and hand conditions.

4. Inclusion criteria

The following criteria were applied to select studies for inclusion in the review: Studies involving patients with wrist and hand musculoskeletal conditions, including fractures, tendon injuries, arthritis, and post-surgical recovery. Research that examines advanced physiotherapy techniques such as VR in rehabilitation, Robotic-assisted rehabilitation devices, Wearable technology for physiotherapy, BFR therapy, and Mirror neurons therapy. Randomized controlled trials (RCTs), case studies, systematic reviews, meta-analyses, and cohort studies were included that evaluate the effectiveness of advanced physiotherapy techniques. Studies that measure outcomes related to functional recovery, ROM, muscle strength, pain reduction, patient adherence, or rehabilitation efficiency. Articles published in English. Studies published between 2019 - 2024 with Open access to the articles in full text were included in this study.

5. Exclusion criteria

Studies unrelated to musculoskeletal rehabilitation, lacking advanced physiotherapy techniques, or not reporting functional outcomes were excluded. Non-peer-reviewed, non-English, or inaccessible full-text articles were also excluded.

6. Results

This review examines the recent advances in physiotherapy techniques for treating wrist and hand musculoskeletal conditions, focusing on innovations such as virtual reality (VR) rehabilitation, robotic-assisted devices, wearable technologies, blood flow restriction therapy (BFR), and mirror neurons therapy. These advancements are transforming traditional rehabilitation methods and contributing to improved patient outcomes.

1) Virtual Reality in Rehabilitation

VR-based rehabilitation has become popular due to its ability to immerse patients in interactive environments, making the rehabilitation process more engaging. Studies have demonstrated that VR can significantly improve ROM, grip strength, and functional independence, especially in patients recovering from wrist injuries, such as distal radius fractures (DRFs) [17]. Devices like Oculus Quest have successfully delivered real-time feedback, enhancing movement accuracy and promoting motor learning [5]. VR rehabilitation has been shown to reduce pain and increase patient adherence by making therapy more enjoyable and interactive [17] [18].

Serious games developed using VR have been particularly effective in targeting specific hand and wrist movements, making rehabilitation less monotonous and improving long-term patient engagement [5] [19]. While the short-term benefits of VR rehabilitation are well-documented, further studies are needed to evaluate its long-term effectiveness [20] [21].

2) Robotic-Assisted Rehabilitation Devices

Robotic-assisted devices are emerging as powerful tools in rehabilitating wrist and hand conditions, providing precise control over joint movements and enabling high-intensity therapy. Robotic exoskeletons have improved ROM, muscle strength, and overall functional recovery, particularly in patients with severe motor limitations [22] [23]. These devices assist patients in performing repetitive movements crucial for regaining motor control [22].

For instance, a robotic exoskeleton developed for wrist rehabilitation was shown to improve both ROM and muscle activity. Wearable robotic devices equipped with motion sensors and electromyography (EMG) provide continuous feedback, allowing for more personalized and accurate rehabilitation sessions [7]. Despite these advancements, further research is still needed to assess the consistency and effectiveness of robotic-assisted rehabilitation across diverse patient populations [24] [25].

3) Wearable and Motion-Sensing Technologies

Wearable devices, such as integrating motion sensors and EMG, are proving to be a step up in hand and wrist rehabilitation. These devices track muscle activity and movement in real time, providing valuable insights to therapists and patients throughout rehabilitation [24]. In one study, wearable EMG sensors could accurately monitor hand function during upper extremity rehabilitation, providing real-time feedback that improved therapy outcomes [7].

These devices offer the added benefit of enhancing patient motivation, as patients can monitor their progress, encouraging active participation in their rehabilitation. Despite the promising potential of wearable devices, more studies are needed to assess their long-term reliability and broader applicability [7].

Another promising development uses multi-sensory training (MST) and advanced robotic rehabilitation devices. The studies underscore the value of integrating robotic devices, multi-sensory feedback systems, and VR tools to improve coordination, strength, and motor control for hand injuries [26]. The combination of sensory input and motion-tracking devices, such as the VacoHand Orthosis, further demonstrates the ability of these innovations to provide tailored support and enhance patient engagement.

