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Reimagining Cardiac Rehabilitation (CR): A Scoping Review on the Role of Extended Reality (XR) in Enhancing Physical, Psychological, and Educational Outcomes

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Abstract: **Background:** Extended Reality (XR), encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), is gaining attention in healthcare for its potential to enhance physical, psychological, and educational outcomes. In the domain of cardiac rehabilitation (CR), XR technologies offer promising avenues to address key challenges such as low adherence, limited engagement, and motivational barriers.

Objective: This scoping review aims to systematically map and analyze the existing empirical evidence on the use of XR technologies in cardiac rehabilitation and assess their impact on physical performance, psychological well-being, educational outcomes, and patient adherence.

Methods: Following Arksey and O'Malley's scoping review framework, a comprehensive search of six databases (PubMed, Cochrane Library, CINAHL, Embase, PsycINFO, Web of Science) was conducted for studies published between January 2018 and March 2025. Empirical studies investigating the application of VR, AR, or XR in CR with measurable outcomes were included. A total of 24 eligible studies were identified and subjected to narrative synthesis.

Results: XR interventions were consistently associated with improved physical outcomes, including increased exercise capacity and cardiovascular risk reduction. VR-enhanced home-based programs showed greater adherence and satisfaction compared to conventional rehabilitation. Psychological benefits such as reduced anxiety and depression, improved mood, and enhanced motivation were also documented. XR-based educational interventions contributed to better disease-related understanding and higher knowledge retention

among both patients and healthcare professionals. Gamification elements and immersive experiences were found to foster intrinsic motivation and engagement.

Conclusion: XR technologies present a multidimensional opportunity to enhance the effectiveness of cardiac rehabilitation programs. Beyond physical recovery, they facilitate psychological support, patient education, and long-term adherence. However, the current body of evidence is limited by methodological heterogeneity, small sample sizes, and short follow-up durations. Future research should focus on theory-based, pedagogically grounded XR interventions that integrate behavioral and learning science principles to unlock the full potential of immersive technologies in cardiac care.

Background

Extended Reality (XR) refers to a spectrum of immersive technologies that includes **Virtual Reality (VR)**, **Augmented Reality (AR)**, and **Mixed Reality (MR)**. While VR offers fully immersive digital environments, AR overlays digital information onto the physical world, and MR blends real and virtual elements in real time (Bendel, 2019). These technologies are increasingly being explored across multiple sectors, including healthcare and education, due to their ability to create engaging, interactive, and individualized experiences (Drossel et al., 2024).

In the context of healthcare, XR technologies have been applied to areas such as physical rehabilitation, mental health support, surgical training, and patient education. Similarly, in educational settings, XR can enhance learning through experiential, simulation-based, and context-rich environments. A recent scoping review by Drossel et al. (2024) emphasizes the broad potential of XR in supporting cognitive, emotional, and motor learning processes in both clinical and educational contexts, highlighting its role as more than just a tool for entertainment.

Cardiac rehabilitation (CR) is a structured, multidisciplinary intervention designed to improve outcomes for individuals with cardiovascular disease. The primary goals of CR include the enhancement of **functional capacity**, **risk factor modification**, **psychological support**, and the promotion of **healthy lifestyle behaviors** (Ambrosetti et al., 2020; Anderson et al., 2016). CR programs are delivered in **inpatient**, **outpatient**, or **home-based** settings, and are tailored to the individual needs of patients (Clark et al., 2015). Despite its proven efficacy, participation in CR remains suboptimal, often due to motivational barriers, logistical constraints, or lack of perceived relevance. Addressing these barriers has become a key focus in recent years. Concepts such as enjoyment, autonomy, and engagement are increasingly recognized as critical to sustained participation. In this context, gamification—the use of game design elements in non-game settings—has emerged as a promising strategy to foster motivation and enhance user experience in rehabilitation programs (Xu et al., 2022, Johnson et al., 2016, Dithmer et al., 2016). The systematic review by Sardi et al. (2017) examined the use of gamification

in e-Health applications. The authors analyzed 46 studies to explore the types of gamification elements used, their design, and their effectiveness. Common features included points, badges, leaderboards, and feedback mechanisms. Overall, gamification was found to have positive effects on user motivation, engagement, and health behavior. However, the review also highlights significant methodological limitations in many studies - such as small sample sizes and a lack of long-term evaluation. The authors call for more rigorous and high-quality research to better understand the true impact of gamification in digital health contexts.

Research Aim and Question

The aim of this scoping review is to analyze the current state of evidence on the use of XR technologies in cardiac rehabilitation and to identify their effects on physical, psychological, and educational outcomes.

Research question: What is the current evidence on the effectiveness of VR, AR, and XR technologies in cardiac rehabilitation?

