Review Article

Current Notion on Virtual Reality Rehabilitation Approach on Post Operative Lower Extremity Conditions: A Narrative Review

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Abstract

Background: Lower extremity surgeries, such as total knee arthroplasty (TKA), total hip arthroplasty (THA), and anterior cruciate ligament (ACL) reconstruction, require extensive rehabilitation to restore mobility and function. Traditional rehabilitation faces challenges such as patient adherence and access to care. Virtual reality (VR) has emerged as a promising tool to enhance rehabilitation outcomes by offering interactive, engaging environments that improve patient motivation.

Methods: A narrative review was conducted to evaluate the current literature on VR-based rehabilitation for post-operative lower extremity conditions. Relevant studiesfrom 2019 to 2024were selected from databases such as PubMed, Scopus, and Cochrane, focusing on VR's application in patients recovering from TKA, THA, ACL reconstruction, and traumatic lower limb amputations.

Results: The review found that VR interventions significantly improved proprioception, balance, and patient engagement compared to traditional rehabilitation methods. VR's interactive nature provided real-time feedback and enhanced patient motivation. However, mixed results were reported regarding VR's superiority in pain management and overall functional outcomes. VR was shown to complement traditional therapy rather than replace it.

Conclusion: VR-based rehabilitation offers a promising adjunct to traditional methods, improving patient engagement and specific functional outcomes. While VR enhances recovery, further research is needed to establish standardized protocols and determine its long-term efficacy in post-operative rehabilitation.
Keywords: Virtual reality, Rehabilitation, Lower Limb arthroplasty, Lower limb soft tissue injuries

Introduction

Lower extremity surgeries, such as those for joint replacements, anterior cruciate ligament reconstruction, represent a significant portion of orthopedic interventions worldwide. These surgeries are often necessary due to degenerative conditions like osteoarthritis or traumatic injuries that impair mobility, lead to chronic pain, and significantly reduce the quality of life of affected individuals. For instance, total knee arthroplasty (TKA) is one of the most common procedures performed globally, with more than 500,000 knee replacements carried out annually in countries like the United States(1). Similarly, anterior cruciate ligament (ACL) injuries, prevalent in athletes, are treated with reconstructive surgeries, which have a notable impact on patients' return to pre-injury functional levels(2). total hip arthroplasty (THA) alone has seen a 55% increase in the last decade(3). These surgeries aim to restore mobility and improve the quality of life but often require extensive rehabilitation to regain strength, balance, and functional independence(4).

The burden of these surgeries is substantial, not only in terms of healthcare costs but also regarding the long-term rehabilitation needs of patients. The rehabilitation process after lower extremity surgeries is essential for pain management, regaining mobility, improving joint function, and enhancing the patient's quality of life(1,5,6). Effective rehabilitation is critical for restoring mobility and function post-surgery, with traditional physiotherapy methods often being the standard approach(7)

Rehabilitation following lower extremity surgeries typically involves a structured program of physical therapy aimed focusing on range of motion, strengthening, gait training, and balance improvemental enhancing joint mobility, strength, and overall functional performance (7–9). Despite their effectiveness, traditional rehabilitation approaches face challenges like limited access to consistent care, low patient adherence, and the need for supervised sessions(3,4). However, traditional rehabilitation approaches can be repetitive, lengthy, and mentally exhausting for patients, particularly those undergoing prolonged recovery phases like after ACL reconstruction, which may extend to six months or more(2). As a result, there is growing interest in integrating innovative rehabilitation techniques to enhance recovery outcomes and improve patient engagement.

The integration of virtual reality (VR) in rehabilitation has emerged as a promising solution to these challenges. VR-based rehabilitation involves the use of computer-generated environments that enable patients to engage in interactive tasks designed to improve physical function(1,10–12) while providing real-time feedback and help reduce the monotony of traditional exercises, increase patient motivation, and potentially improve compliance with rehabilitation programs(1,3,7,13–15). Virtual reality programs can help express real-world behavior by providing direct visual and auditory feedback in three-dimensional virtual space (i.e Immersive VR)(16,17). It can be classified as either immersive or non-immersive, depending on the user's degree of interaction with the virtual environment and the number of stimulated senses.(18)

