EFFECTS OF LUMBAR EXTENSOR FATIGUE ON POSTURAL CONTROL ASSESSED WITH FRACTAL ANALYSIS

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INTRODUCTION

A decrement in the control of quiet upright stance has been reported with fatigue of the lumbar extensors (e.g., Davidson et al., 2004; Madigan et al., 2006). In these and related studies, descriptive measures based on center of pressure (COP) were employed to quantify changes in postural control. COP dynamics, however, appear to have fractal characteristics (Collins & De Luca, 1995; Duarte & Zatsiorsky, 2000). As such, fractal methods may help to describe the complexity of the postural control system (Eke et al., 2002). In this study, we assessed the effects of lumbar extensor muscle fatigue on postural control during quiet upright stance using both a fractal analysis and traditional descriptive COP-based measures.

METHODS AND PROCEDURES

Thirty-two healthy individuals (16 older and 16 young) from the university and local community participated in the study. Mean (SD) age, stature and body mass were 20.9 (1.7) yr, 171.1 (6.8) cm and 67.3 (12) kg for young participants; and 63.2 (5.5) yr, 167.8 (10.6) cm and 77.6 (17.8) kg for older participants. All provided informed consent following the procedure approved by the Virginia Tech Institutional Review Board.

Each experimental session consisted of three stages following an initial warm-up and practice. Within each stage, trials of quiet-upright stance were performed. There were three pre-fatigue trials, followed by fatiguing exercise, and 11 post-fatigue sway trials (over a 30-min period). During stance trials, participants stood as still as possible on a force platform (AMTI, Watertown, MA) while barefoot with their eyes closed, arms at side and feet together. Triaxial ground reaction forces and moments were sample at 100 Hz for 75 s, and the first 10 s and the last 5 s were removed. COP trajectories were obtained in the anterior-posterior (AP) and the medial-lateral (ML) direction and were demeaned in their respective directions.

Fatigue was induced using a dynamometer (Biodex 3 Pro, NY). Participants performed sub-maximal isotonic lumbar exertions (60% of their maximum voluntary contractions) at a pace of 12 repetition/min throughout a range of motion (ROM) of 45 degrees. This exercise was terminated when participants failed to perform exertions over the entire ROM in three consecutive attempts.

As proposed by Eke et al. (2000), the Hurst exponent ($\hat{H}$) was estimated by first classifying each COP trajectory in the AP and ML directions using bridge detrended scaled window variance (bdSWV) analysis with the signal summation conversion. Based on the classification, either dispersional, bdSWV, or detrended fluctuation analysis was applied to the COP trajectory to obtain $\hat{H}$. Four descriptive COP-based measures were also obtained: COP mean velocity (MV), 95% confidence ellipse area (EA95), and mean power frequency (MPF_{AP} and MPF_{ML}). These descriptive measures were normalized using individual anthropometric data (Hof, 1996).

Two-way ANOVAs were performed to determine the effects of age (Older vs. Young) and fatigue condition (Baseline vs. Fatigued vs. Recovered) on the dependent measures. Means of measures obtained in the last three post-fatigue sway trials (20, 25 and 30 min) were used to represent a 'recovered' condition. Significant effects were followed by post-hoc analyses (Tukey HSD), and statistical significance was determined at $p < .05$.

RESULTS

Fatigue had a significant effect on $\hat{H}_{AP}$, which was highest in the recovered condition. Main and interactive effects of age and fatigue were found on $\hat{H}_{ML}$ (Figure 1).

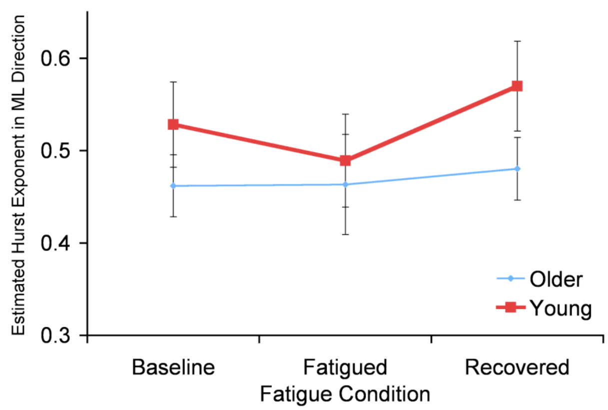

Figure 1. Main and interactive effects of age and fatigue on $\hat{H}_{ML}$. Error bars indicated two standard errors (SE).

Fatigue and age x fatigue interaction effects were found for MV; MV values significantly increased in the fatigued condition, but only for young participants. Fatigue effects were also found on EA95, MPF_{AP} and MPF_{ML}, with larger values found in the fatigued condition.

DISCUSSION

Young participants demonstrated a slight persistence of COP increments in the ML direction in both the baseline and recovered conditions ($\hat{H}_{ML} > .5$), while older participants had a slight anti-persistence of COP increments ($\hat{H}_{ML} < .5$). Changes in $\hat{H}_{ML}$ and MV with fatigue were found only for young participants, which may be related to postural adaptations reported among young people (Madigan et al., 2006). Specifically, lumbar extensor fatigue caused a slight forward lean and an increase in variability of lower extremity joint angle and angular velocity in this group. Older participants may not have adopted such postural adaptations or employed different adaptations.

Descriptive COP-based measures returned to baseline values over ~25 minutes of recovery, comparable to the results in Yaggie and McGregor (2002). Of interest, however, is that $\hat{H}_{AP}$ values increased post-fatigue. It may be that alterations of the postural control system induced by lumbar extensor muscle fatigue were not fully recovered, or that different strategies were adopted. Further study is needed to understand the relationship between postural changes (joint kinematics) and changes in $\hat{H}$ during quiet upright stance with localized muscle fatigue.

REFERENCES

Collins, JJ and De Luca, CJ (1995). *Chaos*, 5:57-63.

Davidson BS et al. (2004). *Eur J Appl Physiol,* 93:183-189.

Duarte, M and Zatsiorsky, VM (2000). *Neurosci Lett*, 283:173-176.

Eke A et al. (2000). *Eur J Physiol*, 439:403-415.

Eke A et al. (2002). *Physiol Meas*, 23:R1-R38.

Hof AL, (1996). *Gait & Posutre*, 4:222-223.

Madigan ML et al. (2006). *Hum Mov Sci*, 25:788-799.

Yaggie, JA and McGregor, SJ (2002). *Arch Phys Med Rehabil*, 83:224-228.