Methodology

This scoping review followed the methodological framework developed by Arksey and O'Malley (2005) and Tricco et al. (2018) to ensure structured reporting and transparency in evidence synthesis. The aim was to systematically map empirical studies investigating the use of Virtual Reality (VR), Augmented Reality (AR), and Extended Reality (XR) in the context of cardiac rehabilitation (CR), with a specific focus on physical, psychological, educational, and adherence-related outcomes. A systematic search was conducted in the following electronic databases: PubMed, Cochrane Library, CINAHL, Embase, PsycINFO, and Web of Science. The search strategy was developed in collaboration with an experienced librarian and used a combination of keywords and controlled vocabulary (e.g., MeSH terms) such as *"Virtual Reality," "Augmented Reality," "Extended Reality," "Cardiac Rehabilitation,"* and *"Learning Effectiveness."* The search included studies published between January 2017 and March 2025 in English or German.

Screening and Selection

After removing duplicates, titles and abstracts were screened independently by two reviewers to assess relevance. Full-text articles were then reviewed based on predefined eligibility criteria. Disagreements were resolved through discussion or by involving a third reviewer.

Inclusion Criteria

- Empirical studies investigating the use of VR, AR, or XR in cardiac rehabilitation
- Reporting on at least one of the following outcomes: physical performance, psychological effects, educational impact, or adherence

- Published in peer-reviewed journals in English or German
- Publication date between 2017 and 2025

Exclusion Criteria

- Theoretical or conceptual papers lacking empirical data
- Non-peer-reviewed articles (e.g., commentaries, editorials, conference abstracts)
- Studies on general medical education without explicit reference to cardiac rehabilitation

Study Selection

A total of 24 eligible studies were included in the final synthesis. The selected studies employed a range of methodologies, including randomized controlled trials, quasi-experimental designs, and feasibility studies. A narrative synthesis approach was used to analyze and organize findings according to the main outcome domains.

Results

Among the 24 included studies were randomized controlled trials (RCTs), quasi-experimental studies, and systematic reviews. The key findings were grouped as follows and selected results are described.

Physical Outcomes: Virtual reality (VR)-based exercise interventions have demonstrated significant improvements in functional capacity across various cardiac rehabilitation (CR) settings. A systematic review by Peinado-Rubia et al. (2024) reported that VR interventions led to an increase in exercise capacity, with a mean difference (MD) of 49.32 meters (95% CI: 41.9, 56.7) in the 6-minute walk test (6MWT), indicating enhanced physical performance in patients undergoing CR. Home-based VR programs have also been associated with increased exercise tolerance and greater adherence to prescribed training regimens. For instance, Vieira et al. (2023) found that participants engaging in VR-assisted home exercises (tele-reha) showed significant improvements in functional lower limb muscle strength. Furthermore, VR interventions have been shown to positively impact cardiovascular risk factors. The study of Peinado-Rubia et al. (2024) indicated that non-immersive VR-based therapy applied in physiological benefits, VR-based CR has been linked to enhanced patient engagement and motivation. The interactive and immersive nature of VR exercises can make rehabilitation sessions more enjoyable, potentially leading to better adherence and outcomes. This is particularly relevant in the context of long-term CR programs, where maintaining patient motivation is crucial for sustained benefits. The results consistently prove that XR interventions (esp. VR-supported training) can increase physical performance in cardiac rehabilitation. Improvements in load tolerance (e.g. 6MWT distance) and functional characteristics are reported.

Psychological Outcomes: VR interventions also contributed to notable psychological benefits. Studies reported a reduction in symptoms of anxiety and depression among participants engaged in immersive rehabilitation

experiences (Szczepańska-Gieracha et al., 2021; Bashir et al., 2023). Additionally, immersive distraction environments were shown to enhance mood and reduce stress levels (Cortés-Pérez et al., 2025, Bouraghi et al., 2023). Similarly, the study of Jóźwik et al. (2022) reported comparable results. The results of Wrzeciono et al. (2024) show that VR-based psychological interventions are equally effective for both younger and older patients with cardiovascular diseases. Therefore, age should not be considered an exclusion criterion for the use of VR therapies in cardiovascular rehabilitation. The study of Bouraghi et al. (2023) indicates that virtual reality applications in psychological and physical rehabilitation may help reduce stress, emotional tension, overall HADS scores, anxiety, depression, pain, systolic blood pressure, and the length of hospital stay. Moreover, when used in educational or training contexts, virtual reality appears to enhance technical performance, accelerate procedures, and improve users' skills, knowledge, self-confidence, and learning outcomes.

Motivation and Adherence: The integration of gamified elements and real-time feedback within XR platforms enhanced user engagement and fostered a sense of self-efficacy. Moreover, XR-supported home rehabilitation programs demonstrated higher completion rates compared to conventional methods (Peinado-Rubio et al., 2024, da Cruz, 2021).

