NEUROROBOTIC REHABILITATION: INTEGRATING BIOMECHANICS, MOTOR CONTROL, ROBOTICS, AND NEUROPLASTICITY IN CONTEMPORARY CLINICAL PRACTICE

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Abstract: *Neurorobotic rehabilitation represents one of the most rapidly evolving approaches in contemporary neurorehabilitation, integrating principles of biomechanics, motor control, and assistive robotics to enhance functional recovery following neurological injury. By enabling high-intensity, task-specific, and precisely guided movement practice, neurorobotic systems directly stimulate neuroplastic mechanisms that underpin motor relearning. The primary aim of this study is to examine neurorobotic rehabilitation from a biomechanical perspective, highlighting how objective biomechanical parameters can be used to optimize therapeutic interventions and support individualized motor recovery. Methodology: The biomechanical framework of neurorobotic rehabilitation is based on the application of robotic systems for gait training and functional movements of both upper and lower extremities, as illustrated by the robotic locomotion and limb-assist devices shown in the provided images. These systems are equipped with integrated force, position, and kinematic sensors, enabling precise assessment of joint angles, joint moments, movement symmetry, and spatiotemporal gait characteristics. The collected biomechanical data are continuously analyzed to adapt task difficulty, loading, and movement trajectories in real time, thereby personalizing therapy. Results: The use of neurorobotic systems allows for a significant increase in the volume and quality of functional movement repetitions, improved regulation of biomechanical loads, and objective quantification of motor recovery. Observed outcomes include enhanced postural stability, improved coordination, and greater movement efficiency, along with increased patient engagement during rehabilitation sessions. Conclusion: Biomechanically informed neurorobotic rehabilitation offers a robust multidisciplinary framework for advancing neurorehabilitation outcomes through precise assessment, individualized intervention, and sustained motor recovery.*

Keywords: *Robot-Assisted Gait Training; Kinematic Analysis; Human–Robot Interaction; Movement Pattern Assessment; Sensor-Based Rehabilitation*