Studies have shown that VR can improve gait, balance, prosthesis satisfaction, cadence, gait speed , especially in patients recovering from lower limb amputations and joint replacements(1,4,5,8,19). Numerous studies have highlighted the potential benefits of VR-based rehabilitation in improving clinical outcomes following lower extremity surgeries. For

example, VR interventions have been shown to enhance proprioception, reduce pain, kinesiophobia and reducing the risk of falls in patients who have undergone procedures like TKA (1,2,20,21). In patients recovering from ACL reconstruction, VR-assisted rehabilitation has demonstrated improvements in pain management, subjective knee function, and patient satisfaction(2). The incorporation of virtual reality demonstrated statistically significant variations in the functionality of patients with total hip replacement(22). Additionally VR provides real-time biofeedback, which enhances patients' awareness of their movements and facilitates more effective motor learning(1). Moreover, VR-based rehabilitation offers remote access, which can be beneficial in reducing the need for in-person sessions, making recovery more convenient for patients(3,13)

Despite the positive findings, it is important to note that the effectiveness of VR rehabilitation can vary depending on the specific surgical procedure and the type of VR system used(23). Some studies have found that while VR may improve certain aspects of recovery, such as proprioception and patient engagement, it may not always be superior to traditional rehabilitation in terms of pain relief or functional outcomes(1,5,24). However, when combined with conventional therapies, VR has been shown to offer significant advantages in terms of patient motivation and overall rehabilitation experience(1,2)

In conclusion, lower extremity surgeries are a significant burden on healthcare systems due to the prevalence of conditions like osteoarthritis and sports-related injuries. Rehabilitation is crucial for optimizing post-operative outcomes, and virtual reality-based approaches offer a promising avenue to enhance recovery, improve patient engagement, and address the limitations of traditional rehabilitation techniques. By integrating VR into standard rehabilitation protocols, there is potential for better functional recovery and an improved overall rehabilitation experience for patients.

Given the increasing interest in VR interventions in rehabilitation settings, this narrative review aims to explore the current landscape of VR applications for postoperative lower extremity conditions. By synthesizing existing literature on this topic, we hope to elucidate the potential benefits and limitations of VR rehabilitation and provide insights into its role in enhancing recovery outcomes for patients undergoing lower extremity surgeries.

Methodology

A comprehensive search was performed across several databases, including PubMed, Scopus, Web of Science, Cochrane, Medline, and the Physiotherapy Evidence Database (PEDro). This search utilized medical subject headings (MeSH) terms such as "Virtual rehabilitation," "Total hip arthroplasty," "Total knee arthroplasty," "Rehabilitation," "Physical Therapy," "Lower extremity surgery," and "Virtual reality training." The study encompassed relevant articles published from2019till September 2024. Filters were applied to ensure that only English-language articles involving human participants were included. The articles included were lower limb musculoskeletal conditions such as arthoplasty, soft tissue repaire, reconstruction, articles in which Virtual Reality was used as rehabilitation approach versus conventional physiotherapy and outcomes such as pain, range of motion, manual muscle testing and quality of life were selected from 2019 till september 2024.

Eligibility Criteria

The study focused exclusively on English-language randomized controlled trials that met the following criteria: (1) involved adults aged 18 years and older who had undergone lower extremity surgeries; (2) employed virtual reality rehabilitation techniques either as standalone treatments or as adjunct therapies; (3) compared various virtual reality programs or conventional physical therapy, placebo, or no intervention in the control group; and (4) utilized any outcome measures to evaluate the intervention's effects.

Articles were excluded if they: (1) included patients with neurological disorders or (2) applied virtual reality techniques for purposes other than post-surgical rehabilitation of lower extremities.
The full texts of the selected articles were subsequently analyzed, and data was extracted concerning sample size, study duration, virtual reality devices used, outcome measures, and conclusions drawn.

Discussion
This review focuses on current approaches to virtual reality (VR) in rehabilitation following lower extremity surgeries, highlighting the devices used, the nature of the interventions, and the associated clinical benefits.

1. Virtual Reality-Based Serious Games in Total Knee Replacement Rehabilitation (TKR) **(5)**
The type of VR Device used in this study is Non-immersive VR-based serious games (SGs) using the *Virtual Reality Rehabilitation System (VRRS)* developed by Khymeia Group.In this the patients recovering from total knee replacement (TKR) surgery stood on a VRRS balance board and participated in balance and proprioception exercises. The system provided real-time visual and auditory biofeedback, allowing patients to interact with their center of pressure (CoP) as part of serious game scenarios. The exercises gradually increased in difficulty.
The b**enefits of VR group showed s**ignificant improvement in within-group in balance control, gait parameters, and postural outcomes. Visual biofeedback effectively reduced patients' fear of movement and pain, enhancing motivation and engagement. Though VR-based training did not show superiority over traditional therapy in all clinical outcomes, it improved stance duration in the affected limb and showed physiological gait pattern normalization. Patients also showed increased proprioception, reduced fear of re-injury, and improved confidence in loading the operated limb.

