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Characterizing the human postural control system using detrended fluctuation analysis

M. Teresa Blazquez, Marta Anguianoa, Fernando Arias de Saavedraa, Antonio M. Lallena, Pedro Carpena a Departamento de Fisica Atomica, Molecular y Nuclear, Universidad de Granada, E-18071 Granada, Spain b Departamento de Fisica Aplicada II, E.T.S.I. de Telecomunicacion, Universidad de Ma?laga, E-29071 Ma?laga, Spain

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ABSTRACT

Detrended fluctuation analysis is used to study the behaviour of the time series of the position of the center of pressure, output from the activity of a human postural control system.

The results suggest that these trajectories present a crossover in their scaling properties from persistent (for high frequencies, short-range time scale) to anti-persistent (for low frequencies, long-range time scale) behaviours. The values of the scaling exponent found for the persistent parts of the trajectories are very similar for all the cases analysed. The similarity of the results obtained for the measurements done with both eyes open and both eyes closed indicate either that the visual system may be disregarded by the postural control system, while maintaining quiet standing, or that the control mechanisms associated with each type of information (visual, vestibular and somatosensory) cannot be disentangled with this technique.

The human postural control system (PCS) integrates various mechanisms that prevent the human body from falling in both statical and dynamical conditions. Information coming from the proprioceptive, vestibular and visual systems is integrated for this purpose and manifests in postural sway. These three systems include a backup procedure which permits a correct body

balance in case some of them fail. The main tool used to investigate this complex balance system has been the stabilogram, which is a measure of the time behaviour of the center of pressure (CoP) of a person standing on top of a force platform. An important part of the investigations carried out by means of the stabilogram were restricted to ‘‘simple’’ statistics of the CoP path, such as distances from the geometric mean CoP, average CoP velocity, total CoP excursion, maximum distance between any two points on the CoP path, enclosed area, etc. [1]. However, the dynamic characteristics of the stabilogram are of fundamental importance, even in the case of quiet standing, and a great number of recent works, mainly in the last decade, have focused on the analysis of the non-stationary time properties of the CoP path [2–6]. The purpose of this work is to apply detrended fluctuation analysis (DFA) to a set of experimental data including 20 measurements for each of the 20 subjects forming the sampling group. Our purpose is twofold. First we want to address the controversy between Collins and De Luca [2] and Delignie?res et al. [6] with respect to the actual presence of a crossover from persistent to anti-persistent behaviour. On the other hand, having at our disposal a large quantity of measurements, we want to find more quantitative results for the scaling properties of the CoP trajectories. Acknowledgements This work has been supported in part by the Junta de Andaluci?a (FQM0220) and by the Ministerio de Educacio?n y Ciencia of Spain (P07-FQM3163). References [1] T.E. Prieto, J.B. Myklebust, B.M. Myklebust, Characterization and modeling of postural steadiness in the elderly: A review, IEEE Trans. Rehabil. Eng. 1 (1993) 26–34. [2] J.J. Collins, C.J. De Luca, Random walking during quiet standing, Phys. Rev. Lett. 73 (1994) 764–767. [3] M. Ferdjallah, G.F. Harris, J.J. Wertsch, Instantaneous postural stability characterization using time–frequency analysis, Gait Posture 10 (1999) 129–134. [4] V.M. Zatsiorsky, M. Duarte, Instant equilibrium point and its migration in standing tasks: Rambling and trembling components of the stabilogram, Mot. Control 3 (1999) 28–38. [5] S. Thurner, C. Mittermaier, R. Hanel, K. Ehrenberger, Scaling-violation phenomena and fractality in the human posture control systems, Phys. Rev. E 62 (2000) 4018–4024. [6] D. Delignie?res, T. Deschamps, A. Legros, N. Caillou, A methodological note on non-linear time series analysis: Is Collins and De Luca (1993)’s open- and closed-loop model a statistical artifact, J. Motor Behaviour 35 (2003) 86–96. [7] SATEL, Manuel d’utilisation des logiciels d’e?valuation des activite?s posturo-cine?tiques, Satel, Blagnac, 2000. [8] A.V. Coronado, P. Carpena, Size effects on correlation measures, J. Biol. Phys. 31 (2005) 121–133. [9] C.K. Peng, S.V. Buldyrev, S. Havlin, M. Simon, H.E. Stanley, A.L. Golberger, Mosaic organization of DNA nucleotides, Phys. Rev. E 49 (1994) 1685–1689. [10] M. Duarte, V.M. Zatsiorsky, Long-range correlations in human standing, Phys. Lett. A 283 (2001) 124–128. [11] C.K.Peng,S.Havlin,H.E.Stanley,A.L.Golberger,Quantificationofscalingexponentsandcrossoverphenomenainnonstationaryheartbeattimeseries, Chaos 5 (1995) 82–87.