



HYBRID EXOSKELETON TRAINING WITH NEUROMODULATION TECHNIQUES AFTER SPINAL CORD INJURY

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Spinal cord injury (SCI) results in profound motor and autonomic dysfunction, often requiring long-term rehabilitation. Robotic exoskeletons and neuromodulation have independently promoted neuroplasticity and motor recovery after SCI. Recent research supports a synergistic approach—hybrid exoskeleton training combined with neuromodulation techniques—as a novel paradigm to enhance sensorimotor outcomes in individuals with SCI. The objective of the current work is to highlight the preliminary methodological and research findings regarding hybrid applications after SCI. Hybrid rehabilitation protocols typically involve exoskeletal assisted walking (EAW; e.g., using Ekso exoskeletons) in conjunction with spinal neuromodulation techniques (trans spinal stimulation or spinal cord epidural stimulation) to activate dormant neural circuits. The stimulation facilitates engagement of spinal locomotor centers, enhances proprioceptive feedback, and supports task-specific neuroplasticity during gait training. The findings from our research group high-

lighted the feasibility of this hybrid approach in the improvement of motor function in persons with SCI. This resulted in increasing EMG activities, steps per minute, walking distance and walking speed. Furthermore, we explored the possibility of altering EAW-mode of assistance between fixed mode and adaptive mode. Our findings indicated that EAW-adaptive mode of assistance mimicked overground ambulation and provided variable levels of assistance that augmented neuroplasticity after SCI. Therefore, the addition of neuromodulation to EAW appears to amplify the effects and may promote carryover improvements in volitional control and independence. Hybrid exoskeleton and neuromodulation strategies offer a promising, activity-based intervention for enhancing recovery after SCI. This integrative approach leverages mechanical assistance and physiological activation to target the spinal circuitry and promote functional reorganization (1-5). Ongoing clinical trials continue to evaluate long-term effects and individualized protocols.

Keywords: spinal cord injury, rehabilitation, neuromodulation, exoskeleton, hybrid techniques.