Sway response and relative stability of the postural control system to an impulsive perturbation

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Although most losses of balance result from a sudden disturbance, the majority of studies examining the response of the postural control system use continuous perturbations. Therefore, it is important to understand how balance and postural control mechanisms are utilized in response to unexpected and transitory disturbances. While impulse response and its associated characteristics are rudimentary concepts in engineering control theory, limited work has been done in this area in the postural control literature. In this investigation, the impulse loading and impulse response control-theory paradigm were used to examine the anterior-posterior sway response to a mild, quick-release tug at the pelvis. The postural control system was modeled as a single-link inverted pendulum with active and passive torques generated by a time-delayed proportional-derivative controller and a spring-damper compensator, respectively. Spectral analysis system identification [1] was used to determine optimal model parameters. The optimization cost function was derived from the modeled and experimental frequency response functions. Frequency response was determined from the power spectral densities of the tug force and displacement of the body center of mass. Further, we propose a new postural stability index based on quantifying the robustness of each modeled system through the maximum of its sensitivity function. The sensitivity function is derived from the system dynamics and active compensator and describes how sensitive a system is to small perturbations in the system [2]; larger values indicate reduced robustness or decreased relative stability of the system. To validate this approach, we examined differences in sway response and relative stability among three age groups (*n*=10 each): young (20-30 years), middle-aged (42-53 years), and older adults (71-79 years). No age-related differences in sway response were detected among model parameters (e.g., gains for the active and passive compensators) or descriptive measures of the center of pressure (e.g., maximum posterior displacement, latency time from peak tug force to max displacement). Maximum sensitivity values, however, were significantly larger for older adults than young or middle-aged adults (*p*=0.02). This result suggests that the maximum of the sensitivity function may be a useful parameter for measuring relative stability or robustness of the postural control system to an external perturbation.

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[1] R.J. Peterka, *J Neurophysiol* 88: 1097-1118, 2002

[2] G. F. Franklin et al. *Feedback Control of Dynamic Systems*, Prentice-Hall, 2002