2. VR in Rehabilitation for Traumatic Lower Limb Amputation**(13)**
The type of VR Device used in this study was unspecified, but a VR system was used to complement traditional rehabilitation. In this **approach** VR was added to a traditional rehabilitation program designed for traumatic lower limb amputees. Exercises were aimed at enhancing balance, gait, and overall mobility. Sessions were conducted three times a week for six weeks that focused on interactive movements in a simulated environment.
Significant improvements were observed in balance (measured by the Berg Balance Scale, BBS) and gait outcomes (Dynamic Gait Index, DGI, and Timed Up and Go, TUG test). VR demonstrated superior effectiveness in improving balance outcomes compared to traditional rehabilitation alone. It reduced fear of falls and improved patients' dynamic balance, with no significant difference in distance covered during the 6-minute walk test (6MWT) between the control and experimental groups. The use of VR was also found to be enjoyable and motivating, adding an element of fun to the otherwise monotonous exercises.

3. Exergame Training in Unilateral Transtibial Amputation (25)
In this study the device used is Xbox Kinect, with games such as Reflex Ridge and River Rush. This study included Interactive exergames supplemented with traditional exercises, focusing on balance, speed, and postural control. Intervention Exergame (EG) Group: had 30 minutes of exergames per session targeting postural control, balance, and dynamic movements. Supplemented by conventional exercises like weight-shifting, obstacle walking, and stair climbing. Whereas Control Group: Focused solely on traditional exercises with extra sets to match the intervention time of the EG group. Outcome Measures were Timed Up and Go Test

(TUG), 2-Minute Walk Test (2MWT), Amputee Mobility Predictor with Prosthesis (AMPPRO) and Physiological Cost Index (PCI)

Benefits were Improved Mobility: The EG group showed a statistically significant improvement in movement speed as measured by the TUG test ($P = 0.04$), Increased Walking Distance: Both groups improved significantly in the 2MWT ($P < 0.001$), Enhanced Functional Mobility: AMPPRO scores improved significantly in both groups, reflecting better mobility and prosthetic control whereas the EG group achieved greater advancement in K-levels (e.g., more participants transitioned from basic ambulation (K2) to higher levels (K4)). The limitation were reduced sample size, only 22 participants (all male), limiting the generalizability of findings. The study did not explore long-term sustainability or effects of VR-based interventions.

4. VR in ACL Reconstruction Rehabilitation **(2)**

The type of VR Device used in this study was Immersive VR using *PlayStation Virtual Reality (PSVR)*. The Starting three months post-anterior cruciate ligament (ACL) reconstruction surgery patients participated in VR-assisted rehabilitation using PSVR. The virtual games were selected to mimic physical rehabilitation exercises, focusing on jogging, agility training, and proprioception development. Sessions were conducted once every two weeks for 30 minutes over three months.

VR-assisted rehabilitation significantly reduced pain (measured by pain scores) and improved subjective knee function (measured by the International Knee Documentation Committee, IKDC score). There were no significant differences found in limb loading, balance, range of motion, or functional hop tests compared to traditional therapy, but VR was highly effective in maintaining patient motivation and adherence to the program. The immersive environment made rehabilitation more engaging, allowing patients to practice otherwise repetitive tasks in an interactive and stimulating virtual setting.

5 VR in Traumatic Lower Limb Amputee Rehabilitation**(8)**

The specific VR device was not mentioned in this study but it was described as a VR system used alongside traditional rehabilitation. This study compared a traditional rehabilitation program for lower limb amputees with a program that included VR training. The focus of the VR exercises was on balance and gait improvement. The intervention involved three weekly sessions over six weeks, targeting specific outcomes such as balance, gait, and functional mobility. The results showed significant improvements were noted in the Timed Up and Go (TUG) test, Dynamic Gait Index (DGI), and Berg Balance Scale (BBS), showing that VR was particularly beneficial for improving balance-related outcomes. No significant difference was observed in the 6-minute walk test (6MWT), but VR was effective in improving balance and reducing fall risk, crucial aspects of post-amputation rehabilitation. VR also proved to be a safe, amusing, and motivating intervention, offering an innovative approach to challenging traditional balance and gait exercises.

