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INFLUENCE OF VISUAL INFORMATION IN POSTURAL CONTROL: IMPACT OF THE USED STABILOMETRIC ANALYSIS METHODS

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ABSTRACT

Introduction: This study aimed to investigate the postural control performance and the contribution of the sensorial systems during upright standing posture through an integrated analysis of the center-of-pressure (CoP) oscillations with time and frequency domain methods. Material and Methods: Volunteers remained on upright standing upon a piezoelectric force platform at two conditions: eyes closed (EC) and eyes opened (EO). Coordinates of the body's CoP were analyzed to obtain stabilometric parameters in the time (anteroposterior (AP) and medial-lateral (ML) amplitude displacement of the CoP) and in the frequency domain (contribution of spectral bands sub 0.3Hz and 1-3Hz). The time-domain parameters inform a postural control performance, while the spectral parameters inform sensorial strategies to ensure a satisfactory postural stability. Results: Time-domain parameters were not significantly different between conditions, while the contribution of Sub 0.3Hz band was higher in EO condition, as well as, the contribution of 1-3Hz band was higher in the EC. Discussion: Our results pave the way for further studies using stabilometric parameters in the time and frequency domain together. Using this integrated approach, it was possible to identify a reweighting from the available sensory cues, since the Sub 0.3Hz band depends on the visual and vestibular input, while 1-3Hz band depends on the proprioceptive input, ensuring a good postural stability even with the visual-deprivation.

Key words: spectral analysis, stabilometry, sensorimotor physiology, signal processing

INFLUENCIA DE LA INFORMACIÓN VISUAL EN EL CONTROL POSTURAL: IMPACTO DE LOS MÉTODOS DE ANÁLISIS ESTABILOMÉTRICOS UTILIZADOS

RESUMEN

Introducción: El objetivo de este estudio fue investigar el desempeño del control postural y la contribución de los sistemas sensoriales durante la postura erguida a través de un análisis integrado de las oscilaciones del centro de presión (CoP) con métodos de dominio de tiempo y frecuencia. Material y método: Los participantes permanecieron de pie sobre una plataforma piezoeléctrica, distribuidos en dos grupos: con ojos cerrados (EC) y con ojos abiertos (EO). Se analizaron las coordenadas de CoP del cuerpo para obtener parámetros estabilométricos en el tiempo (desplazamiento anteroposterior (AP) y medial-lateral (ML) de la CoP) y en el dominio de la frecuencia (contribución de las bandas espectrales sub 0,3 Hz y 1-3 Hz). Los parámetros del dominio del tiempo proporcionan información del control postural, mientras que los parámetros espectrales informan sobre las estrategias sensoriales utilizadas para asegurar una estabilidad postural satisfactoria. Resultados: Los parámetros del dominio temporal no fueron significativamente diferentes entre los dos grupos, mientras que la contribución de la banda Sub 0,3 Hz fue mayor en el grupo de ojos abiertos (EO), así como, la contribución de la banda 1-3Hz fue mayor en el grupo de ojos cerrados (EC). Discusión: Nuestros resultados allanan el camino para nuevos estudios utilizando parámetros estabilométricos en el dominio del tiempo y la frecuencia juntos. Utilizando este enfoque integrado, fue posible identificar una reponderación a partir de las señales sensoriales disponibles, ya que la banda Sub 0,3 Hz depende de la entrada visual y vestibular, mientras que la banda 1-3Hz depende de la entrada propioceptiva, garantizando una buena estabilidad postural incluso con la privación visual.

Palabras clave: análisis espectral, estabilometria, fisiología sensorimotora, procesamiento de señales

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Introduction

A good postural control during upright standing has strong functional significance in daily living activities, as well as for the for the sportive activities, being dependent on the integration of somatosensorial inputs from the proprioceptive, visual and vestibular systems (Ishida, Saitoh, Wada, & Nagai, 2010).

The analysis of the center-of-pressure (CoP) oscillations has been used to study the postural control during upright standing, being applied time and frequency domain methods. Time-domain analysis bring information regarding to the task performance (i.e., postural control performance), but do not allows direct inferences regarding to the sensorial strategies to ensure a satisfactory postural stability. On the other hand, spectral analysis inform little about the task performance, but allows to investigate the contribution of each sensorial system involved in the postural control during upright standing (Redfern et al. 2001; Wada et al. 2001).

