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From Neurophysiology to Neurorehabilitation: A Motor Control Perspective

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Stroke is a leading cause of long-term motor disability worldwide. At six months following the onset of stroke, about 50-70% of patients continue to have upper limb sensorimotor impairments. The most common sensorimotor disorders are spasticity and disrupted muscle activation leading to residual functional deficit. Moreover, significant changes in the structure of movement variability have been reported in neurological populations compared to healthy subjects, resulting in loss of movement stability. A unified framework that couples motor control processes and movement disorders has been proposed within the Referent Configuration Theory. According to the theory, movement emerges according to the difference between the actual body position and the referent body position. The family of endpoint trajectories observed during movement repetition resulting from the intertrial variability of the degrees of freedom contributing to the movement can be characterized with the Uncontrolled Manifold (UCM) analysis. The UCM is based on the hypothesis that the central nervous system is able to organize different sets of elements within the body (e.g., muscles, joints) into task-specific ensembles (i.e., synergies), stabilizing salient performance variables. Growing evidence suggests that stroke may lead to deficits in regulating the referent muscle length, i.e., decreased tonic stretch reflex threshold (TSRT) regulation, resulting in sensorimotor deficits within certain biomechanical joint ranges. Disordered movements can be characterized in temporal and spatial domains using the UCM. Recently, the UCM has also been proposed as a biomarker of movement quality to identify sensorimotor recovery. Other biomechanical approaches within the family of stochastic models have been used to describe spatial-temporal features of movements while accounting for variability. Understanding the relationship between control processes and movement variability may be important for developing personalized clinical approaches based on the individual's specific sensorimotor impairment. Currently, while rehabilitation research strives to improve sensorimotor deficits in post-stroke survivors, the outcomes of clinical trials have been disappointing. The majority of trials reported neutral results, i.e., participants all improved according to the expected level, and no differences were found between the tested intervention and the comparator. Neutral results might reflect the challenges to translating motor control principles and theories into informative research designs and clinical interventions. How motor control theories can be translated into sensorimotor rehabilitation will be highlighted. The potential implications and future directions will be discussed.