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The role of task constraints in relating laboratory and clinical measures of balance

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ABSTRACT

This study tested the hypothesis that age-related postural control deficits are more clearly detected from force plate recordings when using postural control tasks with an explicitly defined goal as opposed to the frequently used quiet stance task. Eighteen older adults (over 65) and seventeen younger adults (under 30) stood on a force plate with visual feedback (VFB) of the center of pressure (COP) and without such visual feedback with eyes open (NVFB). In the VFB condition, online visual feedback about the COP was provided and participants maintained that feedback on a stationary visual target for 80 s. We hypothesized that age-related difference in COP variability (standard deviation of COP position and average absolute maximum COP velocity; AAMV) would be more pronounced in the VFB than in the NVFB condition. In addition, we hypothesized that Berg balance scale (BBS) scores for older adults would correlate more strongly with the COP measures in the VFB condition than in the NVFB condition. Results showed that VFB enhanced age-related differences only for AAMV in anterior–posterior direction. Both age groups decreased postural sway when using VFB. Older adults increased AAMV with VFB while young adults did not, indicating that the task modified their postural control strategy stronger than in younger adults. BBS scores were correlated with the AAMV in both feedback conditions, while COP position variability was more clearly correlated with BBS in the VFB condition. These results suggest that the quiet stance task is sufficient to index balance function if velocity-based COP variables are utilized in the analysis.

1. Introduction

Healthy aging leads to numerous changes in the sensorimotor system [1] that are in turn associated with an increased incidence of injurious falls among people older than 65 [2]. A deeper understanding of human balance and how to measure it objectively are highly relevant topics as the population continues to age. In this paper we tested the hypothesis that balance quality is better assessed using protocols that present clearly specified task goals for participants.

Balance quality is frequently operationally defined based on metrics of spatial variability or temporal structure (e.g., stabilogram-diffusion analysis) of force plate-derived variables such as the center of pressure (COP), which is the average point of application of the ground reaction force vector. The COP is most frequently recorded from participants who are instructed to "stand as still as possible" for a limited amount of time, usually for less than a minute—the so-called "quiet stance" paradigm. The objective of this instruction is to examine the stabilizing capacity of the postural control system in the limit—how well the CNS can control the body to remain stationary. In this case, maintaining a still posture depends on the effective use of feedback from the visual, proprioceptive, cutaneous, and vestibular sensory systems and on the integrity of the musculo-skeletal system to correct for postural deviations from the desired position. Greater COP variability and greater COP velocity are traditionally interpreted as signifying impaired postural control and reduced balance quality [3,4]. Older adults have higher COP velocity compared to younger adults [5–7], indicating that balance quality deteriorates with age consistent with many studies [3,8].

However, greater COP variability does not always correlate well with clinical measures of balance function such as the Berg Balance

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Scale (BBS), Timed Up and Go, or the Tinetti test. Correlations between these scores and COP metrics are typically weak to moderate (Pearson r: .2 to .3) [9]. Berg's original finding for BBS was .55 [4]. Postural tasks other than quiet stance, such as the sensory-organization test (SOT), have been used but the correlation was found to be similarly weak [10]. BBS also weakly correlated with postural sway measures of responses to moving platform perturbations (r = .38) [4]. One explanation for the lack of strong associations is that the two types of tests may measure different aspects of balance—force plate measures are more sensitive to specific sensorimotor deficits whereas the clinical scales are more directed to overall balance function [9,11]. Clinical balance tests also have a different level of precision and are typically used to categorize subjects according to their gross functional balance capacity (e.g., needs a walker or not; likely to experience fall or not) as opposed to detecting relatively small changes in postural control.

Another possibility is that the protocols used for force plate assessments during quiet stance insufficiently constrain postural control. The basic requirement of upright stance is to simply maintain the center of mass within the base of support. For bipedal stance the base of support is related to the spatial boundaries of the feet, which provides a substantially large region of permissible COP locations that satisfy the ill-defined goal of quiet stance [12–15]. Moreover, there is an over-abundance of motor system degrees of freedom for postural control (i.e., more muscles and joints are available than minimally necessary to achieve upright stance), which means there are many different combinations of coordination patterns among these degrees of freedom that can lead to the same observed pattern of COP behavior [16]. As a result, COP variability in quiet stance is not straightforwardly related to functional balance quality, and consequently existing balance deficits or age-related changes in postural control may be masked by the redundancy of the postural control system [17]. Our general hypothesis is that postural tasks with an explicit and quantifiable performance goal will constrain the postural control system more and provide a better picture of the stabilizing capacity of the postural control system (and hence balance quality) than quiet stance.