It is reported that the CoP oscillations depend on the contribution of each sensorial system during the upright standing posture (Wada et al. 2001; Palmieri et al. 2002), with low frequency oscillations related to the visual (0.03-0.3 Hz) and vestibular (below 0.2 Hz) systems and the highest frequency (1-3 Hz) oscillations related to proprioceptive input (Diener et al. 1982; Redfern et al. 2001; Wada et al. 2001).

Previous studies have investigated the influence of addition or deprivation of sensorial information on the postural control through the stabilometric methods (Araújo et al. 2013; Billot et al. 2015; Billot et al. 2013; Pasma et al. 2014), but are limited to evaluate the postural control performance with time-domain parameters, limitating the identification of reweighting strategies from the central nervous system (CNS), according to the available sensorial cues.

To the authors' knowledge, there is no description of studies investigating the influence of vision-deprivation on postural control from healthy subjects, integrating stabilometric parameters obtained in the time and frequency domain, which would allow an integrated analysis involving task performance and the contribution of each sensorial system involved in the postural control during upright standing. Thus, the present study aimed to evaluate the postural control performance and the contribution of the sensorial systems to ensure a satisfactory postural stability with and without the vision available.

Method

Participants

Eight young healthy men (22.75 ± 0.96 years old, 173 ± 1.77 cm, 75.88 ± 3.89 kg) volunteered in this study. They were informed about the experimental procedures and written informed consent form. Ethical approval was provided by the ethics committee of the State University of Southwest of Bahia (CAAE # 16054313.7.0000.0055).

All volunteers denied neuromuscular diseases, recent (i.e., during the last 12 months) musculoskeletal injuries in the lower limbs and spine. In addition, they were instructed to avoid vigorous exercise or physical activity (i.e., ≥ 30 min of physical activity) for 24 hours prior to the experimental procedures.

Experimental procedures

Each participant stood quietly on a piezoelectric force platform (Footwork Pro AM CUBE, France), barefoot, and with the heels 6 cm apart and with 30° external rotation. The volunteers were instructed to stand quietly with their arms hanging at their sides and head in a normal forward-facing position, with eyes closed (EC) or with eyes open (EO) and focused on a stationary target located at eye level, approximately 2 m away. Coordinates of the body's CoP were recorded during 30s for each visual condition and sampled at 40Hz. Additionally, a cardboard template was used to ensure consistent foot positioning between standing trials. The trial order (i.e., EC and EO) was random for each volunteer and a 1-minute rest interval between trials was used, with the volunteers comfortably seated.

The body's CoP displacement was analyzed in MATLAB® software with previously developed routines to obtain stabilometric parameters in the time domain (the CoP displacement amplitude, calculated as the difference between the maximum and the minimum of the COP displacement in anteroposterior (AP) and medial-lateral (ML) axes) and in the frequency domain (the contribution of spectral bands sub 0.3 Hz and 1-3 Hz in the spectrum from the AP and ML axes). The power spectral density of body's CoP oscillations was obtained by applying the Fast Fourier Transform (FFT). The area of the spectrum relating to the band 0-0.3 Hz (i.e., sub 0.3Hz) Hz and 1-3 Hz was calculated and normalized by the total area of the spectrum to obtain the contribution of these bands in the spectrum constitution.

Statistical analysis

Results are presented as mean±standard error (SE). The Student t test was used to compare the stabilometric parameters (i.e., time-domain and frequency-domain parameters) obtained in the EO and EC conditions. All statistical procedures were performed with SPSS 21.0 (SPSS Inc., IBM, Chicago, IL, USA) and a significance level of $p < 0.05$.

RESULTS

The time-domain parameters, CoP displacement amplitude in AP and ML axes, showed no significant difference between EO and EC conditions (p> 0.05, Figure 1).