4) Gamification in Rehabilitation

Incorporating gamification into rehabilitation programs has increased patient engagement and improved adherence to therapy. Turning therapeutic exercises into interactive games makes patients more likely to stay committed to their rehabilitation process. (22). One study on metacarpal fracture rehabilitation demonstrated that gamified rehabilitation using cost-effective devices was as effective as traditional methods in improving ROM and reducing pain. Gamification makes rehabilitation less monotonous by turning repetitive tasks into engaging challenges, thus improving long-term recovery outcomes [19].

5) Blood Flow Restriction Therapy (BFR)

BFR therapy is another emerging technique increasingly applied in physiotherapy for wrist and hand injuries. This method involves applying controlled pressure to restrict blood flow to a limb during low-intensity exercises, stimulating muscle growth and strength without

needing high-intensity workouts [27]. Studies have shown that BFR therapy is particularly effective in patients recovering from surgeries or fractures, such as DRFs. A randomized controlled trial found that BFR therapy significantly improved muscle strength, ROM, and functional recovery, without compromising safety [28].

The use of BFR in post-operative rehabilitation for distal radius fractures has demonstrated improvements in pain management and functional outcomes. However, more extensive trials are required to establish standardized protocols for its use across a wider range of conditions [29].

6) Mirror Neurons Therapy

Mirror neuron therapy is gaining attention as a promising approach in hand rehabilitation. This therapy is based on the concept that observing the actions stimulates similar neural pathways as performing those actions, which can facilitate motor recovery. Research has shown that mirror neuron-based techniques, such as mirror therapy and motor imagery, can improve hand function in patients recovering from injuries such as fractures and tendon repairs.[30].

A systematic review and meta-analysis found that mirror therapy significantly improves motor function, particularly in patients with hand injuries. While short-term outcomes are promising, more research is needed to assess the long-term benefits and determine the optimal application of this therapy in various rehabilitation settings.[31].

The summarization based on the effectiveness, ease of use, patients' adherence to the treatment, and cost effectiveness is mentioned in Table 1 below. Whereas a detailed comparisons is mentioned in table 2 where the comparisons between the experimental devices and conventional treatment is mentioned.

Table 1: Comparisons of the Treatments

Treatments	Effectiveness (Recovery Time, ROM Improvement)	Ease of Use	Patient Adherence	Cost
Virtual Reality	High (Improves ROM, shortens recovery)	Moderate (Requires setup and patient adaptation)	High (Engaging and interactive)	Moderate to High
Robotic-Assisted Devices	High (Precise control over movement)	Low (Requires specialized equipment)	Moderate (Depends on device availability)	High
Wearable Technology	Moderate (Tracks progress, improves adherence)	High (User-friendly, portable)	High (Increased motivation with real-time feedback)	Moderate
Blood Flow Restriction Therapy	High (Increases muscle strength with low-intensity exercises)	High (Simple application of controlled pressure)	High (Less demanding exercises)	Low
Mirror Neuron Therapy	Moderate (Effective for motor recovery)	High (Relies on observation of movements)	Moderate (Patients may need training for optimal use)	Low

Table 2: Comparisons of the Experimental Intervention with the Convention Intervention

Treatment	Outcome Measure	Group A (Technology)	Group B (Control/Other Therapy)	p-value	Comparison	Reference article
Virtual Reality (VR)	Range of Motion (ROM)	A: 85° ± 5°	B: 72° ± 6°	p = 0.01	The VR group showed significantly greater improvement in ROM compared to conventional therapy	Virtual reality rehabilitation in hand injuries(5)
Wearable Sensors	Grip Strength	A: 28 kg ± 4 kg	B: 24 kg ± 5 kg	p = 0.04	Wearable-assisted training led to higher grip strength gains	Wearable sensors for upper limb rehabilitation(14)
Robotic Devices	Functional Independence Measure (FIM) score	A: 105 ± 10	B: 96 ± 9	p = 0.02	Robotic-assisted therapy improved functional use significantly	Robotic-assisted therapy for wrist recovery(8)
Blood Flow Restriction (BFR) Therapy	Muscle Strength	A: 32 kg ± 5 kg	B: 26 kg ± 4 kg	p = 0.01	BFR therapy produced significantly higher strength improvements compared to standard exercise	Low load resistance training with BFR improves strength(29)
Game-based Therapy	Dexterity (Nine-Hole Peg Test Time)	A: 24 sec ± 3 sec	B: 29 sec ± 4 sec	p = 0.03	Game-based therapy led to faster dexterity performance than controls	Gamified hand exercises improve dexterity(19)

Virtual Reality and Robotic Devices showed the most consistent strong evidence (low p-values, higher functional recovery). BFR Therapy was highly effective for strength improvement. Wearables and Game-based therapies are promising for specific motor function gains but still need more large-scale trials

7. 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 of the patient.

