THE RELATIONSHIP BETWEEN STRUCTURAL AND SPATIAL VARIABILITY OF POSTURAL CONTROL IN PERSONS WITH PARKINSON DISEASE.

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INTRODUCTION

Computerized posturography has been widely used in the laboratory setting to evaluate postural stability. To date, various outcome measures have been proposed and used, including the mean velocity of center of pressure (COP) and postural sway area, to evaluate postural stability in healthy adults and various pathological populations. However, these measures are summary statistics of COP movement and are not time-dependent. Given that postural stability must be maintained continuously in time-series, these summary statistics might not be sufficient to fully quantify and understand postural control abilities. Moreover, there is contradicting evidence regarding postural stability in persons with Parkinson disease (PD). Specifically, some previous studies stated that persons with PD exhibited more pronounced postural sway than age-matched healthy individuals, while the other studies have reported that persons with PD exhibit less variability, indicating postural inflexibility in persons with PD [1]. Thus, The time-dependent measures may give further insight into how persons with PD control posture. Recently, approximate entropy (ApEn) and Time-To-Boundary (TTB) have been used to assess subtle changes in postural stability across age and disease. Briefly, ApEn is the regularity statistic representing the complexity of a time-series physiological signal [2]. TTB, which is derived from instantaneous velocity and acceleration, predicts the time it would virtually take the COP to reach the limits of the base of support (BOS) [3]. Lower TTB measures are associated with greater postural instability.

To date, there is a lack of research evaluating how both spatial and time-dependent measures may be related with each other in persons with PD. Thus, the purpose of this study is to examine the relationship among summary, regularity, and frequency-related statistics during quiet standing in persons with PD.

METHODS

Twenty-nine people with idiopathic PD (mean age: 65.1±2.0 years, height: 164.7±6.0cm, mass: 77.3±3.4 kg) participated in this study. A written informed consent was obtained from each participant prior to participation. During testing, each participant was asked to stand as still as possible for 60 seconds on a force platform with their feet 10cm apart. The ground reaction forces under the feet were collected at 360Hz and low-pass filtered at 12.5 Hz using a second-order Butterworth filter. COP velocity (COPVEL), 95% confidence ellipse (Area95), ApEn and mean peak TTB (pTTBmean) in both anteroposterior (AP) and mediolateral (ML) directions were calculated using the time-series COP data. The algorithms for these calculations were based on the previous literature [3,4]. To obtain 95% frequency range (95%FREQ), the raw time-series COP data was detrended, multiplied by a Hanning window, and then transformed to the frequency domain using a discrete Fourier Transformation (DFT) method. The power spectrum was then normalized so that the total power from 0 to 12.5 Hz was equal to 1. All dependent measures were computed using customized MATLAB software (The MathWorks, Inc, Natick, MA). Each participant completed three consecutive trials and all dependent measures were first computed for each trial and then averaged across trials. A Pearson correlation analysis was conducted to assess relationships among the dependent measures. The level of significance was set at α=0.05.
RESULTS

Area95 was not significantly related to any other dependent measures except COPVEL (r=0.53, p<.05). ApEn and TTB measure were significantly related. Specifically, ApEn in AP direction was negatively related to mean peak TTB in both directions (pTTBmean-AP: r=-.67 and pTTBmean-ML: r=-.48, both p<.05). The same pattern was also found in ApEn in ML direction (pTTBmean -AP: r=-.59 and pTTBmean-ML: r=-.65, both p<.05). As for the relationship between ApEn and the frequency component, ApEn in ML direction was positively related to 95%FREQ only on ML direction (r=.79, both p<.05), while ApEn in AP direction was positively related to 95%FREQ on both directions (AP: r=.66, ML: r=.68, all p<.05). The pTTBmean on each direction was related to each other (r=.78, p<.05), but they were negatively correlated only with 95%FREQ in ML direction (pTTBmean-AP: r=-.55, pTTBmean-ML: r=-.56, both p<0.05), not in AP direction. The COPVEL was significantly related to both ApEn (AP: r=.47, ML: r=.51, both p<.05) and pTTBmean (AP: r=-.74, ML: r=.48, both p<.05) in both directions but not to frequency components.

DISCUSSION

The present study demonstrated that spatial measure (Area95) was not significantly related to any of the outcome measures, except COPVEL. This finding may be expected since Area95 only represents the magnitude of postural variability, and the other dependent measures (i.e., ApEn, TTB, 95%FREQ) assess the structure of its variability, which is indicative of time-dependent postural dynamics. Although sway magnitude has been widely used to evaluate postural control, our results indicate that evaluating only “magnitude” of postural fluctuation cannot fully capture an individual’s postural control ability. Indeed, some participants with PD who exhibited a small magnitude of COP (i.e., small Area95) swayed at higher frequency range and/or manifested lower pTTBmean. Previous literature suggested that postural fluctuation at a higher frequency range is indicative of reliance on visual information and age-related balance deterioration [5]. It appears that our findings are contradicting, but may indicate postural inflexibility often observed in persons with PD, rather than good postural control ability.

The other intriguing finding is the positive relationship between ApEn and 95%FREQ. High ApEn values indicate lower regularity and high complexity of COP oscillation, and vice versa. Generally, reduction of afferent input leads to more predictable time-dependent postural control, called the loss-of-complexity hypothesis [5,6]. However, we also found that our PD participants who manifested unpredictable (reduced regularity) COP oscillation tended to show COP patterns in the high frequency range. These conflicting results indicate that high ApEn may also be indicative of compromised postural abilities which may be a result of disease-related muscle co-contraction. High ApEn values may also be the consequence of high sway frequency that persons with PD chose to overcome their limitations, rather than the manifestation of high adaptability in postural control. The alternative explanation is that both parameters are measuring the same characteristic of postural control. Further investigations are needed to identify the relationship between complexity and frequency-related measures.

In conclusion, it is imperative to evaluate postural dynamics and instability from multiple perspectives, such as spatial magnitude, time-dependent structure, and frequency components of COP variability. Relying on only one aspect of postural control may be detrimental and may possibly lead to misinterpretation of true biological capabilities.

REFERENCES