INTRODUCTION

The ability to maintain balance during standing is attributable to the complex, nonlinear interactions of multiple postural control systems, which is manifest as the highly irregular displacements in center of pressure (COP) during standing. The complexity of COP displacements can be quantified by metrics such as multiscale entropy (MSE), which measures system dynamics over multiple time scales (Costa et al., 2007) and is a more sensitive measure of physiologic health than simple variability (Costa et al., 2002). Traditional methods of measuring balance do not quantify the dynamic interactions of these systems.

The process of aging, and age-associated syndromes such as frailty may result in the degradation of complex interactions among postural control systems and manifest as a loss of complexity in COP dynamics. Furthermore, frail individuals may not be able to adapt to a superimposed stress or distraction that challenges balance, leading to falls and other adverse outcomes. Therefore, we hypothesized that frail elderly people would show a loss of complexity in COP displacements during quiet standing compared to healthy elderly controls, and that a divided task would further reduce the complexity of balance dynamics in frail individuals.

METHODS AND PROCEDURES

Data were analyzed from the Mobilize Boston Study, an ongoing population-based study of 800 community-dwelling older adults (Leveille et al., 2007). Each participant’s frailty status (not frail, pre-frail, frail) was determined using the five symptoms of unintentional weight loss, slow gait, weakness, low activity, and exhaustion as defined in (Fried et al., 2001). Frailty is predictive of future falls, disability, and death. Participants exhibiting 1-2 symptoms were denoted “pre-frail,” and those with 3 or more were denoted “frail.”

Participants (n = 571, age 77.9 ± 5.5) stood on a 6-DOF force plate for 30 seconds for 10 trials. Of the ten, five trials were performed concurrently with a serial subtraction mental arithmetic dual-task. Center of pressure (COP) excursions in anteroposterior (AP) and mediolateral (ML) directions were sampled at 240Hz. The recorded COP data was detrended using empirical mode decomposition to remove low-frequency artefacts (Wu et al., 2007). Sample entropy...
was calculated after each successive coarse-graining (averaging then down-sampling) of the COP signal. Entropy values were integrated over the time scales to calculate MSE. MSE was calculated for each trial, and averaged over the 5 trials of the same condition. The effect of the dual-task and frailty on MSE was assessed using mixed-model ANOVA (SAS 9.1).

RESULTS

Of the participants 37% were pre-frail and 7% were frail. Baseline MSE of AP sway was lower in the pre-frail group, compared to the non-frail group, and it was even lower in the frail group compared to the other groups (p<0.002). MSE of COP was lowered with the dual-task for both AP and ML sway (p<0.001; Figure 1). The decrease of MSE during the dual-task was similar for all groups. RMS sway increased with dual-task as previously reported (Shumway-Cook et al, 1997) but it was not correlated with MSE (r² < 1%).

DISCUSSION

Frailty was associated with a loss of complexity in the dynamics of postural sway. This may be because frailty is associated with the degradation of integrated postural control networks that enable the body to maintain upright stance. Performance of a dual-task further reduced this complexity. This may be because the dual-task utilizes frontal lobe resources necessary for attention, sensory integration, and motor control, thus diminishing the reserves necessary to maintain balance (Yogev-Seligmann et al., 2007).

Being frail did not predict a larger reduction in MSE with dual-task, but postural control may be further compromised by the dual-task. Thus, frail elderly people may be at increased risk of falls when distracted by cognitive activities during standing.

REFERENCES

Yogev-Seligmann G et al. (2007). Mov Disord, in press.

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