ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

CLASSIFICATION OF QUIET STANDING CONTROL BY PERCEPTRON NEURAL NETWORK AND PRINCIPAL COMPONENT ANALYSIS: A PILOT STUDY

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SUMMARY

This work aims at classifying the body sways based on principal components of elliptical sway area (EA) and mean velocity (MV) of center of pressure by perceptron neural network. A sample of 27 young, healthy male adults was monitored during a stabilometric test, standing on a force platform during 3 min, with eyes closed, and feet in a closed position. The data were stored in a matrix, where rows represent subjects and the columns the sway path, MV, both in mediolateral and anterior-posterior axis, and EA. Then, PCA was applied. The median of MV and EA were used for performing the separation in two groups with lower and greater values than median. The perceptron neural network was performed to classify subjects based on sort values of MV and EA. The overall explained variance was 90% with 76% in the first component. The perceptron neural network classified linearly the subjects in two groups, with greater error when the EA was the discriminant variable than MV. The mean velocity was more effective as a target during the performance of the neural network.

INTRODUCTION

Various control mechanisms are discussed in the maintenance of upright posture. Among these studies, Zatsiorsky and Duarte [1] modeled the body sways as composed by two components: rambling, which refers to the slow migration of the reference from one instant equilibrium point (IEP) to another, and trembling, composed by high-frequency oscillations around the IEP. In our interpretation, IEP can represent the stabilization of center of pressure (COP) by proportional-derivative feedback, which was used by Peterka [2] for modeling quiet standing control. Moreover, trembling can correspond to exploratory-performatory behavior as stated by Riley et al. [3]. Comparing rambling and trembling model with classical and simple measures of COP displacement, we can assume the elliptical sway area (EA) and mean velocity (MV) as stability and control measures, respectively. While the COP moves in an area limited by base of support delimited by feet [4], its MV is strongly sensitive to sensory condition [5].

As the quiet standing can show different patterns among subjects, a classification of the pattern of COP displacement based on classical variables would be important for their interpretation. The method widely used for classifying different clinical patterns is the principal component analysis (PCA) [6], which is particularly performed during gait analysis in pathological conditions [7]. Based on the scores of the PCA the neural network would be a good tool for classifying different patterns of control. One type of neural network able to performing such process is the perceptron. This neural network is a linear classifier for supervised classification of an input into one of several possible non-binary outputs.

This work aims at classifying the body sways based on principal components (PCs) of EA and MV by perceptron neural network.

METHODS

Subjects – Participated in this study 27 young male subjects, with age 25 ± 6 years (mean ± standard deviation), body mass 79.7 ± 8.7 kg, and height 1.77 ± 0.05 m, with no history of neurological disorders or orthopedic diseases. The experimental protocol was approved by the Ethical Human Research Committee of the Federal University of Rio de Janeiro (CAAE – 0034.0.239.000-10), and all subjects were voluntary and signed a free informed consent before inclusion in the study.

Stabilometric Data Recording – The COP displacements were measured by a force platform AccuSwayPlus (AMTI, USA) at a sample rate of 200 Hz. The force plate was automatically initialized by the software Balance Clinic (AMTI, USA) before each stabilometric test. The signals were saved and exported in text format for further processing with programs written in MATLAB version 6.5 (The Mathworks, USA).

Balance Assessment – The subjects were initially submitted to an anamnesis and anthropometric measurements. Each subject was oriented to stay three minutes over the force platform in the quiet standing position, barefoot, with arms relaxed, with eyes closed and feet positioned in according to the Association Française de Posturologie [8].

Pre-Processing – The stabilometric signals were pre-processed by a 2^{nd} order digital Butterworth low-pass filter with cutoff frequency 2 Hz, applied in direct and reverse directions to avoid phase shifts. Then, the signal was decimated to 5 Hz.

Data Processing – A linear detrend procedure was applied on COP displacement signals in the anterior-posterior and mediolateral directions. The classical variables sway path (SP), MV and EA were calculated. The SP was obtained from total length of COP, whereas MV was the ratio between SP and the duration of the trial (180 s). Additionally, EA was calculated by the PCA approach [9].

The data were stored in a matrix, where rows represent subjects and the columns the SP, MV, both in mediolateral and anterior-posterior axis, and EA. Then, PCA was applied and the data from each subject were represented by their PC scores. The two PC with higher variances were stored to further analysis.

The median of MV and EA were used for performing the separation in two groups with lower and greater values than median, and the PC scores were visually identified by different labels. The median subject was discarded. The perceptron neural network was performed to classify subjects based on sort values of MV and EA.

RESULTS AND DISCUSSION

The overall explained variance was 90% with 76% in the first component. The use of the first two PCs allowed localizing each subject on a diagram (Figure 1). This analysis showed two separate groups in different regions of the scatter plot. The perceptron neural network classified linearly the subjects in two groups, with greater error when the EA was the discriminant variable (Figure 1A) than MV (Figure 1B).

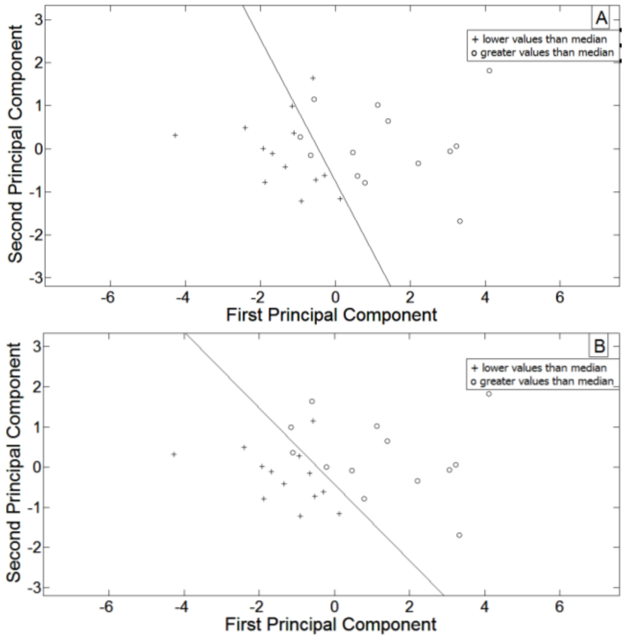

Figure 1: Scores of the principal components and straight line fitted by perceptron neural network to classify subjects in two groups based on elliptical sway area (A) and mean velocity in mediolateral axis (B).

Indeed, using the EA as a target to perform classification by perceptron resulted on one and two misclassification of lower and greater EA than median. Furthermore, the MV showed one misclassification to each group.

This results show that the MV is more sensitive than EA in COP behavior and consequently more effective to classification with neural network. This pattern was observed in Tahayor et al. [4] study, where different loads applying in quiet standing position does not induced changes in the sway area.

CONCLUSIONS

As a conclusion, the perceptron classified the PC scores of subjects in high and low mean velocity and elliptical sway area. The mean velocity was more effective as a target during the performance of the neural network.

ACKNOWLEDGEMENTS

This study was partially supported by the Brazilian agencies CNPq and CAPES.

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