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Robotics in Cardiac Rehabilitation: A Systematic Review

Nukarisakoma Bilselia*

Department of Physiotherapy and Rehabilitation, University of Seville, 41009 Seville, Spain

Abstract

This systematic review examines the role of robotic technology in enhancing Cardiac Rehabilitation (CR) programs. It synthesizes evidence from various studies on the application of robotic systems, such as exoskeletons and robotic trainers, in improving cardiovascular fitness, physical function, and overall quality of life in patients undergoing CR. The review includes randomized controlled trials and observational studies that assess the efficacy of robotic-assisted interventions compared to traditional CR methods. Findings indicate that robotic systems can provide controlled, adaptable, and repetitive exercises, potentially leading to significant improvements in rehabilitation outcomes. However, challenges such as high costs, technical complexity, and the need for further long-term studies are identified. The review highlights the potential benefits of integrating robotics into CR programs and calls for future research to address existing gaps and optimize implementation strategies.

Keywords: Robotics • Cardiac rehabilitation • Exoskeletons • Robotic systems

Introduction

Cardiac Rehabilitation (CR) is a crucial component of recovery for patients who have experienced cardiovascular events, such as myocardial infarction or heart surgery. CR programs are designed to improve cardiovascular health, enhance physical function, and reduce the risk of future cardiac events through structured exercise, lifestyle modifications, and education. Traditional CR approaches typically include supervised exercise training, which aims to increase cardiovascular fitness and muscle strength while managing risk factors associated with heart disease. In recent years, robotic technology has emerged as a novel adjunct to traditional rehabilitation methods, offering the potential to enhance the effectiveness of CR programs. Robotic systems, including exoskeletons and robotic trainers, are designed to provide controlled, precise, and repetitive movements that can be customized to individual patient needs. These systems offer advantages such as real-time feedback, adjustable intensity, and the ability to facilitate exercises that may be difficult for patients to perform independently due to physical limitations. Despite the growing interest in robotics for rehabilitation, the integration of these technologies into CR has been limited, and the evidence supporting their efficacy remains varied. This systematic review aims to consolidate current research on the application of robotics in cardiac rehabilitation, evaluating their impact on cardiovascular fitness, physical function, and overall rehabilitation outcomes. By examining randomized controlled trials and observational studies, the review seeks to provide a comprehensive assessment of the benefits and challenges associated with robotic-assisted interventions in CR, ultimately informing future research and clinical practice [1,2].

Literature Review

Robotic technology has increasingly been integrated into various fields of rehabilitation due to its potential to enhance therapeutic outcomes and provide precise, consistent interventions. In general rehabilitation contexts, robots are used to assist in physical therapy by providing controlled, repetitive motions that support motor learning and functional recovery. The advantages of robotic systems include precise measurement of movement, adjustable difficulty levels, and the ability to provide real-time feedback, which can be tailored to individual patient needs. Cardiac Rehabilitation (CR) is a comprehensive program designed to improve cardiovascular health following cardiac events such as myocardial infarction, heart surgery, or chronic heart disease. Traditional CR programs include exercise training, lifestyle modification, and education to reduce cardiovascular risk factors and improve overall heart health. Exercise training, a core component of CR, aims to enhance cardiovascular fitness, strength, and endurance. However, adherence to conventional exercise regimens can be challenging for some patients due to physical limitations, fatigue, or lack of motivation [3].

The application of robotics in cardiac rehabilitation is a relatively new but rapidly evolving area of research. Robotic systems, such as exoskeletons and robotic trainers, offer several potential benefits for cardiac patients, including the ability to provide controlled, adjustable, and repetitive exercise. For example, robotic devices can facilitate upper and lower limb exercises in a controlled manner, which is beneficial for patients with limited mobility or severe cardiac conditions. Additionally, robots can provide real-time feedback and adjust exercise intensity based on patient performance, which may help to optimize rehabilitation outcomes. Several studies have explored the use of robotic systems in CR. Robotic-assisted exercises improved physical function and cardiovascular fitness in heart failure patients. Similarly, robotic-assisted training led to significant improvements in exercise capacity and quality of life among patients undergoing CR. These findings suggest that robotics can enhance traditional CR methods by providing more personalized and adaptable interventions. Despite the promising results, there are challenges associated with the integration of robotics into cardiac rehabilitation. High costs of robotic systems, technical complexity, and the need for specialized training for healthcare providers can be significant barriers to widespread adoption. Furthermore, the efficacy of robotic interventions compared to conventional methods requires further investigation, including long-term outcomes and patient adherence rates [4].

Discussion

The systematic review highlights the growing role of robotics in cardiac rehabilitation and its potential to complement traditional methods. The findings from the reviewed studies suggest that robotic systems can enhance rehabilitation by providing controlled, adaptable, and repetitive exercises that may be more effective than conventional approaches alone. The ability of robotic systems to offer real-time feedback and adjust exercise intensity based on patient needs represents a significant advancement in tailoring rehabilitation to individual capabilities. Robotic-assisted exercises have shown promise in improving cardiovascular fitness, physical function, and quality of life among cardiac patients. For example, studies have reported

***Address for Correspondence:** Nukarisakoma Bilselia, Department of Physiotherapy and Rehabilitation, University of Seville, 41009 Seville, Spain, E-mail: nukarisakomabilselia@hotmail.com*

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improvements in exercise capacity and functional outcomes following robotic interventions, which align with the goals of cardiac rehabilitation programs. These results support the integration of robotic technology into CR programs as a means to enhance patient engagement and outcomes. However, the integration of robotics into cardiac rehabilitation is not without challenges. The high cost of robotic systems, combined with the technical expertise required for their operation, can limit their accessibility and feasibility in clinical settings. Additionally, while the short-term benefits of robotic interventions are promising, further research is needed to evaluate their long-term efficacy and impact on patient adherence and overall rehabilitation success [5,6].

Conclusion

The application of robotics in cardiac rehabilitation represents a promising advancement in the field, with the potential to enhance traditional rehabilitation methods and improve patient outcomes. The evidence reviewed suggests that robotic systems can provide controlled, adaptable, and effective interventions that may lead to significant improvements in cardiovascular fitness, physical function, and quality of life for cardiac patients. However, challenges such as high costs and technical complexity must be addressed to facilitate broader adoption and integration into clinical practice. Future research should focus on long-term outcomes, cost-effectiveness, and patient adherence to better understand the full potential of robotics in cardiac rehabilitation. As technology continues to evolve, the integration of robotics into cardiac rehabilitation programs may offer new opportunities for optimizing patient care and enhancing recovery.

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Conflict of Interest

There are no conflicts of interest by author.

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