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Age related changes in balance performance during self-selected and narrow stance testing

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ABSTRACT

Background: Various balance tests have been considered as fall risk screening tools however there is a lot of variability in the methods and outcome measures reported. Based on previous research examining age-related changes in balance and differences between fallers and nonfallers, the purpose of this investigation was to examine age-related balance changes, as reflected in medial-lateral center of pressure (CP) velocity, in community-dwelling/independently living adults (≥60 years) during self-selected and narrow stance testing with eyes opened and closed.
Methods: Two hundred and thirty adults aged 60 yrs or older completed one 45 s trial under two stances (self-selected, narrow) and two visual conditions (eyes opened, eyes closed). Average medial-lateral CP velocity was computed from the CP data, with preliminary analysis demonstrating positive skewness and association with body height. A sway velocity index (SVI) was created by a natural logarithm transformation and dividing by body height. Multiple linear regression was used to determine the association between age, visual condition, stance, and sex with SVI.
Results: Age, visual condition, stance and sex were all demonstrated to be significant predictors of SVI, with the combination of the predictors explaining 25% of the variance in the SVI.
Conclusions: These results confirm the balance testing protocol and SVI to be sensitive to age-related changes in balance performance. The results of this study should help future research aimed towards establishing a quick, easy to administer, and readily interpretable instrumented test for assisting with identifying potential balance impairments in older adults who have yet to demonstrate outward deficits.

1. Introduction

The increased risk for a fall associated with aging, as well as the physical, psychological, functional and economic consequences of a fall, is well documented (Thapa, Gideon, Brockman, Fought, & Ray, 1996). Although the factors influencing increased fall risk are complex (Boulgarides, McGinty, Willett, & Barnes, 2003), balance performance appears to be one potentially modifiable factor that may lessen fall risk (Buatois, Gueguen, Gauchard, Benetos, & Perrin, 2006; Maki, Holliday, & Topper, 1994; Stel, Smit, Pluijm, & Lips, 2003). Various balance tests have been considered as potential fall risk balance screening tools (Boulgarides et al., 2003; Brauer, Burns, & Galley, 2000; Thapa et al., 1996), however the extent to which balance testing can predict fall risk remains unknown (Boulgarides et al., 2003). The ideal balance screening test would be quick, easy to administer, and provide readily interpretable results (Bauer, Groger, Rupprecht, & Gassmann, 2008; Bigelow & Berme, 2011) to indicate whether more in-depth assessments are needed.

Independent of fall history, declining balance ability with increasing age has been demonstrated (Baloh et al., 1994; Baloh, Corona, Jacobson, Enrietto, & Bell, 1998; Choy, Brauer, & Nitz, 2003; Era & Heikkinen, 1985; Era et al., 2006; Hurley, Rees, & Newham, 1998). Independently living older adults may only show subtle deficits compared to those residing in assisted living centers thereby requiring more precise instrumented balance assessments (Brauer et al., 2000; Laughton et al., 2003; Pajala et al., 2008). Often, force platforms and center of pressure (CP) based variables are the most common methods of conducting an instrumented balance assessment and reflecting balance performance, respectively (Piirtola & Era, 2006). Despite a number of studies using force platforms to investigate age-related changes in

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balance, full synthesis across the studies is very difficult because of the wide variations in the type of participants (community-dwelling/independently living vs. institutionalized residence) and the testing conditions and outcome measures utilized. For example, numerous CP outcome measures have been reported during various stances on force platforms. Barring a couple of exceptions (Pajala et al., 2008; Vieira Tde, de Oliveira, & Nadal, 2009), CP excursions in the medial-lateral direction appears to better discriminate between fallers and non-fallers (Bigelow & Berme, 2011; Melzer, Benjuya, & Kaplanski, 2004; Park, Jung, & Kweon, 2014; Stel et al., 2003) as well as predict future falls (Bergland, Jarnlo, & Laake, 2003; Brauer et al., 2000) than anterior-posterior or two-dimensional excursions. CP velocity is related to the frequency of the CP excursions, thereby providing a different perspective than CP standard deviation and area. While CP velocity identified differences between young and older adults (Prieto, Myklebust, Hoffmann, Lovett, & Myklebust, 1996), whether medial-lateral CP velocity can detect an association between age-related changes in balance performance in older adults remains unknown.

