QUIET-STANCE BEHAVIOR CAN PREDICT THE DYNAMIC POSTURAL CONTROL RESPONSE

E.T. Hsiao-Weksler¹, K. Katadare¹, J. McKillop¹, W. Liu¹,², L.A. Lipsitz³, and J.J. Collins¹

¹Center of BioDynamics, Dept of Biomedical Engineering, Boston University, Boston, MA, USA
²Dept of Physical Therapy Education, Univ of Kansas Medical Center, Kansas City, KS, USA
³Hebrew Rehabilitation Center for Aged, Harvard Medical School, Boston, MA, USA

Email: ethw@bu.edu, Web: http://cbd.bu.edu/abl/

INTRODUCTION

Fluctuations in the center of pressure (COP) during quiet-standing can be represented as a correlated stochastic process (Collins and Deluca, 1993). For many stochastic systems, the fluctuation-dissipation theorem (FDT) can be applied. This theorem compares the correlations in the fluctuations of a system and its relaxation to equilibrium following a perturbation. More specifically, it provides a relationship between the output of a quasistatic system, and the system’s dynamic response to a perturbation. Recently, Lauk et al. (1998) applied the FDT to show that in young adults COP fluctuations during quiet stance could be used to predict the dynamic response of the postural control system to a weak perturbation. Young individuals, however, rarely have postural control problems. Therefore in this study, we examined whether this method could be extended to elderly individuals, including those with a history of falling.

METHODS

Seventeen healthy, community-dwelling elderly adults (7 with a history of falling, 10 without; age: 68-86 yrs; weight: 51-81 kg, height: 1.5-1.7 m) and ten young adults (age: 21-30 yrs; weight: 51-89 kg, height: 1.6–1.8 m) were included in this study.

Twenty randomly-presented trials were conducted on each subject: 10 quiet-standing trials and 10 perturbed trials, all 30 s in duration. To generate a weak impulse perturbation (a backward tug), the subject was tethered to a suspended 11 kg weight that was released after a random delay of 10-20 s. After the weight fell, the tether slackened and allowed the subject to readjust to an upright posture. The subject stood with both feet on a forceplate, arms crossed at the chest, and eyes open. Anterior-posterior (AP) COP data (Fig.1) were determined from the forceplate recordings.

For the quiet-standing trials, the derivative of the correlation function, dC(t)/dt, was calculated from the average of all 10 trials. This was accomplished by first determining the autocorrelation of COP fluctuations of each trial, and then calculating its derivative. The time of the maximal amplitude was used as the trigger point. Each trial was normalized to unity at the trigger point. Results from all trials for a given subject were then averaged.

For the perturbed trials, the response function R(t) was calculated from the average of the COP measurements for all 10 trials. The time of the maximal sway amplitude following the perturbation was used as the trigger point (Fig.1b). Each trial was then normalized to unity at the trigger point.

Applying the FDT, the two functions were fit to a linear regression with errors in both variables, R(t) = a + b·(dC(t)/dt), for each subject, for the first 4 s (or 480 data points). The goodness of fit was evaluated by a $\chi^2$
test with \( v = 478 \), that is, \( \chi^2 = 478 \) represents a moderately good fit, and the fit improves as \( \chi^2 \) decreases.

**RESULTS AND DISCUSSION**

For all young, eight elderly non-fallers, and all elderly fallers, results from the \( \chi^2 \) test indicate that the two curves are significantly well matched (\( \chi^2 \) values between 45 and 431), which imply that the two curves can be linearly predicted from one another. Two of ten elderly non-fallers had \( \chi^2 \) greater than 652. Thus, in the majority of cases, we can predict the behavior of \( R(t) \) from \( dC(t)/dt \).

All subjects exhibited the expected curve shape (Fig. 2), i.e., both curves decay from 1.0 and then fluctuate around an equilibrium state. The curves can be visually evaluated over three conditions: the rate of decay, the magnitude of the equilibrium state, and the time at which equilibrium was attained. \( \chi^2 \) decreases as the similarities between the two curves increase.

These results suggest that it may be possible to predict an individual’s postural control behavior during a weak disruption to balance from quiet-stance COP data. This implies that the postural control system may use the same control mechanisms under quiet-stance and perturbed conditions.

Clinically, these findings suggest that elderly individuals, especially those with compromised postural stability, may not need to be perturbed to have their postural control capacity characterized. Consequently, testing procedures may be safer since subjects would not be put at risk to falls during tests that involve perturbations. Additionally, this would eliminate the need for complicated perturbation devices since only quiet-stance data would be necessary.

**REFERENCES**


**ACKNOWLEDGEMENTS**

This study was funded by grants from the NIH, NIDRR, and NSF.

![Fig.1.](image1.png)

Fig.1. (a) Typical 30 s AP COP times series for quiet-stance trial. (b) Typical AP COP time series for perturbed trial; arrow indicates application of perturbation.

![Fig.2.](image2.png)

Fig.2. Response function \( R(t) \) (bold) and derivative of correlation function \( dC(t)/dt \) (thin) for a subject; \( \chi^2 = 59 \).