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Changing control strategies during standard assessment using computerized dynamic posturography with older women

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Abstract

The goal of this investigation was to explore the use of spectral analysis to examine the data obtained during computerized dynamic posturography (CDP). In particular, we examined whether spectral analysis would provide more detailed information about underlying postural control strategies and potential learning across conditions and trials of the sensory organization test (SOT). Twenty older women between the ages of 60 and 72 (mean = 65.2) were assessed using standard testing protocol. Participants showed significant improvements from the first to the second trials in their equilibrium scores in the more difficult conditions. This finding was reflected in the spectral analysis data by a shift in the frequency distribution towards greater power in the lower frequency range. This frequency change likely reflects a change in the ankle strategy used to maintain balance during the more difficult conditions.

Keywords: Balance; Computerized dynamic posturography; Spectral analysis

Balance control has been investigated for well over 200 years, with researchers using a variety of different techniques. One common approach to examining postural control, especially in clinical settings is computerized dynamic posturography (CDP). This technique assesses how well an individual integrates sensory information relevant for balance control. The main purpose of this investigation was to examine the usefulness of spectral analysis to examine the data obtained from CDP assessment.

In CDP, individuals stand on a force platform surrounded by a visual enclosure. Both the platform and visual surround can be stationary or sway-referenced to the individual's own motion. In sway-referenced conditions, shifts of the center of pressure (COP) in the anterior–posterior direction are accompanied by a forward or backward rotation of the force plate and/or visual surround. Sway-referencing of the platform renders somatosensory information from the ankle joints inaccurate, causing the subject to rely more heavily on visual and/or vestibular inputs. Sway-referencing of the visual surround renders the visual information relevant for balance control inaccurate, causing the subject to rely more heavily on somatosensory and/or vestibular inputs.

In standard CDP testing procedures performance is assessed in terms of an equilibrium score derived by calculating a center of gravity sway angle based on the subject's height, weight, and center of pressure data. This score is calculated for each trial with respect to a theoretical limit of stability [1,2] determined by comparing the maximum range of sway angle obtained for an individual with values determined from a norming sample. The equilibrium score is expressed as a score from 0, indicating large degrees of sway that approach the limits of stability, to

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100, indicating very little sway. If an individual loses his or her balance a score of 0 is assigned [3].

Traditionally, CDP has been used primarily as a clinical tool to diagnose and assess the nature of balance impairments in individuals. Specifically, CDP can be used to assess whether individuals are having difficulty integrating somatosensory, vestibular, or visual information relevant for balance control. In addition, by analyzing the shear forces on the platform it is possible to assess whether individuals are making postural adjustments primarily using the ankle (referred to as an ankle strategy) or hip joint (referred to as a hip strategy). Investigators have used CDP to examine changes in sensory integration across the life span [4–8], generally showing that equilibrium scores increase from childhood to adolescence, reach maximum values in adulthood (20–60 years), and decline in older adulthood. The greatest age related differences in equilibrium scores are typically found in conditions that involve sway-referencing. These conditions pose the greatest challenge.

Researchers have also used CDP to investigate individuals with a variety of sensory impairments [6,9] or specific diseases [10]. In clinical settings, CDP is used for assessment, rehabilitation, and management of individuals with balance difficulties [11]. Researchers have also used CDP to evaluate particular interventions including Tai Chi [12] and vibrotactile prosthetics [13].

In the present investigation we employ power spectral analysis on the data obtained from CDP to explore how the frequency components of the center of pressure displacement data vary as a function of the different conditions of the sensory organization test (SOT) and repeated trials. Many researchers have examined the frequency components of postural sway during quiet stance using power spectral analysis [14,15]. Generally the spectral density function of COP movement obtained for normal adults during quiet stance has a large amount of power at low frequencies (less than 0.5 Hz), little power above 1 Hz, and does not show any clearly discernable peaks [16]. These findings have led some researchers to question the value of examining frequency distributions [17]. Many researchers examining sway frequency during quiet stance report the PSD values obtained from averaging data over subjects or repeated trials. This approach tends to remove any discrete peaks that may be present in the spectra of individual subjects. When single trial data is examined discrete peaks can sometimes be observed even during quiet stance. In addition, relatively large individual differences in the structure and characteristics of the power spectra can be seen [18]. These individual differences may be particularly informative for detecting individuals with specific disorders [19] or individuals who might be at risk for falls or other balance related problems.

To date, few researchers have examined the frequency characteristics of postural control under sway-referenced conditions. In one study investigating the effects of alcohol consumption across the life span, Ahmad et al. found that alcohol consumption was positively correlated with increases in the spectral power obtained between 2–4 and 4–6 Hz in sway-referenced conditions of the SOT [20]. Very little power is typically found at these frequencies for healthy adults. Additional research suggests that a combination of frequency and amplitude measures may provide an effective means for identifying older fallers [21] and malingerers from individuals with actual postural difficulties [22]. The main goal of the current study was to examine variations in the power spectra across conditions and repeated trials of the SOT. A related goal was to determine whether this approach would provide details regarding underlying control strategies and learning across trials.

1. Method

1.1. Participants

Twenty older women (mean age = 65.2, range from 60 to 73) enrolled in a larger 2-year prospective study participated in this investigation. Participants were excluded if they reported: (a) any history of neurological disorder, (b) a history of gait or balance problems, or (c) impaired mental status, as assessed by the Pfeiffer Mental Status Questionnaire [23]. We included only participants who did not lose their balance during the sensory organization test (SOT).

1.2. Procedures

1.2.1. Functional balance and gait assessment

To compare our sample to other studies examining older adults we assessed participants' functional balance using the Berg Balance Scale [24], gait performance over a 7-m path, and the Timed Up and Go [25]. For the 7-m walk participants were instructed to walk at their normal walking speed.

1.2.2. Computerized dynamic posturography

The EquiTest computerized dynamic posturography system (NeuroCom International, Clackamas, OR) was used for computerized dynamic posturography. This system consists of a force platform that can be sway-referenced (rotated around the ankle joints in response to an individual's postural adjustments). This device includes a visual surround that also can be sway-referenced. By systematically altering the movement of the visual surround, force platform, and visual information the device can assess an individual's ability to utilize information received by the somatosensory, visual, and vestibular systems.

Standard protocol for administering the sensory organization test (SOT) was followed. For safety, participants wore a harness attached to an overhead bar throughout testing. The SOT includes six conditions: (1) normal vision, fixed support; (2) eyes closed, fixed support; (3) vision sway-referenced, fixed support; (4) normal vision, support sway-