POSTURAL STIFFNESS MODEL AND OUTDOOR FALLS IN OLDER ADULTS: THE MOBILIZE BOSTON STUDY

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INTRODUCTION

Falls are a serious problem in the health of older adults. Recently, *outdoor* falls have been recognized as a distinct problem occurring even in healthy, middle age and older adults who otherwise don't exhibit typical symptoms of fall risk. Because the outdoors pose greater opportunities for mechanical perturbations on the postural system, the capacity to absorb these perturbations, quantified as mechanical stiffness and damping, may explain outdoor fall risk that other measures of balance function cannot [1]. Cognitive distractions that divert attentional resources seem to impair postural control, and thus may help explain fall risk. Standing posture can be modeled as a inverted pendulum with stiffness and damping, which represent muscle tone, reflexes, and anticipatory control [2]. During dual task, the lack of attentional resources may lead to the inability to maintain adequate muscle tone and thus enough stiffness or damping to maintain upright standing, unable to respond to perturbations.

We tested whether postural stiffness and damping predict the prospective risk of outdoor falls in a representative sample of community-dwelling older adults. We also tested if measuring this during dual task would improve our ability to predict falls in a representative sample of community-dwelling older adults, the MOBILIZE Boston Study cohort.

METHODS

The MOBILIZE Boston Study is a prospective study examining risk factors for falls, including pain, cerebral hypoperfusion, and foot disorders in the older population [3]. The study includes a representative population sample of 765 elderly volunteers age 70 or above from the Boston area. Center of pressure (COP) and falls data with ≥6 months of falls follow-up data were available in 640 participants, who were 77.9±5.3 years old, with height of 1.63±0.10 m and weight of 73.9±15.5 kg. 65% were female.

Subjects stood barefoot with eyes open on a force platform (Kistler 9286AA). The COP data were sampled at 240 Hz in anteroposterior (AP) and mediolateral (ML) directions. Subjects performed two sets of five quiet standing (QS) trials, 30 seconds each. One set included a serial subtractions task (dual task; DT).

Postural stiffness was calculated as previously described [2], where the postural system is modeled as an inverted pendulum with stiffness and damping. Movement of center of mass (COM) was estimated. Fourier transform of the difference between COP and COM was fit to a damped oscillator model to determine K_e (stiffness) and B (damping). K_e, and B values were determined for each trial using MATLAB 7.4, and then scaled to body size [4] and log-transformed.

Falls were reported using a monthly mail-in postcard calendar from each participant, after the COP measurement, with mean follow-up of 17 months (range 6-32 months). The associations between $\boldsymbol{K_e}$ and $\boldsymbol{B}$ values with prospective rate of falls were determined using a negative binomial regression [5] including other covariates associated with falls using SAS 9.1. They include age, sex, race, education, daily alcohol use, gait speed, executive function, depression, disability, peripheral neuropathy, Berg balance scale, urinary incontinence, and history of falls.

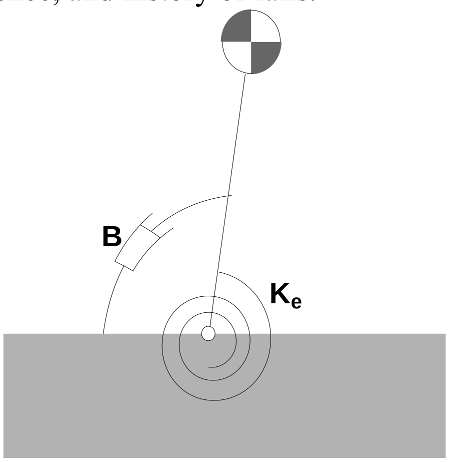

Figure 1. Damped-oscillator inverted pendulum model of quiet standing. Stiffness (***K_e***) and damping (***B***) describe the resistance to perturbations in the postural system.

RESULTS AND DISCUSSION

Greater postural stiffness (adjusted RR[1]=0.70 ($CI_{95\%}$ 0.50-0.96); p=0.03) and damping (RR=0.49 ($CI_{95\%}$ 0.29-0.82) p=0.007) were associated with lower fall rates outdoors. Results were similar for those measured during dual task. Measurements from AP and ML directions also yielded similar results (Table 1).

The results indicate that the observed stiffness and damping during quiet standing is linked to clinical outcomes of falls. The ability to manage external perturbations may be a key aspect of avoiding falls, particularly outdoors. The decrease in postural stiffness and damping may precede other risk factors for falls. Causes of this decline require further study. Dual tasking did not add to the prediction of falls. The postural system during standing may not be affected by the dual task enough to explain fall risk. A more sophisticated model of postural control that incorporate cognitive function may better explain the role of cognitive distractions on falls. Of note, mechanical stiffness here does not imply osteoarthritic "stiffness" due to joint inflammations or motor rigidity due to Parkinson's disease or other neurologic conditions.

CONCLUSIONS

Greater stiffness and damping in measured during quiet standing was associated with less risk out outdoor falls. Decline in stiffness and damping may be an early marker of fall risk in healthy older adults. Stiffness and damping during dual task were no better at predicting falls than during quiet stance.

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Table 1: Adjusted rate ratios (RR[1]) of the association between stiffness, damping, and outdoor fall rates

Measurement condition		Association of Stiffness K_e with Outdoor Falls			Association of Damping B with Outdoor Falls		
		RR[1]	95% CI[3]	P-value	RR	95% CI	P-value
AP	QS	0.70[2]	0.50 - 0.96	**0.026**	0.64	0.37 - 1.10	0.1
	DT	0.74	0.56 - 1.00	**0.048**	0.61	0.39 - 0.95	**0.027**
ML	QS	0.66	0.46 - 0.93	**0.017**	0.49	0.29 - 0.82	**0.007**
	DT	0.70	0.51 - 0.98	**0.036**	0.56	0.36 - 0.85	**0.007**

AP = anteroposterior values. ML = mediolateral values. QS = quiet stance; DT = dual task. [1]Fall incidence Rate Ratio (RR): increase in fall risk associated with a unit increase in the predictor variable. For example, [2]RR=0.70 indicates that fall rate decreases by a factor of 0.7 (30% reduction) for each unit increase in K_e (after scaling to body size and log-transform). [3]95% CI = 95% confidence interval (CI) of the RR. If the CI includes 1 (i.e., null), the predictor is not significantly associated with fall risk at p = 0.05.