Gait & Posture 40 (2014) 556–560

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Visual availability, balance performance and movement complexity in dancers

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ARTICLE INFO

Article history:
Received 28 February 2013
Received in revised form 12 May 2014
Accepted 30 June 2014

Keywords:
Balance ability
Complexity
Dance
Visual information

ABSTRACT

Research regarding the complex fluctuations of postural sway in an upright standing posture has yielded controversial results about the relationship between complexity and the capacity of the system to generate adaptive responses. The aim of this study is to compare the performance and complexity of two groups with different levels of expertise in postural control during a balance task. We examined the balance ability and time varying (dynamic) characteristics in a group of 18 contemporary dancers and 30 non-dancers in different visual conditions. The task involved maintaining balance for 30 s on a stability platform with opened or closed eyes. The results showed that dancers exhibited greater balance ability only in open eyes task than non-dancers. We also observed a lower performance in both groups during the test with closed eyes, but only dancers reduced their complexity in closed eyes task. The main conclusion is that the greater postural control exhibited by dancers depends on the availability of visual information.

1. Introduction

Postural control during the maintenance of an upright standing posture is a fundamental motor act that provides the basis for locomotion and most other movement tasks [1]. The postural control system regulates the body's postural sway during upright standing through the complex interaction of somatosensory, visual and vestibular sensory feedback networks, numerous brain regions, and the musculoskeletal system [2–4]. Complexity is defined as the number of system components and coupling functions (interactions) among the components [1]. This complexity can be observed in the upright standing posture through fluctuations of postural sway [4–6] and has increasingly led scientists to analyze postural stability through non-linear mathematical tools [7–11].

The results observed through this type of analysis have allowed scientists to relate lower complexity levels to a worse performance [12] related to aged and unhealthy systems [13]. Haran and Keshner showed the benefits of a balance-training program, in which the unhealthy participants improved their postural control, and the complexity of postural sway was increased [14].

By applying different levels of difficulty, depending on the availability of visual information, studies have shown a reduced performance associated with less postural sway complexity when the subjects kept their eyes closed [11,15]. However, some authors state that, depending on the specialization of the sample in proprioceptive tasks, the decrease in performance will generally be significant. Some results have shown that gymnasts only worsen their performance on stability tasks with closed eyes compared to another group of athletes [16].

However, other studies appear to be inconsistent with this relationship between performance and system complexity. Some age-related studies have observed a greater complexity of the system related to worse performances on postural control tasks [9,10]. High levels of complexity may indicate that the system is becoming less sustainable. This assumption is close to the traditional interpretation of variability as a measure of disorder and noise [10].

The relationship between complexity and performance in balance tasks has been previously analyzed in dancers. Stin et al. have observed that young dancers exhibit greater postural control with greater complexity compared to other groups of

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http://dx.doi.org/10.1016/j.gaitpost.2014.06.021

participants without experience in balance skills [7]. However, Schmit et al. did not observe differences in postural control between dancers and track athletes [11]. These authors observed differences in behavioral complexity between both groups with greater complexity or irregularity in the postural stability of dancers. Schmit et al. argued that there is a qualitative difference, rather than quantitative, in the balance task between these two groups [11].

Because of the controversy in the results, the aim of this study was to evaluate the relationship between complexity and performance through a comparison of two groups of different levels of expertise in postural control (dancers and non-dancers), and two levels of availability of visual information during a balance task. The following are the hypotheses of this study: (1) expert dancers will show greater complexity and a better performance during the balance task than non-dancers in both visual conditions, and (2) both groups will show a greater complexity with a better performance in the balance task when visual information is available.

2. Method

2.1. Participants

Eighteen undergraduate dancers (all females) from the Spanish Royal Conservatory of Dance and thirty healthy young women without any experience in dance participated in the study. All dancers were specifically trained in contemporary dance and ballet for a minimum of five years. The remaining thirty women served as a control group and were not explicitly trained in balance tasks.

The participants signed a written informed consent document prior to the experimental session. Table 1 shows the descriptive data, including age, weight and height of the sample. The study protocol was approved by the ethics committee of Extremadura University.