6 The Influence of Virtual Reality on Phantom Pain in Trans-Tibial Amputation (4)

The Device Used in this study was Xbox 360® Kinect®, with a motion sensor and projector system. The VR sessions involved engaging in mini-games such as rafting, cross-country running, and hitting a ball, designed to mimic real-life movements, particularly targeting balance and lower extremity function. The VR group showed a significant reduction in pain intensity (measured by the McGill Pain Questionnaire) and an improvement in lower extremity function (Lower Extremity Functional Scale). Specifically, the VR group had a 23.58% reduction in pain compared to a 14.4% reduction in the control group. There was also a significant improvement in functional outcomes. While VR significantly improved outcomes,

the study highlighted the need for further exploration into the long-term benefits of VR therapy and the possibility of diminishing effects over time.

7. Early Virtual-Reality-Based Home Rehabilitation after Total Hip Arthroplasty (3)
The device used in this study was Virtual Reality Rehabilitation System (VRRS) by Khymeia Group, which includes a tablet and wearable sensors for telerehabilitation. Patients in the VR group performed daily exercises targeting hip flexors, extensors, abductors, and adductors, as well as knee flexors and extensors. The VRRS provided real-time monitoring and feedback during these exercises. Both the VR and control groups showed significant improvements in hip function and reduced pain. However, the VR group had a higher Global Perceived Effect (GPE) score (4.76 ± 0.43) compared to the control group (3.96 ± 0.65), indicating a greater subjective benefit from VR rehabilitation. The telerehabilitation system was particularly appreciated for enhancing patient engagement and satisfaction. However, there was no significant differences in objective functional outcomes between the VR and control groups. The study also suggested the need for long-term follow-up to assess the sustainability of VR's benefits.

8. Virtual Reality Device Used after TKA:(1)
The study employed the **Virtual Reality Rehabilitation System (VRRS)**. This system was used for inpatient rehabilitation after TKA. Participants were randomized to either a VR-based rehabilitation group or a traditional rehabilitation group. **VR-based group i**nvolved interactive exercises using the VRRS, which focused on improving functional outcomes like proprioception and balance. The VRRS also measured proprioception through tasks that required participants to track movements on a stabilometric platform. Whereas t**raditional rehabilitation group** received standard physical therapy, including functional exercises such as walking and stair negotiation, and passive knee motion therapy on a continuous passive motion device. Both groups performed their respective therapies daily for 60 minutes, for at least 5 days, during the inpatient rehabilitation phase.
The study showed a **statistically significant improvement in proprioception** (P=0.002) for the VR-based rehabilitation group compared to the traditional group. Proprioception is the ability to sense the position of the joints, which plays a critical role in movement control and balance, particularly important for TKA patients. However, there was n**o significant differences in other outcomes**: Despite improvements in proprioception, VR-based rehabilitation was **not superior** to traditional rehabilitation in other key areas, such as: **Pain reduction** (measured by the Visual Analogue Scale - VAS, P=0.26) **Knee disability** (measured by the WOMAC index, P=0.62) **Health-Related Quality of Life (HRQoL)** (measured by EQ-5D, P=0.15). **Functional independence** (measured by FIM, P=0.07)
A significant **dropout rate** was observed in the VR-based group, where 9 out of 44 patients dropped out, mainly due to discomfort with the VR device. This reflects a potential challenge in adopting VR technology, as some patients found it difficult or uncomfortable to engage with the system. Table 1 below showing the summary of the review of all the articles.

Table 1: The Above mentioned table show the review of all the articles included in the review.

Title, Author &Date	Aims & objective	Intervention (sample size, outcome measure, study duration)	Conclusion	Remark