Stance width is a second testing parameter that has varied in the literature and has potent influence on balance performance. Stance width has included self-selected (Bigelow and Berme, 2011; Laughton et al., 2003; Pajala et al., 2008; Riemann and Piersol, 2016; Stel et al., 2003), standardization based on participant body height (Choy et al., 2003), and standing with feet and heels together (Bigelow and Berme, 2011; Thapa et al., 1996), with some studies not specifying stance width (Brauer et al., 2000; Thapa et al., 1996). The advantage to using a self-selected stance would be facilitation of a quicker and more easily administered screening test (Bigelow & Berme, 2011), however it also may allow participants with balance deficits to adopt a wider and more stable stance position, thereby decreasing the sensitivity of the test to detect impairments. Remarkably, balance differences between older adult fallers and non-fallers using a self-selected stance was reported as well as high numbers of non-faller participants being unable to complete a feet together stance with eyes closed (Bigelow & Berme, 2011). Using a narrow stance, slightly wider stance than toes and heels touching, may fill the need for a challenging and sensitive task that can be completed by many older adults. A recent investigation demonstrated near-identical intersession reliability between self-selected and standardized narrow stance widths in older adults (Riemann & Piersol, 2016). Whether self-selected or narrow stance widths are sensitive to age-related changes in balance performance is unknown. Therefore, the purpose of this investigation was to examine age-related balance changes in community-dwelling/independently living adults (≥60 years) during self-selected and narrow stance testing with eyes open and closed. We hypothesized that the narrow stance tests would demonstrate a stronger association with age than the self-selected stance.

2. Methods

Two hundred and thirty adults (118 men, 112 women) aged 60–93 yrs (71.2 ± 8.1 yrs, 77.3 ± 17.4 kg, 1.70 ± 0.11 m) participated in this study at one of three data collection locations, Armstrong State University, Adelphi University and RehabWorks at the Kennedy Space Center. Participants were solicited from community senior centers and programs and workplaces, as well as through advertisements in local newspapers. Participants were excluded if they had sustained more than one fall in the past year, as one fall could be a random event that does not reflect a balance disorder (Melzer et al., 2004). All participants were void of uncorrected visual impairments, neurological disorders (stroke, Parkinson's disease, multiple sclerosis), cognitive impairments, or confounding orthopedic issues based on their completion of a comprehensive medical questionnaire. Prior to commencing the study, local Institutional Review Board approvals were attained at each data collection site and all participants gave written informed consent.

Participants completed one trial of four balance tests consisting of two stances (self-selected, narrow) and two visual conditions (eyes open, eyes closed). Testing was conducted unshod and participants were cued to stand as "motionless as possible" while maintaining their hands on their hips during completion of each trial. The narrow stance involved the participants' toes and heels being 0.075 m apart. During the eyes open conditions, participants were asked to focus on a target that was placed 1.8 m anterior to their testing location and 1.6 m superior to the support surface. Each trial duration was 45 s with 30 s rest between trials. A 45 s trial length was used as a compromise between having a time-efficient screening test and sufficient trial length needed to capture slower body sway (Riemann & Piersol, 2016). Prior to commencing the 45 s data collection, participants assumed the testing condition for 3s. If a compensatory event or loss of balance occurred during a trial, participants were given one re-test opportunity. All testing was conducted on the Biodex SD (Biodex Medical Systems, Shirley NY), a commercially available stabilometer that when used in the static (fixed platform) mode, records center of CP data at a 40 Hz sampling frequency. Average medial-lateral CP velocity was computed from the CP data.

3. Statistical analysis

Exploratory analysis of the average medial-lateral velocities for all four balance testing conditions demonstrated positive skewness. Following a natural logarithm transformation, skewness was eliminated and formal normality tests became non-significant. The potentially confounding effects of height and mass were examined by computing Pearson Correlational Coefficients. Based on statistically significant relationships between height and all four balance testing conditions, each participant's natural logarithm transformed velocities were divided by their height. The resulting value, sway velocity index, can be summarized by the following equation,

$$Sway\ Velocity\ Index = \frac{Ln(CPV_{ML})}{BH}*1000$$

where $\mathrm{CPV_{ML}}$ is the medial-lateral CP velocity (mm/s) and BH is the participant's body height (mm). A multiplier was used to produce valuethat could be rounded to one decimal place.

Standard descriptive statistics, including mean and standard deviations, were calculated for the continuous variables. Frequencies were found for the categorical variables. Pearson correlations were determined for comparison between continuous predictors (age and stance width) along with the outcome variable of sway velocity. The association between the independent variables (age (years), visual condition (eyes open or closed), stance position (narrow or self-selected stance), and sex (male or female) and the dependent variable of sway velocity index were assessed using a multiple linear regression analysis. Assumptions of linearity, normality, multicollinearity, and outliers were all assessed and met. Additionally, to further explore the self-selected stances, descriptive statistics concerning self-selected stance width and the difference between self-selected and narrow stance were tabulated. Pearson correlations were conducted to determine the relationship self-selected stance width had with age followed by simple linear regression models to predict SVI from the stance width during the self-selected conditions (eyes open, eyes closed). All analyses were performed using SPSS (IBM SPSS, Inc. 23.0, Chicago, IL, USA) with an alpha level of 0.05.

4. Results

The continuous predictors of age ($r = 0.23$, $P < 0.001$) and step width ($r = -0.25$, $P < 0.001$) were significantly correlated with SVI. As age increased so did the SVI, however when the step width increased the SVI decreased.

Velocity measures were significantly higher in the narrow stance