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Is postural behavior in quiet standing random?

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TITLE: Is postural behavior in quiet standing random?

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Significance and Objective: The maintenance of human vertical body orientation (bipedal standing) is essential to the performance of activities of daily living and maintenance of someone's independency. Although the task of quiet standing seems trivial, it requires an intricate interaction of several elements forming the neuromuscular system. For decades, research groups worldwide have focused their efforts on understanding these interactions by measuring the body sway, an important approach to the study of these neurophysiological principles. For example, when a person is asked to stand quietly, the point of application of the ground reaction force, known as center of pressure (COP), shows a natural migration that is very sensitive to changes in the neural mechanisms used to control the large number of muscles responsible for the stabilization of the leg and trunk. Therefore, a large number of previous investigations have focused on the development of computational methods aiming to assess postural balance by including measures, such as COP range, COP trajectory length, COP mean velocity, root mean square and frequency analysis. However, a drawback of these measurements is their ability to describe only the magnitude of the postural sway. The structure and regularity of the postural sway (eg., how the COP trajectory emerges in time) are still not clear. In order to fill this gap, we further investigated the temporal aspect of postural sway behavior by using the approximate entropy statistical method (ApEn) to measure the randomness and regularity of the postural sway in quiet standing. It is hypothesized that the postural sway in quiet standing does not follow a repetitive pattern of fluctuation along time.

Research Methodology: The behavior of the body sway was investigated by analyzing the randomness and regularity of the COP displacement over time when standing upright. We used the ApEn method, which is an algorithm that measures correlation, persistence, or regularity of time-series data. A time series with many repeating patterns of fluctuations renders it more predictable and thus results in a relatively small ApEn. On the other hand, higher ApEn values are caused by less predictable movements and imply more independent control processes. Fourteen healthy young adults (± 29 years old, ± 79 kg, ± 171 m) participated as volunteers in the study. They were asked to stand quietly on a force platform for 35 seconds while keeping their body as vertical and still as possible. The antero-posterior and medio-lateral COP (COP_{AP} and COP_{ML}, respectively) signals recorded by the force platform were used in the study. ApEn for each direction (ApEn_{AP} and ApEn_{ML}, respectively) and cross-approximate entropy between AP and ML directions (crossApEn) were computed with a series of custom-written software routines (Matlab R2012b, The MathWorks). In order to investigate the pattern of fluctuation of the postural sway, fourteen data series of different sine waves and fourteen random data series were artificially created to simulate a predictable and a random pattern of data series fluctuation, respectively. ApEn for each of these twenty eight data series were computed. Parametric tests were used to analyze the dependent variables (ApEn_{AP}, ApEn_{ML}, crossApEn, ApEn_{PREDICTABLE}, and ApEn_{RANDOM}) and the level of significance was $\alpha=0.05$.

Results: The results showed that the COP_{ML} displacement presented a repetitive pattern of fluctuation in time. However, the COP_{AP} displacement was not as predictable as in the medio-lateral direction. In addition, there was a phasic relationship between COP_{AP} and COP_{ML} displacement.

Conclusion: These findings support the idea that the upright stance control in healthy adults is not a simple process. In order to maintain balance in a vertical posture, the participants

presented a predictable medio-lateral postural sway and a less repetitive pattern of postural sway in the antero-posterior direction. And despite the more random sway in one direction, the postural sway between both directions was synchronized along time. Our findings not only support the importance of the temporal aspect of postural control to maintain balance when standing upright but also extend the use of the ApEn method as an additional tool to detect subtle changes in the randomness and regularity in postural control in clinical assessments involving special populations suffering any neuromusculoskeletal disorder.