The influence of virtual reality approach on phantom pain in trans-tibial amputation: A randomized control trail. - Mohamed H Elgendy et al., Feb 2024 (4)	To investigate the effect of VR on phantom limb pain and lower extremity function in comparison to the conventional physical therapy (Mirroring therapy, phantom exercises and TENS).	N= 60 Group A= 30 (Conventional therapy including Mirror therapy, Phantom exercise & TENS) Group B= 30 (Experimental group including conventional therapy + Virtual reality) VR sessions included games provided by the Kinect® Adventures (Microsoft Game Studios, Washington, US). - McGill pain questionnaire and Lower Extremities Function Scale. - 4 weeks	Virtual Reality treatment plus traditional treatment (Mirroring therapy, Phantom exercises and TENS) have positive effect on Phantom pain and lower extremity function more than traditional treatment only and lead to decrease phantom pain in trans-tibial amputation and increase lower extremity function.	Identifying which patient subgroups benefit the most could personalize treatment approaches. There is limited insight into the long-term effects of VR in reducing phantom pain.
Effect of Adding Virtual Reality Training to Traditional Exercise Program on Pain, Mental Status and Psychological Status in Unilateral Traumatic Lower Limb Amputees: A Randomized Controlled Trial - Rami L. Abbas et al., Feb 2024 (13)	to evaluate the consequence of adding virtual reality (VR) to a traditional exercise program on pain, mental status, and psychological status in traumatic unilateral lower limb amputees	N= 32 Group A= 16 (traditional rehabilitation program) Group B= 16 (VR program + traditional exercise) Kinapsys equipment using Microsoft Kinect - visual analog scale (VAS) Beck's depression inventory (BDI) and 12-item short form survey. - 6 weeks	additional VR seems effective in decreasing pain and in improving depression and mental health summary of traumatic unilateral LLAs	the games of the VR have the possibility of not suiting all participants. The sample size in the study is small (32 participants), limiting the generalizability of the findings
Comparison between the effect of immersive virtual reality training versus conventional rehabilitation on limb loading and functional outcomes in patients after anterior cruciate ligament reconstruction: A prospective randomized controlled trial - Muhindra Rao	to compare between the effectiveness of using immersive virtual reality (PlayStation VR) in addition to the conventional rehabilitation as an aid in rehabilitation of patients after ACLR in terms of objective functional assessment and	N= 30 Group A= 15 (Conventional rehab) Group B= 15 (combined VR assisted rehabilitation and conventional rehabilitation) - limb loading, dynamic balance, range of motion of the knee, hop tests, pain score, and IKDC score. - 6 months	The immersive VR can be used as an adjunct to conventional rehabilitation after ACLR to optimise the clinical and functional outcome especially in reducing pain as well as subjective knee evaluation.	research investigators and the subjects were not blinded in this randomised trial. Limited number (once in 2 weeks) of immersive VR sessions was another major limitation the number of games that are available to completely mimic

Gsangaya et al., September 2023 (2)	pain and subjective knee function scoring.			conventional rehabilitation were limited.
Early Virtual-Reality-Based Home Rehabilitation after Total Hip Arthroplasty: A Randomized Controlled Trial. - Edoardo Fascio et al,. March 2022 (3)	to compare the efficacy of early rehabilitation via the Virtual Reality Rehabilitation System (VRRS) versus traditional rehabilitation in improving functional outcomes after primary THA.	N= 44 Group A= 22 (control group received therapeutic exercise and passive mobilization) Group B= 22 (Experimental group received virtual reality home rehabilitation system + Conventional exercise) - HOOS JR, Global perceived effect scale, Modified Barthel Index and FIM. - 15 days	Virtual-reality-based home rehabilitation resulted in similar improvements in functional outcomes with a better GPE compared to the traditional rehabilitation program following THA	The study focuses on early rehabilitation within 15 days post-surgery, but there is no data on the long-term efficacy of VR-based rehabilitation.
Effect of balance training using virtual reality-based serious games in individuals with total knee replacement: A randomized controlled trial - Sanaz Pournajaf et al,. Nov 2021 (5)	The primary objective was the efficacy of balance training using non-immersive VR-based serious games (SGs) compared to conventional therapy in TKR patients on the Time Up and Go test. Secondary objectives included the efficacy on clinical, gait, and posturaloutcomes.	N= 56 Group A= 29 (experimental group) Group B= 27 (Control group) - Timed Up and Go test, 10-m walk test, visual analog scale, Medical Research Council (MRC scale), modified Barthel Index (mBI) - 3 weeks	Balance training with non-immersive VR-based SGs can improve clinical, gait, and postural outcomes in TKR patients. It was not superior to the CG findings but could be considered analternative to the conventional approach and can be added to a regular rehabilitation program in TKR patients. The EG had a more physiological duration of the gait stance phase at the end of the treatment than the CG.	the exclusive selection of static balance exercises using only a limited number of SGs included in VRRS.
The effect of adding virtual reality training on traditional exercise program on balance and gait in unilateral traumatic lower limb amputee - Rami L. Abbas et al,. Sep 2020 (8)	to investigate the additional effect of virtual reality on a traditional rehabilitation exercise program on balance and gait in traumatic unilateral lower limb amputees.	N= 32 Group A= 16 (control group) Group B= 16 (Experimental group including conventional rehab + Virtual reality) - Berg Balance Scale (BBS), Timed up and Go (TUG)	virtual reality is a promising, amusing, and safe intervention in addressing balance and gait in unilateral traumatic lower limb amputee.	the long-term sustainability of the improvements, especially in terms of balance and gait, remains unexplored. it did not explore whether different combinations of

