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Original paper

Power spectral density in balance assessment. Description of methodology

MAŁGORZATA SYCZEWSKA[1]*, TERESA ZIELIŃSKA[2]

[1] Department of Paediatric Rehabilitation, The Children's Memorial Health Institute, Warsaw, Poland.
[2] Department of Mechanics, Energetics and Aviation, Technical University of Warsaw, Poland.

One of the methods used in clinical setting to assess the balance function is the measurement of the centre of pressure trajectory (COP). The COP trajectory is strongly dependent on the body centre of mass trajectory (COM), but in case of balance problems the corrective signals influence this dependence. The aim of the present study is to explore the possibility of using power spectral density function of the COP vs. COM signal in assessing the amount of correction signals. As the aim was a methodological one, only one healthy adult subject participated in the study. This subject performed five balance tasks of increasing difficulty. The COP trajectory was recorded using the Kistler force plate, and COM trajectory was calculated based on the marker trajectories placed on the subject's body and simultaneously recorded with VICON 460 system. The COM data were subtracted from COP trajectory in anteroposterior (AP) and lateral direction. Next the power spectral density (PSD) was calculated for the new signals. The power spectral density is very low for easiest condition, but increases with the difficulty of task. Moreover, it also provides information in which plane (sagittal or frontal) more correction movements are needed to maintain stability.

Key words: *balance, power spectral density, COP, COM*

1. Introduction

Maintaining the upright body posture in a stable and safe way is one of the prerequisites of everyday life activities. Keeping balance in standing position requires proper functioning of the sensory system, integration of the signals coming from them, and intact motor control [1]. In many diseases this ability is affected [2]–[4]. In patients with balance problems the aim of the treatment is to restore the balance function, or at least to prevent its further deterioration. Therefore, the assessment of balance function is one of the most common functional tests performed in clinical settings. One of the methods used for this assessment is posturography [1], [5]. The sway of the centre of pressure (COP) is measured with the help of force plates, and various parameters are then calculated from the COP trajectory. Postural sway results from corrective signals, which tries to keep the COP within the safety limits. More difficult tasks require more corrections from the central nervous system (CNS). Although the COP trajectory is strongly dependent on the body centre of mass (COM) [6], [7] the amount of the correction signals should influence this dependence. Therefore the aim of the present study is to explore the possibility of using power spectral density function of the COP vs. COM signal in assessing the amount of correction signals.

2. Material and methods

As the aim of the study was to check if the power spectral density function could be used in balance

* Corresponding author: Małgorzata Syczewska, Department of Paediatric Rehabilitation, The Children's Memorial Health Institute, al. Dzieci Polskich 20, 04-730 Warszawa, Poland. Phone: +48-22-1851748. E-mail: m.syczewska@czd.pl
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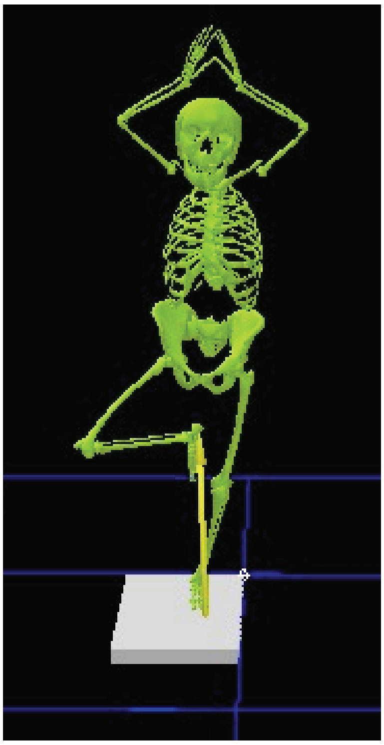

Fig. 1. The Plug-In-Gait full body model of the “Tree” asana, version 2, with body mass distributed mainly in frontal plane

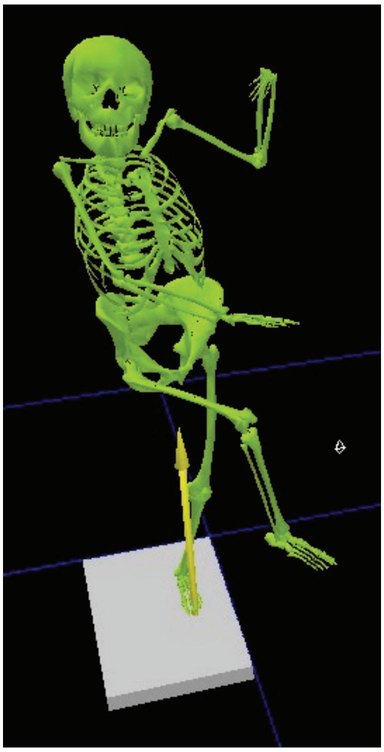

Fig. 2. The Plug-In-Gait full body model of “Dancing Shiva” asana with one upper and one lower extremities shifted in front of the body

studies, only one healthy adult subject participated in the study. The subject, although healthy, has had some individual postural features: posterior pelvic tilt and knee hyperextension. She performed several standing tasks:

