SMALLER SWAY DURING QUIET STANCE ATTRIBUTES TO EFFECTIVE USE OF BODY VELOCITY

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INTRODUCTION

The nature of the control mechanism responsible for ensuring stability during quiet standing has attracted the attention of many researchers, since larger sway is supposed to relate to falling, which is a serious problem in elderly. However, the mechanism that determines the sway size remains unclear.

Using cross-correlation analysis, we found that the modulation of calf muscle activity matches body sway during quiet standing, and that the muscle activity precedes body sway with about 200ms [1]. It was also demonstrated that the central nervous system attributes a significant role to the body velocity information in order to generate the preceding motor command [1, 2].

In the present study, we tested the hypothesis that a more effective utilization of the body velocity information leads to an improved stabilization of the body.

METHODS

Experimental study: 24 young (Mean age 27yrs; Male 11, Female 13) and 22 elderly (66yrs; M 11, F 11) healthy subjects were asked to stand quietly for 90 sec and five trials. The body sway and electromyogram (EMG) in the right soleus muscle were measured. Due to the space limitation, we do not compare distinct age group characteristics in this abstract.

Simulation study: We provided an explanation for the experimental results by means of a numerical simulation. Human quiet stance was simulated using an inverted pendulum model regulated by a proportional and derivative (PD) controller. The parameter sets of the simulation, such as proportional gain (Kp), derivative gain (Kd) and closed-loop time delay, were selected with the goal of generating a realistic cross-correlation function (CCF) between the motor command and body sway as demonstrated in [2].

Analysis: The correlation coefficient (CC) and time shift (TS) were determined using the peak of CCF between body sway and EMG (Experimental study) or motor command (Simulation study). Sway size was evaluated as the standard deviation of body sway.

RESULTS AND DISCUSSION

Figure 1 shows the results of the experimental study. The results indicate that for a person, who sways less, CC is smaller (A) and TS longer (B). For both age groups, this tendency is more distinct in male than in female subjects (not shown in this abstract).

The experimental results inspired us to consider the contribution of the velocity information in the central nervous system. We reported in [1] that a larger Kd generates a faster fluctuation of the motor command. Therefore, the CC between body sway and motor command is expected to be smaller when the body is controlled by means of a larger Kd gain. The relation is shown in Figure 2A. Also, a controller with a larger Kd gain is capable of producing a longer TS, since the phase of the derivative time series leads the position time series [2], as shown in Figure 2B. Additionally, since a larger Kd is more capable of compensating the noise torque, the ratio of Kp/Kd correlates with the sway size (r=0.316, p<0.01). As a result, a smaller sway size relates to a smaller CC and longer TS for the simulation as well (Figure 2C, D).

Comparing the results in the experimental and simulation studies, we conclude that the person who shows the smaller body sway utilizes the larger body velocity information.

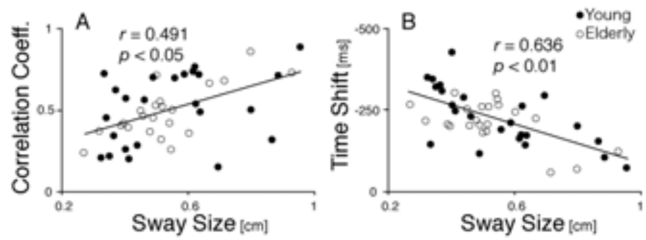

Figure 1: Results of the experimental study. Sway size vs. CC (A) and TS (B) of the CCF between EMG and body sway. Note that the positive CC indicates that the larger EMG correlates with the forward body position, that the negative TS indicates that the EMG precedes the body sway, and that the vertical axis of B is reversed.

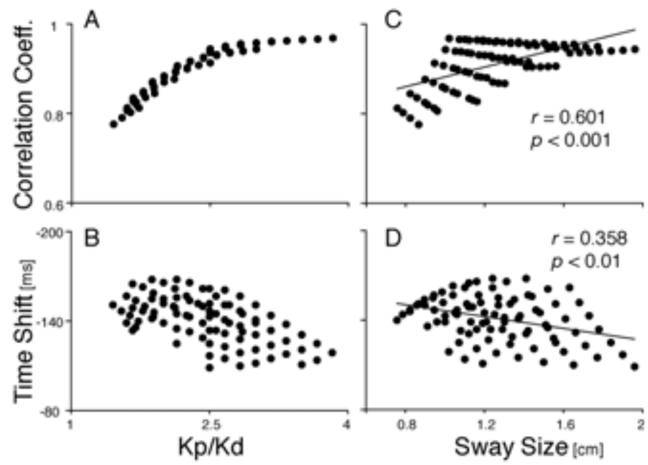

Figure 2: Result of the simulation study. The ratio of Kp/Kd vs. CC (A) and TS (B) of the CCF between motor command and body sway. Sway size vs. CC (C) and vs. TS (D). Plots are from 89 simulations. See notes in Fig. 1.

REFERENCES

1. Masani, et al. *J Neurophysiol* **90**, 3774-3782, 2003.
2. Masani et al. *Gait and Posture*, in press.