THE EFFECT OF INITIAL LEAN ON HUMAN POSTURAL SCALING

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INTRODUCTION

We examined how the central nervous system adjusts postural responses with initial forward lean of the body. Postural feedback responses appear to scale nonlinearly with perturbation magnitude in order to accommodate biomechanical constraints such as allowable ankle joint torque [1]. Initial forward leaning, which is observed among the elderly who are inactive or afraid of falling, brings subjects nearer to the limit of stability [2] and alters the biomechanical constraint. We hypothesized that the central nervous system is aware of body dynamics and further restrains postural responses when subjects initially lean forward prior to a perturbation.

METHODS

We applied fast backwards perturbations of various magnitudes to 12 healthy young subjects (3 male, 9 female) aged 20 to 32 years. Subjects were instructed to quietly stand on a hydraulic servo-controlled force platform with their arms crossed over their chests, and to recover from a perturbation by returning to their upright position. Initially subjects were either standing upright or standing with a half-maximum forward lean. Half-maximum lean is defined as the posture, in which the center of pressure is located at half the maximum magnitude that subjects could achieve without stepping or falling. The force platform translated backward with various ramp displacements ranging 1.2 – 15 cm, all with the duration of 275 msec. Perturbations occurred in blocks of seven displacements, with the perturbation size for each block randomized. For each trial, kinematics and ground reaction force data were recorded and then used to compute net joint torques, employing a least squares inverse dynamics method.

To examine the scaling of multi-joint postural responses, we examined the changes in trajectories of ankle vs. hip joint torques as a function of perturbation magnitude and initial lean. We used optimization methods to identify a set of equivalent feedback control gains for each trial so that the biomechanical model incorporating this feedback control would reproduce the empirical response [1]. There are three components to this identification: a 3-segment inverted pendulum biomechanical model of body dynamics, a linear feedback control to stabilize this model [3], and an optimization procedure to produce model responses with the best fit to the data. We compared the joint torque trajectories with a predicted constraint on allowable ankle torque, and also examined how the identified feedback gains changed with initial learn.

RESULTS AND DISCUSSION

We found that joint torque and feedback gains gradually scaled as a function of perturbation magnitude before they reached the biomechanical constraint, and scaling became more severe with initial forward lean (see Fig. 1). For example, the model suggests that the magnitude of ankle joint angle feedback to ankle torque was smaller in leaning trials than on initially upright trials, as if the subjects experienced a larger postural perturbation in leaning trials. These results imply that the central nervous system restrained postural responses to accommodate a more limiting biomechanical constraint imposed by the forward posture. The gradual scaling of postural feedback gains indicates that the postural control can be interpreted as a feedback scheme with scalable gains.

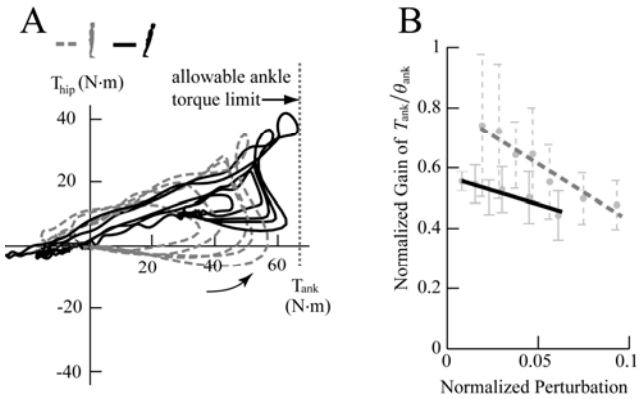

Figure 1: Changes in postural response scaling for two different initial postures. (A) Trajectories of joint torques also scaled with initial lean. Joint torque for leaning trials more conservatively scaled for forward posture. (B) Normalized feedback gains and their linear regressions as a function of perturbation magnitude for upright posture (dashed line) and forward lean posture (solid line).

CONCLUSIONS

Human postural responses scale as a function of perturbation magnitude as well as initial lean to accommodate biomechanical constraints. This scaling implies that the central nervous system is aware of body dynamics and biomechanical effects of initial position so it can restrain postural responses when subjects initially lean forward.

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ACKNOWLEDGEMENTS

This work support in part by NIH grants DC0231201 and AG06457. C. L. Shupert contributed to data collection.