FRACTAL DYNAMICS OF HUMAN STABILOGRAM IN QUIET STANCE

[1] Jianhua Wu, [2]Ning Pan and [3]Keith R. Williams
[1]Division of Kinesiology, University of Michigan, Ann Arbor, MI 48109;
[2]Biological & Agricultural Engineering, [3]Exercise Biology, University of California, Davis, CA 95616;
Email: wjhwu@umich.edu

INTRODUCTION

To reveal the dynamics of center of pressure (COP) such as the magnitude and direction of displacements between COP points, a stabilogram-diffusion analysis (DFA) was proposed [1]. The DFA assumes a COP profile as a fractional Brownian motion (fBm), and applies the basic relation of a long-memory process, which expresses a typically unbounded process with an unlimited diffusion, to estimate the Hurst coefficient. As COP profiles are usually bounded due to physiological limits, the DFA thus conducted to COP naturally biases the results [2]. We first examined if a COP profile is a fBm signal, and then used a bridge detrended scaled window variance method (bdSWV) to estimate the Hurst coefficient if applicable.

METHODS

Twelve healthy female college students volunteered in this study. The subjects stood barefoot on a Kistler® 9287 force platform as still as possible in 1) eyes open (EO) and 2) virtual dynamic vision (DV). Three trials were collected for each subject at 100 Hz for 60 seconds. COP data in anterior-posterior (AP) direction were analyzed. Raw data were filtered by a second order Butterworth with cutoff frequency 5 Hz.

A power-law $q(f) \sim 1/f^{\beta}$ exists in the Fourier power spectrum of a fBm signal, where $q(f)$ is the power at a frequency f, and β is the scaling exponent with $1<\beta<3$. A power spectral analysis (PSA) was conducted to raw COP data, and β was estimated for the frequencies lower than 1/8 of the sampling rate [3].

A fBm signal obeys the scaling law $Var(\Delta x) \sim \Delta t^{2H}$, where $Var(\Delta x)$ is the variance of the displacement Δx, Δt is the time interval, and H is the Hurst coefficient with $0<H<1$. When $H>0.5$, COP is positively correlated (persistence), i.e., the direction of the past COP movement will be likely continued in the future movement. A higher H in this context denotes a higher level of persistence. Conversely, when $H<0.5$, COP is negatively correlated (anti-persistence). A lower H here represents a higher level of anti-persistence [2]. The bdSWV [4] was conducted to the filtered COP data such that 1) data were partitioned into non-overlapping windows in one time interval, 2) a bridge detrending was performed and standard deviation (SD) was calculated within each window, 3) average SD was calculated for each time interval, 4) H was estimated in the log-log plot of average SD versus time intervals.

RESULTS AND DISCUSSION

Scaling exponent β (Table 1) was within the range of 1 to 3, indicating that a COP profile is a fBm signal regardless of visual condition. Two linear portions were observed through the bdSWV method irrespective of visual condition (Figure 1) such that the short- and long-term regions were separated by a transition point T, which was close to 1 second (Table 1). H_s was higher than 0.5 and H_l was lower than 0.5 in both visual conditions (Table 1), similar to the findings by a DFA analysis [1]. Two control schemes may be expected in quiet stance such that persistence dominates in the short-term region while anti-persistence governs in the long-term region [1]. This implies that the postural control system may not use input from the visual, vestibular and somatosensory systems to regulate muscle activities unless the input reaches a threshold.

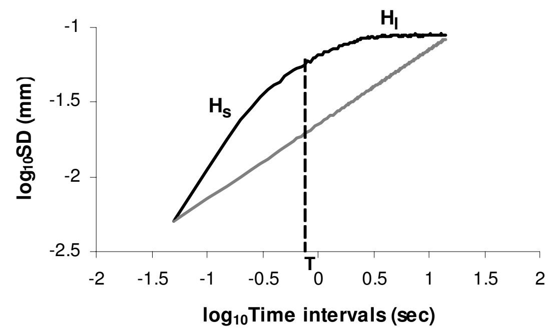

Figure 1: A representative log-log plot of average SD vs time intervals. T is transition point, H_s and H_l is the Hurst coefficient for short- and long-term regions, respectively.

H_s in DV was significantly higher than that in EO, while H_l in DV was significantly lower than that in EO (Table 1). Dynamic visions yielded higher levels of persistence and anti-persistence in the short- and long-term regions, respectively. The higher anti-persistence in DV may be due to the increase of the activity of musculature in quiet stance.

CONCLUSIONS

It was concluded that a COP profile is a fBm signal, and the bdSWV is able to reveal the fractal dynamics of COP profiles.

REFERENCES

1. Collins JJ, et al. *Exp Brain Res* **95**, 308-318, 1993.
2. Delignieres D, et al. *J Mot Behav* **35**, 86-96, 2003.
3. Eke A, et al. *Eur J Physiol* **439**, 403-415, 2000.
4. Cannon MJ, et al. *Physica A* **241**, 606-626, 1997.

ACKNOWLEDGEMENTS

Thank National Textile Center for funding this study.

Table 1: Results of PSA and bdSWV method (* denotes a significant difference between EO and DV at p<0.05 level)

	β	T	H_s	H_l
EO	2.34	0.84	0.89	0.12
DV	2.60*	0.90	0.94*	0.08*