– standing with eyes open, feet parallel, distance approximately equal to pelvic width;

– standing with eyes closed, feet parallel, distance approximately equal to pelvic width;

– standing on one leg in yoga asana “Tree”, version one;

– standing on one leg in yoga asana “Tree”, version two (figure 1);

– standing on one leg in yoga asana “Dancing Shiva” (figure 2).

The last three tasks require high level of correction from CNS; therefore, they were chosen to mimic the behaviour of patients with balance problems. Moreover, in “Tree” asana the lower and upper extremities are situated in the frontal plane, while in “Dancing Shiva” asana one lower extremity and one upper extremity are in front of the subject, in sagittal plane, changing considerably the mass distribution in space. Each task lasted approximately one minute.

The COP trajectory was recorded using the Kistler force plate. Simultaneously the kinematic data were recorded (35 markers were placed on all subject’s body segments) using VICON 460 system. The data were later used to calculate body COM using Plug-In-Gait model. The kinematic data were sampled at a frequency of 60 Hz, and force platform data with 1980 Hz. The frequency of the force plate and kinematic data was later transferred to 60 Hz during the data processing procedure.

The COM data were substracted from COP trajectory in anteroposterior (AP) and lateral directions. Next the power spectral density (PSD) was calculated for the new signals. This function describes the amount of power carried by the signal distributed among the frequencies [8], and thus could illustrate the amount of corrections the CNS must exhibit to maintain the desired body posture.

3. Results

The results obtained are presented in figures 3 and 4. Figure 3 shows the difference between COP and COM trajectories in lateral and AP directions in two conditions: eyes open (the smallest difference), and in “Dancing Shiva” asana (the highest difference). Figure 4 shows the power spectral density of the new signals (COP-COM) for four conditions: eyes open, eyes closed, “Dancing Shiva”, and “Tree”, version 2.

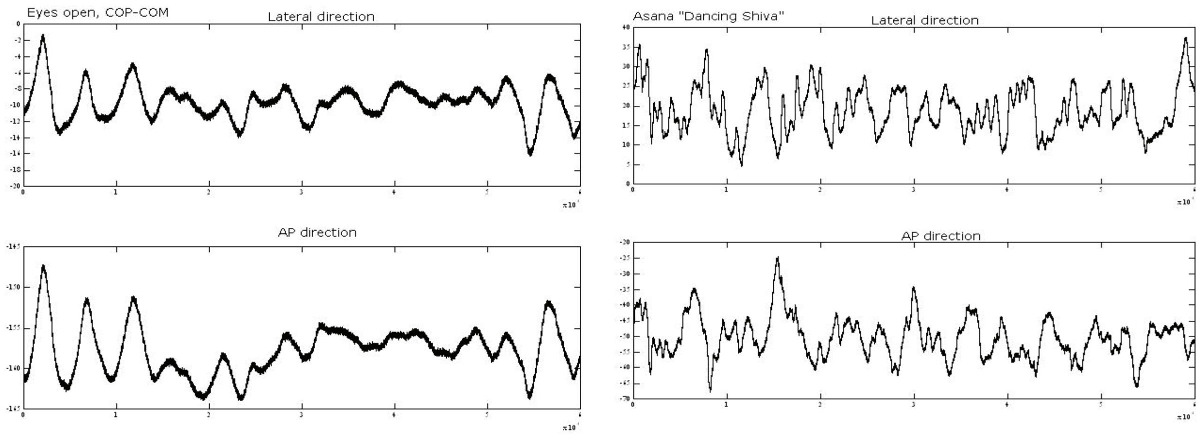

Fig. 3. COP-COM in lateral and AP directions during eyes open condition and “Dancing Shiva” condition

