#16: Studies of postural synergies: A sensitive tool for early Parkinson's disease

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One of the cardinal features of Parkinson's disease (PD) is postural instability or balance impairment, which becomes more prevalent with disease severity. This disabling symptom of PD represents a fundamental change in disease progression signifying the transition from Hoehn and Yahr (HY) stage-II to HY stage-III. Although many studies have investigated the effect of PD on motor functions, there is no standardized technique to measure balance instability. We hypothesized that multi-muscle synergies may be used as a biomarker sensitive to changes in motor coordination, even in PD patients with no clinical symptoms of postural instability. We also explored the sensitivity of indices of synergic control to dopamine-replacement treatment. These studies were done under the framework of the uncontrolled manifold (UCM) hypothesis. Eleven HY stage-II PD patients and eleven age-matched healthy controls stood on a force-platform and performed three main tasks: voluntary cyclic body sway, quick discrete body sway forward, and a quick load release from extended arms resulting in a postural perturbation. Four muscle groups with parallel modulation in activation levels (M-modes) were identified from surface electromyographic (EMG) activity of 13 leg and trunk muscles on the right side of the body, using principal component analysis with factor extraction and Varimax rotation. Multiple linear regression was used to link small changes in M-modes to shifts of the center of pressure in the anterior-posterior direction (COPAP) the Jacobian matrix. Further, a synergy index was computed reflecting the relative amount of inter-trial M-mode variance within the null-space of the Jacobian. Compared to healthy controls, PD patients showed: (1) a lower amount of variance accounted for by the identified M-modes, (2) lower synergy indices during steady-state standing, and (3) delayed and reduced anticipatory synergy adjustments (ASAs: a drop in preparation to a quick action). In a follow-up study, five HY stage-II and five HY stage-III PD patients were tested both off and on their PD medications. Off-drug, the differences between PD patients and controls were larger, due in part to the lower amount of the M-mode variance preserving the COPAP coordinate. These results support the idea of impaired multi-muscle synergic control of posture in PD patients without clinically identifiable postural problems. It allows quantifying three PD-associated problems in postural control: (1) The less consistent organization of muscles into groups (M-modes); (2) Lower postural stability during steady-state tasks; and (3) Impaired ability to prepare to a quick action. The third one may be causally related to episodes of freezing, which represent one of the most disabling symptoms of PD. The findings highlight the importance of balanced interaction among brain loops involving the basal ganglia and cerebellum.