Chapter 3
Robotics and IoT Integration for Smart Remote Rehabilitation and Patient-Centered Healthcare Systems

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ABSTRACT

The growing burden of chronic illness, aging populations, and mobility impairments has increased the need for personalized, scalable rehabilitation. This chapter presents a patient-centric framework integrating Robotics and IoT to deliver intelligent, remote therapeutic solutions. It features modular robotic systems, biosignal sensors, edge/cloud computing, and real-time feedback loops. Key elements include gesture recognition, anomaly detection, gamification, and AR/VR interfaces. Use cases show clinical and economic impact across diverse settings. Ethical, regulatory, and data security considerations are addressed through alignment with global standards. Future directions include digital twins and emotion-aware robotics to support inclusive, next-gen rehabilitation.

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INTRODUCTION

The global rise in ageing populations and the increasing prevalence of chronic conditions such as stroke, neurodegenerative diseases like Parkinson's and Alzheimer's, and orthopedic injuries have created an urgent need for continuous and personalized rehabilitation services. Traditional in-clinic rehabilitation models, while clinically effective, are increasingly limited by accessibility challenges, especially for individuals in rural or underserved areas. These models also face issues related to scalability, high operational costs, and disruption of care continuity, particularly in cases where long-term therapy is essential. Patients often struggle with logistical burdens, delayed access to services, and inconsistent follow-up, which collectively undermine clinical outcomes and engagement.

The digital transformation of healthcare has significantly reshaped rehabilitation delivery models. Remote rehabilitation technologies, including telemedicine, wearable biosensors, smart home systems, and cloud-based applications, have emerged as crucial tools for closing the accessibility gap, especially following the disruptions caused by the COVID-19 pandemic, (Akbari, Haghverd, & Behbahani, 2021). These technologies allow patients to remain engaged in therapy without the need for frequent travel and offer real-time feedback to clinicians, thereby enabling dynamic and data-driven adjustments to therapy protocols, (Ahmad et al., 2022). Artificial intelligence-based analytics now assist in monitoring patient performance, predicting recovery trends, and personalizing treatment plans, (Khan et al., 2023). Studies have shown that digital platforms equipped with motion tracking, haptic feedback, and mobile connectivity can improve adherence rates, reduce therapy dropouts, and enhance functional recovery in various clinical populations, (Ianculescu, Andrei, & Alexandru, 2019). For example, recent research reported dropout rates ranging from 3% to 13% in remote cardiac rehabilitation programs lasting under 12 weeks, demonstrating that short-term remote programs can achieve relatively high patient adherence, (Nishio et al., 2025).

Remote rehabilitation is a broad concept that encompasses the supervised use of various communication technologies such as smartphones, tablets, laptops, and television systems during all stages of the patient's rehabilitation journey. This concept is more inclusive than narrower terms like telerehabilitation or mHealth, which typically refer to specific tools or delivery formats. Modern remote rehabilitation platforms now deliver therapeutic guidance along with reminders, educational materials, emotional support, and remote assessments. These features help improve patient compliance, increase awareness, and maintain continuity of care. Personalization through user-centric design, adaptive goal setting, and contextual feedback enhances engagement and therapeutic outcomes. However, factors like