CHANGE OF POSTURAL FEEDBACK GAIN SCALING BY AGING
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INTRODUCTION
We examined how age affects how postural strategies change as perturbation magnitude changes. Previous studies showed that young adults continuously scale postural response gains from ankle strategy to more and more hip strategy with increasing biomechanical constraints but it is now known whether elderly subjects show the same scaling (Park et al., 2004). Postural responses were analyzed with full-state feedback control whose gain parameters characterize the response of each group. The gain scaling indicates that the elderly relies more on hip strategy, while the young continuously changes from ankle to hip with perturbation magnitude.

METHODS AND PROCEDURES

Subjects
Young (7 females, 23-28 yrs) and elderly (6 males and 1 females, 53-81 yrs) subjects with no history of balance problem participated after signing the consent form.

Experiment data collection
Backward perturbations of magnitude ranged from 3-15cm were applied to the subjects with duration of 275msec. The maximum magnitude was designed to induce frequent heel-lifts or steps. Subjects stood upright on a movable force plate, and were instructed to keep the balance, not to lift their heels off the ground if possible. All subjects experienced total five sets of seven randomly ordered perturbations. For each trial, ground reaction force and kinematic data were recorded for 10 seconds including the early 2 seconds prior to perturbation onset (Park et al., 2004).

Biomechanical model with feedback gain
Human body was modeled as two segment inverted pendulum in sagittal plane. Full-state feedback control model was used to describe the human postural response to external perturbations. Control gain parameters of full-state feedback model were obtained by optimization method using MATLAB.

RESULTS
Full-state feedback simulation reproduced the experimental data with the goodness of fit ($R^2=0.84±0.35$ in the young and $0.86±0.30$ in the elderly).

Joint kinematic data showed that the elderly relies more on hip strategy. Joint angle trajectories of the elderly are composed of smaller ankle and larger hip motion in compared to those of the young (Figure 2 top). Joint torque trajectories were more uniformly scaled with perturbation magnitude for the elderly (Figure 2 bottom left). However, joint trajectories of the young continuously change its characteristic shape when perturbation magnitude increases (Figure 2 bottom right).

Maximum allowable ankle joint torque significantly reduced for the elderly (Figure 2 bottom right). Though it is not shown in the figures, the elderly experienced frequent heel-lifts or steps at large perturbation magnitudes.
Gain parameters corresponding to 15cm perturbation were not included to fit the scaling trend with linear regression (Figure 3) because most of the elderly subjects violated flat foot constraint. Feedback gain scaled with perturbation magnitude for young subjects, but not significantly for the elderly. The young gradually scaled $T_{\text{ank}}/\theta_{\text{ank}}$ as a function of perturbation magnitudes, while the elderly barely changed the gain at the intermediate perturbations (Figure 3 top). They also showed smaller and almost invariant gain $T_{\text{hip}}/\theta_{\text{hip}}$ with perturbation magnitudes, while the young showed slightly increasing trend.

**DISCUSSION**

Smaller ankle motion in combination with large hip motion indicates that the elderly rely more on hip strategy in response to broad range of perturbation. Less flexible strategy change from ankle to hip was also observed from the gentle gain scaling slope. Reduced maximum ankle joint torque of the elderly might be attributed by their fear of fall, which was reflected in discontinuous postural strategy change as well as frequent heel-off or steps at large perturbations.

**SUMMARY**

The elderly relies more on hip strategy, while the young continuously changes from ankle to hip with perturbation magnitudes. These strategy changes could be quantified by gain scaling slope.

**REFERENCES**


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