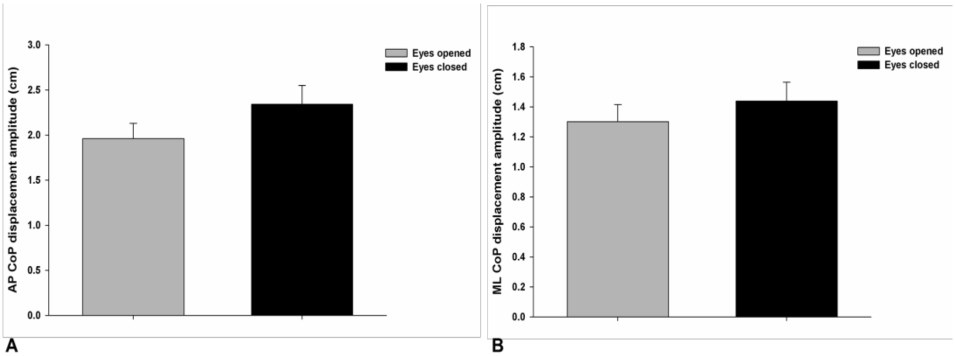

FIGURE 1: Mean ± SE of CoP displacement amplitude in anteroposterior (AP) and medial-lateral (ML) axes with eyes opened and closed.

The spectral band sub 0.3Hz was significantly higher at EO condition (p <0.05), while the 1-3Hz band was significantly higher at EC condition (p <0.05) as presented in figure 2.

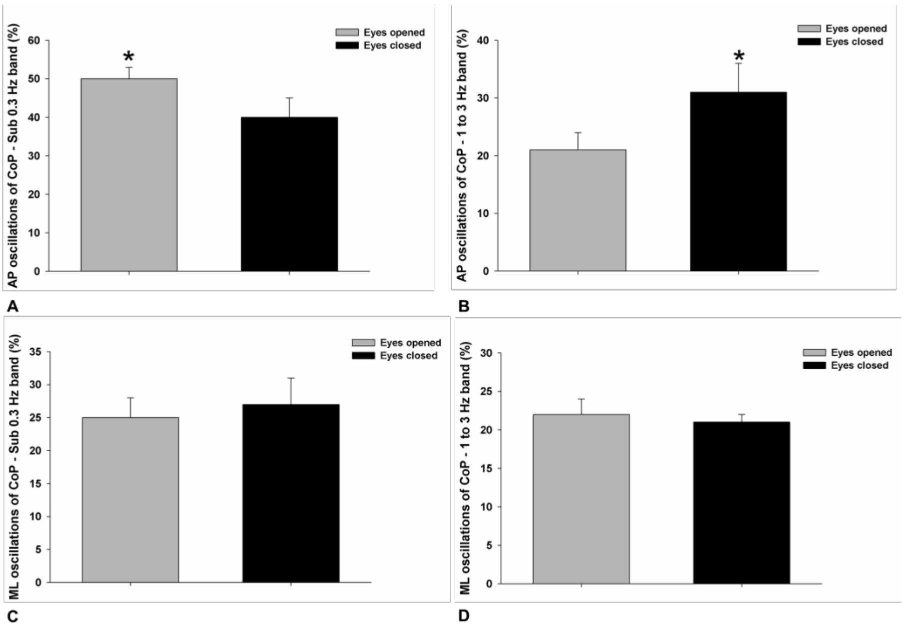

FIGURE 2: Mean ± SE of CoP oscillations in the sub-3 Hz (A and C) and 1 to 3 Hz (B and D) bands at the anteroposterior (AP) and medio-lateral (ML) axes with eyes opened and closed.

DISCUSSION

The goal of this study was investigate the postural control performance and the contribution of the sensorial systems during upright standing posture through an integrated analysis of the CoP oscillations with time and frequency domain methods. Our results showed that the postural control performance was not compromised by the vision deprivation, which was associated to a significant change in the contribution of spectral bands obtained with frequency domain methods. Specifically, the sub 0.3 Hz band was higher at the eyes opened condition, while 1-3 Hz band was higher at the eyes closed condition.

The sub 0.3 Hz band comprises the CoP oscillations dependent of sensorial integration based in the inputs from the visual and vestibular systems (Wada et al. 2001; Redfern et al. 2001). However, the contribution of vestibular system inputs during the standing posture (i.e., in static condition) is considered insignificant (Mergner, Hlavacka, & Schweigart, 1993). Thus, the quantification of the sub 0.3 Hz band in the studied condition is dependent on the visual inputs, which is confirmed by our results, where the sub 0.3 Hz band is significantly higher in the eye opened condition, than in the eye closed condition.

