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Title: Characterizing the sway response of the human postural control system to an impulse perturbation

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This study explored methods to characterize the response of the postural control system to an impulsive disturbance to balance. Previous studies have examined the response to perturbations of a persistent nature (e.g., continuous pseudo-random translations of a moving platform). Most losses of balance, however, result from a sudden and transient disturbance. To better replicate these transient disturbances, we examined the response to a mild backward impulse force applied to the pelvis (Hsiao-Wecksler et al., J Biomech 36, 2003). Ten young adults (YA: 20-30 yrs), ten middle-aged adults (MA: 42-53 yrs), and ten older adults (OA: 71-79 yrs) performed 20 randomized trials (10 perturbed and 10 quiet-standing). The trials lasted for 30 s and subjects stood with eyes open on an AMTI force plate. The sway response was measured using anterior-posterior fluctuations of the center of pressure (COP) and was evaluated using descriptive parameters and spectral analysis system identification. Descriptive parameters included displacement measures (maximum posterior displacement, displacement range, normalized maximum posterior displacement, and response latency) and frequency measures (total power, median frequency, 95% power frequency, and frequency dispersion). A model of a single-link inverted pendulum controlled by a proportional-derivative controller with a time delay was fit to the experimental data by minimizing the difference in magnitude of the experimental and modeled frequency response functions found using spectral analysis (Peterka, J Neurophysiol 88, 2002). The robustness of the modeled system was quantified through the maximum of the sensitivity function, which describes how sensitive a system is to small perturbations or changes in the system. The maximum posterior displacement and displacement range tended to be greater for OA than YA or MA, but these trends were not statistically significant ($p > 0.08$). Maximum sensitivity values, however, were significantly larger for OA than either YA or MA ($p < 0.001$), suggesting that OA are more sensitive to small disturbances and closer to the point of instability. While both descriptive and spectral analysis parameters were used to characterize the impulse response, only the maximum sensitivity showed significant differences, suggesting it may be an important parameter to consider when examining the postural control system.

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