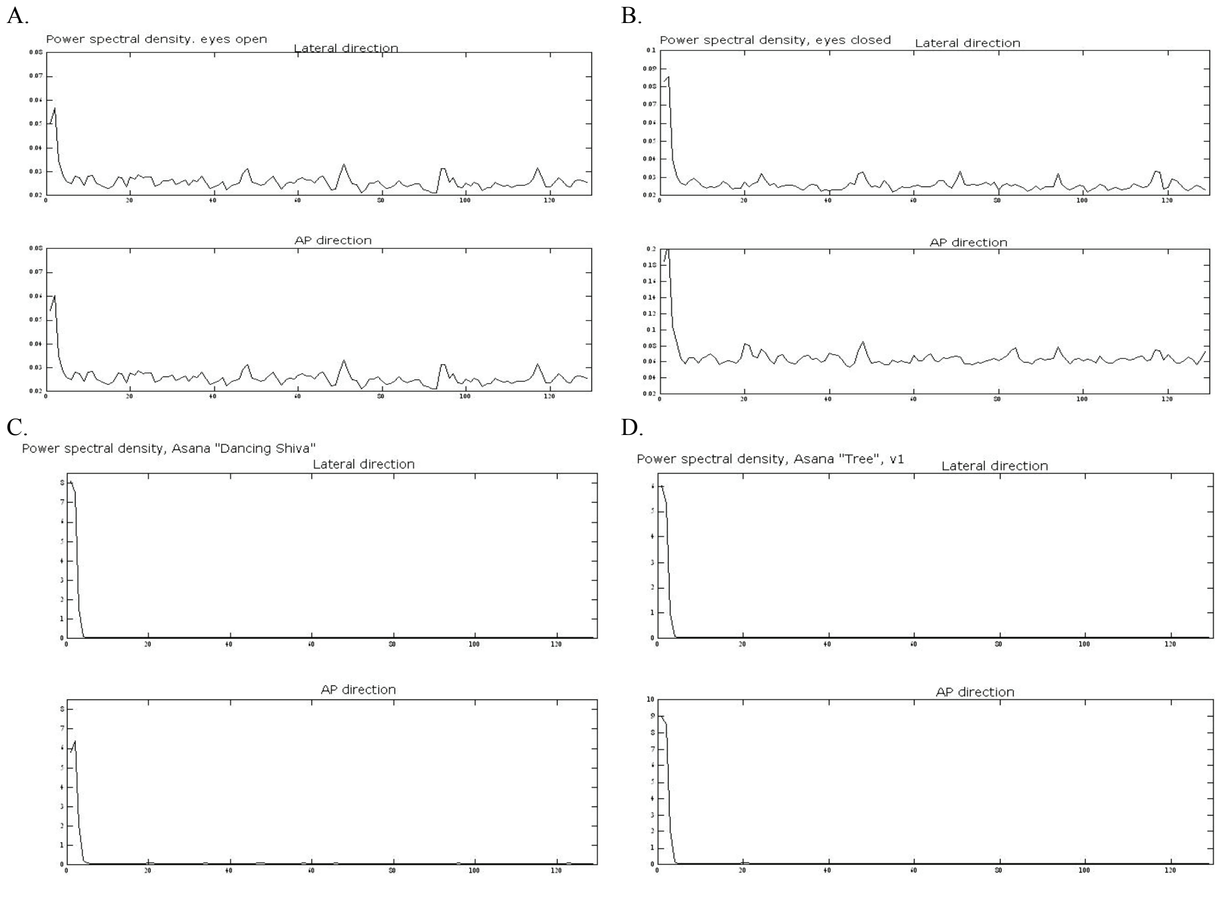

Fig. 4. Power spectral density of COP-COM signals in lateral and AP directions for four conditions: eyes open (A), eyes closed (B), “Dancing Shiva” (C), and “Tree”, version 2 (D)

4. Discussion

Although COM and COP trajectories are dependent on each other, the results show that in all four conditions there is a difference between them, both in AP and in lateral directions (sagittal and frontal planes). This difference is small in the case of eyes open condition, but increases with the difficulty level of the balance task.

The power spectral density is very low for the eyes open condition, thus reflecting the small amount of energy the CNS needs to do corrections, but increases with the difficulty of task. The difference between “eyes open" and "eyes closed" tasks is very small, due to the fact that for a healthy person the absence of vision during normal quiet standing does not affect the stability of the body. The more difficult tasks require more corrective movements and thus the CNS is required to perform constant control in order to maintain body posture while standing on one leg (all three asanas).

All correction signals, regardless of the balance task, show the highest power connected with low frequencies, up to 5 Hz. This fact is connected with mechanical properties of the human body. The eyes open and eyes closed tasks require lowest amount of corrections, while "Dancing Shiva" the highest.

During the eyes open and "Tree" version 2 conditions the maximum values of PSD are approximately the same for AP and lateral directions, while in eyes closed and "Tree" version 1 conditions the energy is higher in AP direction, and in "Dancing Shiva" in lateral direction.

Thus the power spectral density method enables not only the assessment of the level of balance task difficulty, but also provides information in which plane (sagittal or frontal) more correction movements are needed to maintain stability. The results point to the possible use of the power spectral density function for the assessment of the amount of corrections needed to maintain the desired body posture. In the next step, this approach should be used in a group of patients with balance deficits, and if the results are positive it can be used in clinical practice.

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