To test this hypothesis, we utilized a postural control task in which participants were provided with online visual feedback about their COP and instructed to keep the COP on a predefined target (visual feedback; VFB) or simply stand as still as possible while looking at the same screen but without visual COP feedback (no visual feedback; NVFB). We hypothesized that (1) the VFB condition would reveal greater differences in COP variability between groups of participants with different balance function levels (younger vs. older adults) than the NVFB condition and (2) the correlation between BBS scores and COP variability would be stronger in the VFB than in the NVFB condition within the older adult sample.

2. Method

All experimental procedures were approved by the Institutional Review Board at the University of Cincinnati. All participants gave informed consent to participate.

2.1. Participants

The characteristics of the sample are reported in Table 1. Young adults participated for research credit in the Department of Psychology at the University of Cincinnati. The exclusion criteria for the younger adults were recent musculo-skeletal injuries or a regimen of anti-depressant medication. Community-dwelling older adults were recruited by verbal invitation from Cincinnati Recreation Commission centers where they attended social events or engaged in physical exercise. The inclusion criteria were to be over 65 and perceive themselves as generally healthy. Exclusion criteria for the older adults included impaired or not corrected-to-normal vision, previous diagnosis of a neurodegenerative disease, stroke, diabetes, or a consistent regiment of antidepressant medication. Overall, the sample reflected an active and healthy group of older adults. Seventeen participants self-reported to be physically active: Nine took part in a physical exercise class for seniors at one of the recreation centers (45 min, 3 times a week), two played volleyball, one bowled every week, and five did exercise walking. Four reported having an incident of falling (1, 1.5, 7, and 12 years ago) and seven reported having lost balance without a fall within last year. Two older adults who met these study criteria were later excluded from the analysis and are not included in Table 1: One reported using a cane and the other had a low BBS score (42), which skewed the results of the correlation analyses.

2.2. COP measurement and visual feedback display

A force plate (Bertec 4060-NC, Columbus, OH) was used to calculate the anterior–posterior (AP) and medio-lateral (ML) COP signals according to: $COP_{AP} = (-h \times F_{ML} + M_{AP})/Fz$ and $COP_{ML} = (-h \times F_{AP} + M_{ML})/Fz$, where h is the thickness of the material covering the force plate (h = 0.005 m) and Fz is the ground-normal force. The force (F) and moment (M) data were sampled at 50 Hz. Instantaneous visual feedback about the COP was provided with a gain of 1 on a computer display (17 in diagonal; 1024 × 768 pixels) positioned at eye level 1.5 m in front of the participant. In the VFB condition, participants were required to maintain the feedback dot (15 pixels; 0.5 cm) at the center of a target square (90 × 90 pixel; 3 × 3 cm). The center of the target was marked by the intersection of two lines that bisected it vertically and horizontally (Fig. 1).

2.3. Procedure

Prior to performing the experimental trials participants self-selected a stance that did not lead to any perceivable forward/backward lean or left/right foot pressure asymmetry when maintaining the feedback dot on the center of the target. The position of the feet (hip-width apart) was outlined and used by the participant for the rest of the experiment.

The instruction in the VFB condition was to maintain the feedback dot at the center of the target as closely as possible. In the NVFB condition, no feedback dot was visible, and the instruction was to stand as still as possible while looking at the target square—this was the standard quiet stance condition. Four trials in each feedback condition (trial duration was 80 s) were presented in a

Table 1
Sample characteristics.

Group	N	Men/women	Age (years)	Age range (years)	Weight (kg)	Height (cm)
Young adults	17	3/14	19.35 ± 1.32	18–23	62.87 ± 10.98	163.70 ± 10.29
Older adults	18	4/14	72.83 ± 8.92	60–90	78.65 ± 18.22	163.97 ± 13.00

Note: Mean ± SD is presented for age, weight, and height.