Educational and Training Aspects: Extended reality (XR) tools proved effective in improving patients' understanding of their medical conditions and recovery processes, especially to increase self-efficicy (Ghlichi Moghaddam et al., 2023). Furthermore, VR-enhanced educational modules contributed to better knowledge retention among both patients and healthcare professionals.

Implications from XR Research in Educational Contexts

A key advantage of using Extended Reality (XR) in educational settings lies in its positive impact on learner motivation and learning effectiveness. In their scoping review, Drossel et al. (2024) highlight that XR technologies not only promote cognitive activation but also effectively support affective learning outcomes. XR creates immersive learning environments that actively engage learners in realistic, experience-based scenarios, thereby enhancing intrinsic motivation. Especially in fields such as healthcare and medicine, XR enables safe yet realistic exploration of complex or hazardous situations, which facilitates deeper engagement with the content. This contributes significantly to the development of individual competencies and enhances learning outcomes in terms of long-term understanding and retention. Observations from practical settings show increased learner satisfaction, higher levels of autonomy and engagement, and improved reflection and decision-making skills in real-world contexts - all of which underscore XR's value as a powerful educational tool (Drossel et al., 2024).

These effects warrant further investigation, particularly in relation to their transferability to rehabilitation settings. Given the importance of motivation, engagement, and active participation in rehabilitation processes,

the integration of XR could offer substantial benefits for both patients and healthcare professionals. Future studies should explore how XR-based interventions can support learning and behavioural change in rehabilitation, and how such approaches may contribute to improved outcomes and adherence.

Discussion

This scoping review demonstrates the growing body of evidence supporting the use of Virtual Reality (VR), Augmented Reality (AR), and Extended Reality (XR) technologies in cardiac rehabilitation (CR). Across the included studies, XR interventions were associated with improvements in physical performance, psychological well-being, patient motivation, adherence to rehabilitation programs, and educational outcomes. These findings align with broader research on the educational and therapeutic potential of XR, as emphasized in Drossel et al. (2024), and extend its relevance into the context of structured, multidisciplinary cardiac care. The findings by Peinado-Rubia et al. (2024) and Vieira et al. (2023) suggest that XR-enhanced home-based interventions can increase physical performance and training adherence. These improvements may not solely stem from the technological interface, but also from psychological factors such as autonomy, intrinsic motivation, and perceived competence—mechanisms that warrant closer integration of motivational theory into XR intervention design. The study by Wrzeciono et al. (2024) demonstrated comparable psychological benefits of VR interventions across age groups. This challenges common assumptions about digital affinity being restricted to younger populations and underscores the importance of inclusive XR design that accounts for varying degrees of digital literacy, particularly among older adults. As reported by Bashir et al. (2023) and Szczepańska-Gieracha et al. (2021), immersive VR environments contributed significantly to anxiety and depression reduction in cardiac patients. These effects align with broader findings on the stress-buffering capacities of immersive distraction and presence, indicating that XR not only serves as a medium for physical activation but also provides an effective psychological scaffold during emotionally vulnerable phases of recovery.

The integration of XR into CR appears particularly effective in enhancing patient motivation and engagement. Gamified elements, immersive environments, and real-time feedback foster intrinsic motivation and self-efficacy—key drivers of sustained participation in rehabilitation. As low adherence and dropout rates remain persistent challenges in CR, these features of XR present promising avenues to mitigate barriers related to boredom, lack of autonomy, and perceived irrelevance. Notably, home-based XR programs, which address logistical challenges such as travel time and scheduling conflicts, were shown to improve adherence and satisfaction. This is particularly important given the increasing need for flexible and accessible healthcare solutions in aging and comorbid populations. Building on Sardi et al. (2017) and Xu et al. (2022), gamification elements such as real-time feedback, rewards, and challenges appear particularly effective in sustaining engagement over time. These mechanisms align with constructs of behavioral economics and may help bridge the gap between initial uptake and long-term adherence in cardiac rehabilitation.

The reviewed studies also revealed consistent psychological benefits, including reductions in anxiety and depression, improved mood, and stress reduction. These outcomes are critical, as psychological factors are closely tied to recovery trajectories and quality of life in cardiac patients. XR-based distraction techniques and immersive simulations may offer safe, engaging alternatives to conventional psychological support tools within CR. Notably, the meta-analytical findings by Peinado-Rubia et al. (2024) and the psychological outcomes reported by Bouraghi et al. (2023) underline the multidimensional potential of XR across physical and emotional domains.