2.2. Performance task and apparatus

The performance task used to measure balance ability was a stabilometer (Model 16020, Lafayette Instrument Inc., Lafayette, IN), in which the tilt angle, recorded by a SMEG330 electrogoniometer (1-KHz data collection rate) represented the criterion measure. The tilt angle was the participant's error score reflecting deviation (medio-lateral) from the target horizontal platform position (0°).

The stabilometer platform (0.66 m × 1.08 m × 0.025 m) was placed 0.16 m from the frame and 0.22 m from the floor. The range of the stabilometer was set to ±20° from a horizontal position. The stabilometer task has been shown as a valid and reliable measure of balance [17].

2.3. Procedure

The participants were asked to stand barefoot on the platform maintaining stability from the horizontal position for 30 s in two visual conditions: open eyes (OE) and closed eyes (CE). The order of the conditions was randomized between the participants.

Table 1
Descriptive and anthropometric data of all participants.

Group	Age (years) (average ± SD)	Weight (kg) (average ± SD)	Height (cm) (average ± SD)
Dancers	23.32 ± 2.58	65.73 ± 7.96	171.91 ± 7.02
Non-dancers	22.23 ± 1.79	65.94 ± 10.53	169.97 ± 7.56

The participants were instructed to adopt a shoulder-width stance with their arms held at their sides. The participants were further directed not to speak during the trials. At the beginning of each trial, the participants assumed the aforementioned stance. Data collection was initiated after the participants felt comfortable and ready. The participants were allowed to rest for 3 min between the conditions.

To ensure that there was no rest of vision during the closed eyes condition, all participants placed an ocular mask on their face.

2.4. Data analysis and reduction

Data obtained from electrogoniometer was subsampled to 100 Hz. To evaluate the performance in postural stability, the absolute error of the tilt platform was measured as the average of the absolute distance (AE) to the horizontal angle of the platform. In addition, we assessed participant's balance control trough the standard deviation (SD) and mean velocity (MV).

Non-linear time series analysis was applied to the angular displacement of the platform. The complexity of the postural sway dynamics was calculated by two methods: Sample Entropy (SampEn) and Permutation Entropy (PE). Higher values of SampEn thus represent lower repeatability of vectors of length m to that of $m + 1$, which marks a lower predictability of future data points and a greater irregularity within the time series. SampEn was performed using the following input parameters for the analysis algorithms: 0.15 for tolerance (r) (in proportion to the SD of the signal) and 2 for vector length (m). The selection of these values was based on the procedures suggested by Cavanaugh et al. [18]. We have included PE to reduce the influence of the magnitude of the time series, and therefore the influence of the tolerance window parameter. Permutation entropy is independent of the data magnitude because it measures the entropy of sequences of ordinal patterns derived from m-dimensional delay embedding vectors [19]. PE was performed using 5 for vector length (m).

In order to assess the robustness of SampEn and PE method, we have applied them modifying input parameter: SampEn was applied on angular displacement signal using different r (0.15, 0.20 and 0.25 in proportion to the SD of the signal) and m (2, 3 and 4). PE was applied modifying m from 4 to 6. Higher r and m values increased entropy output. Nevertheless its influence seems similar in all conditions and does not affect result interpretation.

2.5. Statistical analysis

Normality of the data distribution was evaluated by calculating asymmetry, kurtosis and the Kolmogorov–Smirnov method with the Lilliefors correction. All variables were normally distributed. A mixed-design analysis of variance (ANOVA) was performed to test the mean differences between the two groups (dancers and control), vision conditions (repeated measures factors) and interactions. A post hoc analysis with a Bonferroni adjustment was used for multiple comparisons. Pearson's correlation coefficient tested for correlations between the variables of the present study. Significance was established at $p < 0.05$. SPSS 16.0 (SPSS Inc, Chicago, IL, USA) was used for all statistical procedures.

3. Results

An example of a medio-lateral deviation of the platform tilt angle from the target horizontal position (0°) for dancers and non-dancers in both visual conditions is shown in Fig. 1. Higher medio-lateral deviations can be observed in the CE condition compared to OE condition. The data from the dancer performance show lower deviation than non-dancer mainly in the OE condition.

Table 2 shows the relationship between the AE, SD and MV of the tilt platform and the vision conditions. All the participants performed significantly better in the balance task in the OE condition compared to the CE condition. Both groups