The absence of difference among visual conditions (i.e., EO vs EC) in the ML axis corroborate with findings from (Araújo et al., 2013), but differ from the findings in the AP axis, since the cited study found a significant difference between the EO and EC conditions. Methodological differences could explain the divergences between these studies, since in (Araújo et al., 2013) the sample merged men and women, in addition involved only the time-domain analysis method.

Despite the trend of greater CoP displacement amplitude at EC condition, it was not observed significant differences among visual conditions, indicating that the studied sample (young health subjects) was able to maintain the satisfactory postural control even at visual deprivation. The results from spectral analysis may explain this fact, revealing a reweighting of sensorial integration at vision-deprivation condition since the contribution of sub 0.3 and 1-3Hz bands were different at each condition.

In fact, the postural adjustments depends on the integration of the sensorial inputs from somatossensorial, vestibular and visual systems (Nashner, 1981), so that the contribution of each of these systems to the posture adjustments during upright posture depends on the availability and reliability in each one (Horak et al. 2011; Shumway-Cook and Woollacott 2000). Redfern et al. (2001) states that the reduction of the proprioceptive inputs, like in peripheral neuropathy conditions, leads to a greater dependence of the visual system to maintaining a satisfactory postural balance. Similarly, it is expected that the removal of visual information, as performed in this study by the eyes closure, will lead to an increase in the contribution of the proprioceptive system information, which was confirmed in this study with the spectral analysis.

In line with the exposed hypothesis, the concomitant decrease in the sub 0.3 Hz band and increase in the contribution of 1-3 Hz spectral band in the eyes closed condition indicates a change in the sensorial integration by the CNS, increasing the weight to the proprioceptive information to the detriment of the visual system, maintaining the CoP adjustments accurate enough to ensure satisfactory performance in the task (i.e., upright standing posture).

Two previous studies (Nagy et al. 2004; Nagy et al. 2007) have applied a similar approach, involving time and frequency domain together, but studied postural control in ironman athletes (Nagy et al., 2004) and elders (Nagy et al., 2007). Besides the sample differences, some methodological aspects difficult direct comparisons with our study, since they used shorter recorded time (20 seconds), sample rate (16Hz) and support base (feet positioned side by side with no space between them). In addition, the spectral analysis was carried out to quantify three spectral bands from CoP oscillations: sub 0.3, 0.3-1 and 1-3 Hz, and the results was compared as absolute values (i.e., absolute power spectral density from each spectral band). In our study, the power spectral density was normalized to obtain a relative contribution of each spectral band in the spectrum constitution, as done by Wada et al. (2001) and the interest bands was only sub 0.3 and 1-3Hz, since the physiological significance of these bands seem better established, as presented in the methods section.

It is important to emphasize that our study was developed with healthy young adults and the applied methodology could be applied in further studies involving different samples, such as the elderly, children at different stages of development, adults with sensorial and/or motor impairments, since the spectral bands stratification proposed here was sensitive to changes in the availability of sensorial information, as well as, the use of normalized spectrum enable comparisons with different samples and conditions.

It is plausible to hypothesize that different samples, such as the elders without sensorial impairments, may present spectral behavior of the CoP oscillations similar to the observed here, but not be able to maintain the postural control satisfactorily with eyes closed owing to the factors related to the muscular system aging. Then, the postural control analysis and interpretation based on the set of temporal and spectral parameters together, as proposed here could enable the stratification of postural control impairments originated from the sensorial, motor or sensorimotor integration factors.

Our results showed that healthy young adults can maintain a good postural control even with vision-deprivation, which was associated to a concomitant decrease in CoP oscillations in the sub 0.3 Hz band and increase in the 1-3 Hz band, indicating a greater contribution of proprioceptive cues to the maintain a satisfactory postural control, compensating the absence of visual cues. These findings are expected for young healthy adults, but shed light on a promissing approach using time and frequency domain methods together (i.e., in a complementary way), since the time-domain parameters inform task performance and the sub 0.3 Hz and 1-3 Hz spectral bands inform the used sensorial strategies to carry out the task satisfactorily.

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