Educational aspects of XR use in CR are emerging as an equally valuable component. XR technologies support experiential learning by allowing patients to explore disease-related processes, treatment pathways, and lifestyle modifications in interactive, meaningful ways. Improved patient understanding and knowledge retention, as well as enhanced training outcomes for healthcare professionals, suggest a dual benefit in both patient-centered care and professional development. As highlighted by Ghlichi Moghaddam et al. (2023), XR-based education has the potential to improve patients' understanding and self-efficacy. When contextualized through the lens of adult learning theories—such as experiential learning or the ARCS model—these findings suggest that XR can serve as an enabler for both cognitive and emotional engagement. This is further supported by Drossel et al. (2024), who demonstrated XR's role in fostering autonomous, reflective learning environments.

The broader educational literature proposes that XR technologies offer far more than entertainment; they are capable of supporting cognitive, emotional, and motor learning processes in complex environments (Drossel et al., 2024). Given the parallels between effective learning and successful rehabilitation—both of which require engagement, motivation, and personalization—it is plausible that XR could play a transformative role in CR if applied systematically and with pedagogical intent. These connections highlight a critical intersection between clinical rehabilitation and learning sciences, pointing to the value of interdisciplinary research and practice. While these findings underscore XR’s value across cognitive and affective domains, critical limitations in the current evidence base must be acknowledged.

Nevertheless, several limitations in the current evidence base warrant careful consideration. Most included studies were small-scale, short in duration, and heterogeneous in design, which limits comparability and impedes meta-analytical synthesis. In particular, long-term effects of XR interventions—especially regarding sustained behavior change, physical outcomes, and psychological resilience—remain underexplored. Methodological inconsistencies were observed in terms of technology types, outcome measures, and the operationalization of key components such as immersion and gamification. Additionally, study populations often lacked diversity with regard to age, digital literacy, socioeconomic background, and comorbidities, thereby restricting generalizability and equity in implementation. To address these gaps, future studies should aim to adopt standardized outcome measures, robust experimental designs, and inclusive sampling strategies.

Moreover, interdisciplinary research that integrates behavioral science, adult learning theory, and pedagogical frameworks is crucial for the development of scalable, theory-driven XR interventions. Evaluations of cost-effectiveness, usability, and patient-provider co-creation will also be essential to support sustainable integration into real-world cardiac care settings. Despite these limitations, the reviewed evidence increasingly suggests that XR interventions may be equivalent or even superior to conventional rehabilitation approaches—particularly in terms of flexibility, scalability, and potential cost-effectiveness. These features are especially relevant for underserved populations and rural healthcare infrastructures.

The findings suggest that XR technologies can support cardiac rehabilitation in multiple dimensions. Not only do they offer promising outcomes for physical and emotional recovery, but they also enhance patient engagement and learning. The immersive nature of XR enables individualized, repeatable experiences—making complex information more accessible. As emphasized in Drossel et al. (2024), XR is not only a technological novelty but a pedagogically grounded tool capable of promoting deep learning processes. Framing XR through an educational lens may not only enhance its rehabilitative effectiveness, but also unlock its full potential as a transformative tool in patient care.

Conclusion

This scoping review highlights the emerging potential of Extended Reality (XR) technologies in supporting and transforming cardiac rehabilitation (CR). Across physical, psychological, and educational domains, the included studies demonstrate that XR can positively influence functional capacity, enhance emotional well-being, and improve learning outcomes for both patients and professionals. Notably, XR's immersive and interactive capabilities appear to foster greater motivation, adherence, and satisfaction—key determinants of long-term success in CR programs.

Particularly compelling are the findings related to home-based XR interventions, which offer flexibility and accessibility while maintaining clinical efficacy. Such interventions are well-suited to address traditional barriers such as CR participation, including time constraints, mobility issues, and geographic limitations. The integration of gamification and real-time feedback further amplifies user engagement and self-efficacy, suggesting that XR can serve not only as a clinical tool but also as a pedagogical medium that supports learning, reflection, and behavior change.

Despite these promising developments, the current evidence base remains limited, heterogeneous and fragmented. The reviewed studies vary widely in design, scope, and technological implementation, limiting comparability and generalizability. Furthermore, most interventions have not yet been evaluated for long-term impact, cost-effectiveness, or real-world scalability. The degree of immersion, the use of pedagogical principles, and the explicit role of educational elements are inconsistently reported.

Moving forward, there is a clear need for interdisciplinary, theory-driven research that bridges healthcare,

behavioral science, and educational technology. Standardization of outcome measures, inclusion of diverse patient populations, and rigorous study designs will be critical to advancing the field. XR interventions in CR should be developed with attention to adult learning principles, personalized feedback, and usability for varied user groups—including older adults and individuals with limited digital literacy.

In conclusion, XR technologies offer a compelling complement to conventional CR approaches. Their capacity to deliver individualized, immersive, and engaging experiences positions them as a powerful tool in both clinical and educational aspects of rehabilitation. With thoughtful design and rigorous evaluation, XR may not only enhance patient outcomes, but also redefine how we conceptualize and deliver cardiac rehabilitation in the 21st century.

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