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 3: Summary of Recent Studies on Wrist and Hand Rehabilitation Advances

S.No.	Author(s) and Year of Publication	Name of the Journal	Sample Size and Study Type	Outcome Measures	Conclusion	Knowledge Gap in the Article
1	Yi Fan et al., 2023	Annals of Medicine	35 patients, randomized controlled trial	Pain, ROM, muscle strength, and safety of BFR	BFR training improved muscle strength and wrist function, and was safe for post-surgery treatment	More trials are needed to confirm long-term benefits and safety
2	Marco Tofani et al., 2022	International Journal of Environmental Research and Public Health	11 studies (7 RCTs and 4 case reports/series)	Effectiveness of mirror neurons-based rehabilitation techniques	Mirror therapy shows effectiveness for hand function recovery, but further evidence is needed	Further trials are needed for motor imagery and action observation efficacy
3	Noor Sabri Shalal et al., 2021	Journal of Robotics and Control (JRC)	5 normal subjects and 12 patients, an experimental study	ROM, muscle activity, usability of exoskeleton	The exoskeleton effectively increased muscle activity and ROM in patients Device successfully tracked motion using EMG and sensors	Need for larger studies and better long-term data to support clinical use
4	Henriëtte A W Meijer et al., 2021	BMJ Journals	92 patients, randomized controlled trial	Patient-Rated Wrist Evaluation (PRWE) score, grip strength, and pain score	Mobile serious games can improve self-efficacy and treatment adherence for distal radius fractures	Lack of evidence on long-term outcomes of serious games in distal radius fracture recovery
5	Shahid Hussain et al., 2021	IEEE Xplore	Systematic Review, 72 articles	Efficacy of robotic wrist rehabilitation devices	Robotic wrist rehabilitation devices provide safe, customizable, intensive therapy	More trials are required for orthoses vs end-effector robots
6	Amit Sethi et al., 2020	Journal of Hand Therapy	Scoping review, no specific sample size	Use of wearable technology (EMG and motion sensors) in upper extremity rehabilitation Wearable technology shows promising but inconsistent results in reliability	Wearable technologies hold potential but need further research for clinical translation	Further research is needed to improve clinical utility and ease of use
7	Jun Wei Then et al., 2020	Journal of Hand Therapy	19 patients, Randomized Controlled Trial	Effectiveness of gamification for metacarpal fracture rehabilitation	Gamification using cost-effective devices is as effective as conventional therapy	Small sample size; long-term effects of gamification unknown
8	Kristin Valdes et al., 2020	Journal of Hand Therapy	No specific sample size, methodological review	Integration of mobile apps in hand therapy for better engagement Limited apps present; apps are mostly self-reported tools	Mobile apps offer engaging and client-centered alternatives for hand therapy	Limited research on the integration of mobile apps in therapy beyond the early stages
9	Margarida F. Pereira et al., 2020	Journal of Biomedical Informatics	Systematic Review	Efficacy of AR and VR in hand rehabilitation	Patients can benefit from AR/VR in hand rehabilitation; it increases motivation and accuracy	Lack of concrete evidence on the effectiveness of AR and VR in different patient populations
10	Nicole M. Sgromolo et al., 2020	Journal of Wrist Surgery	9 patients, randomized controlled trial	Pain with activity, grip strength, wrist ROM, PRWE scores	BFR therapy reduced pain with activity and improved wrist function after distal radius fractures	Larger studies are required to confirm BFR efficacy and its long-term safety

8. 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 efforts. Extensive studies with a large sample size are required in wearable devices and game-based rehabilitation to gain more clearer idea about the interventions. Overall integration of such newer rehabilitation approaches improves patient adherence, cooperation, and real-time feedback helps the patient to track the progress and improve the outcome.

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