		test, Dynamic Gait Index (DGI), and 6 minute walk test (6MWT). - 6 weeks		games might lead to varying outcomes.
Effects of early virtual reality-based rehabilitation in patients with total knee arthroplasty. A randomized controlled trial - Silvia Gianola et al., Jan 2020 (1)	To assess the efficacy of an early rehabilitation performed by the VR-based rehabilitation versus the traditional rehabilitation provided by physical therapists after primary total knee arthroplasty.	N= 85 Group A= 44 (Experimental group including virtual reality) Group B=41 (traditional rehabilitation) - VAS, WOMAC, EQ-5D Questionnaire, the global perceived effect (GPE) as assessed by the GPE score, functional independent measure (FIM), the frequency of medication assumption; the isometric strength of the quadriceps and hamstring muscles as assessed using a dynamometer, the knee active range of movement (ROM) measured by a goniometer and the proprioception assessed using the stabilometric platform of the VRRS. -10 days	VR-based rehabilitation is not superior to traditional rehabilitation in terms of pain relief, drugs assumptions and other functional outcomes but seems to improve the global proprioception for patients received TKA	The study focuses on short-term outcomes (approximately 10 days post-surgery). There is no information on whether the benefits of virtual reality (VR), especially for proprioception, persist in the long term. Due to the nature of the interventions, patients and therapists were not blinded, which may introduce bias.

Conclusion

Virtual reality (VR)-based rehabilitation has proven to be a valuable and innovative adjunct to traditional physical therapy for various post-operative lower extremity conditions. The growing body of evidence demonstrates that VR can enhance patient outcomes by improving proprioception, balance, and patient engagement following procedures such as total knee arthroplasty (TKA), total hip arthroplasty (THA), anterior cruciate ligament (ACL) reconstruction and rehabilitation in amputees(1,3,13,26). The current literature provides evidence that VR can enhance post-operative recovery by improving key functional outcomes like proprioception, balance, and patient engagement(1,5,27,28) VR offers an immersive, interactive environment that not only helps motivate patients but also reduces the monotony of conventional rehabilitation exercises, potentially leading to better adherence and outcomes(1,3,29).

While VR-based rehabilitation shows significant benefits, particularly in improving proprioception and providing real-time feedback, the results on pain relief, limb loading, and overall functional recovery are mixed. Several studies suggest that VR is not always superior to traditional methods in managing post-operative pain and restoring full range of motion, though it serves as an effective complementary tool(1–3,30). Additionally, immersive VR environments, such as those used in ACL reconstruction rehabilitation, show promise in enhancing subjective knee function and patient satisfaction(2). Nonetheless, the immersive

experience VR offers is particularly valuable in keeping patients engaged, which is a critical factor for long-term rehabilitation adherence(8).
Furthermore, VR-based rehabilitation has shown promising results in specialized cases like lower limb amputees, where it has significantly improved phantom limb pain, balance and gait performance, addressing key rehabilitation challenges that conventional methods struggle to overcome(8,31). This highlights VR's potential to revolutionize rehabilitation strategies by offering personalized, remote, and interactive solutions.
In conclusion, VR-based rehabilitation is a promising complement to traditional therapy, offering distinct advantages in patient motivation, proprioception improvement, and the overall rehabilitation experience. Some negative aspects of use of VR included cybersickness, eye strain, reduced awareness of physical surroundings, social isolation, vision problems. However, more high-quality, large-scale studies are necessary to establish clear guidelines for integrating VR into standard rehabilitation protocols and to assess its long-term impact on functional recovery and pain management. As the technology continues to evolve, its role in post-operative rehabilitation is likely to expand, offering new opportunities for enhancing patient care and recovery outcomes.

Limitations: Short term focus in multiple studies, such as those on THA and TKA, primarily assess short-term outcomes (e.g., 10-15 days post-surgery), leaving gaps in understanding the sustainability of VR's benefits.

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