Chapter 6
Robotics and Neuroscience in Rehabilitation:
Modern Approaches to Motor Disorders

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ABSTRACT

This monograph explores the intersection of robotics and neuroscience in the field of motor neurorehabilitation, focusing on the development and application of brain-computer interface (BCI) systems. Emphasizing principles of neuroplasticity, it examines how technologies such as EEG-based BCI, functional electrical stimulation

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(FES), virtual reality (VR), and robotic exoskeletons can be integrated into closed-loop, feedback-rich rehabilitation platforms. Special attention is given to hybrid systems combining multiple sensory modalities to enhance user engagement and therapeutic outcomes. The monograph also discusses current challenges in clinical translation, including signal variability, training demands, and hardware limitations, while highlighting promising advances in AI-driven algorithms, wearable EEG solutions, and co-adaptive control strategies. Overall, it argues for a shift toward personalized, home-based rehabilitation technologies that empower patients with motor impairments to achieve greater autonomy and functional recovery.

INTRODUCTION

In recent years, the field of physical therapy and neurorehabilitation has witnessed a transformative shift through the integration of advanced robotic technologies. These systems, broadly defined as motorized interactive platforms with embedded control algorithms, are specifically engineered to assist patients in performing therapeutic movements. Acting either as guided tools or autonomous agents, robotic devices have demonstrated substantial efficacy in improving muscular strength, fine motor coordination, and movement precision. More importantly, they serve as potent modulators of neuroplastic mechanisms, which are central to the recovery of motor function following neurological injury (Cheng et al., 2020).

Robotic solutions for rehabilitation span a diverse technological spectrum. This includes wearable powered exoskeletons that facilitate locomotion or upper-limb movements by delivering joint-specific torque, as well as end-effector systems that enable patients to engage in controlled, repetitive task execution (Zakharov et al., 2020). In contrast to conventional therapeutic techniques, robotic systems provide high-resolution spatiotemporal control over movement trajectories, ensuring both consistency and adaptability throughout the course of recovery.

A key advantage of robotic rehabilitation lies in its capacity to deliver multi-modal sensory-motor stimulation. The continuous loop of real-time feedback not only enhances motor learning but also stimulates the central nervous system in ways conducive to plastic changes. These changes are largely experience-dependent and arise through intensive, repetitive, and task-oriented training that aligns with principles of Hebbian learning and sensorimotor reinforcement (Yoo & Lee, 2023). By adapting to the evolving capabilities of the patient, robotic systems dynamically support cortical reorganization, strengthen residual neural connections, and promote the recruitment of alternative neural circuits—processes that are fundamental to the restoration of voluntary motor control.

Application of Kirlian Captures and Statistical Analysis of Human Bioelectricity and Energy of Different Organs: Observations and Graphical Notations