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Quantitative trunk sway and prediction of incident falls in older adults

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ABSTRACT

Poor balance and balance impairments are major predictors of falls. The purpose of the current study was to determine the clinical validity of baseline quantitative static trunk sway measurements in predicting incident falls in a cohort of 287 community-dwelling non-demented older Americans (mean age 76.14 ± 6.82 years; 54% female). Trunk sway was measured using the SwayStar™ device, and quantified as angular displacement in degrees in anterior-posterior (pitch) and medio-lateral (roll) planes. Over a one-year follow-up period, 66 elders (23%) reported incident falls. Anterior-posterior angular displacement was a strong predictor of incident falls in older adults in Cox proportional hazards models (hazard ratio adjusted for age, gender, education, RBANS total score, medical comorbidities, geriatric depression scale score, sensory impairments, gait speed, and history of fall in the past 1 year ((aHR) = 1.59; p = 0.033) whereas, angular displacement in the medio-lateral plane was not predictive of falls (aHR = 1.35; p = 0.276). Our results reveal the significance of quantitative trunk sway, specifically anterior-posterior angular displacement, in predicting incident falls in older adults.

1. Introduction

Balance or the ability to distribute one's weight in an effort to remain upright and steady is a complex and multifaceted construct involving successful integration of sensory, motor, and musculo-skeletal systems, which are all impacted by increasing age [1,2]. Static balance or the ability to sustain the body in equilibrium within its base of support [3] is typically measured during bipedal standing. Since the body is never really motionless during standing, body sway can be measured in two planes: 1) anterior-posterior (forward-backward movement) and 2) medio-lateral (left-right movement). Much of the research is in agreement that medio-lateral control of balance occurs mainly at the hips and trunk, while anterior-posterior control of balance occurs mainly at the ankles [4].

Postural sway during standing has been linked to falls in the elderly using mainly force plate technology with and without sensory disturbances [5–8]; however, these investigations have yielded inconsistent findings in regards to fall prediction being associated with either medio-lateral or anterior-posterior trunk sway (see [9] for review). Innovative technology now provides advanced reliable and valid quantitative assessments of multi-directional static balance performance [i.e.,trunk sway; 10–12], but its clinical utility in predicting incident falls in older adults is unknown. The main objective of the current study was to establish the clinical validity of quantitative trunk sway performance during undisturbed standing with eyes open in medio-lateral and anterior-posterior directions in predicting incident falls over a one-year follow-up period in 287 community-dwelling older Americans using the SwayStar™ system. Given the fact that over three-fourths of older Americans have balance problems and are consequently more likely to fall [13], we surmised that baseline trunk sway could be a marker of 'steadiness' to predict incident falls. Herein, we set out to test our hypothesis that individuals at risk for future falls would demonstrate significantly increased angular displacement at baseline compared to elders without a fall.

2. Materials and methods

2.1. Participants

Older adults recruited for the Central Control of Mobility in Aging (CCMA) study at the Albert Einstein College of Medicine (AECOM) in Bronx, NY with available trunk sway data and one year of standardized follow-up fall interviews (see Section 2.3 below) were included. CCMA study procedures have been described elsewhere [14,15]. In brief, potential community-dwelling participants ages 65 years and older and English speaking were identified from a population list of lower Westchester County, NY. Exclusion criteria included presence of dementia, significant loss of vision or hearing, inability to ambulate

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independently even by using a walking device, and current or past history of neurological or psychiatric disorders or medical procedures that may affect mobility. For the purposes of the current study, individuals with Parkinson's disease were excluded. All participants provided written informed consent to the experimental procedures, which were approved by AECOM's institutional review board and were in accordance with the *Declaration of Helsinki*.

Participants were deemed non-demented using validated cut scores from the AD8 Dementia Screening Interview [cutoff score ≥2; 16] and the Memory Impairment Screen [MIS; cutoff score < 5; 17], and later confirmed using consensus clinical case conference procedures [see 18] where the presence of mild cognitive impairment syndrome (MCI) was also determined. Global cognitive status was assessed with the Repeatable Battery for Assessment of Neuropsychological Status (RBANS) and depressive symptomology was characterized using the Geriatric Depression Scale (GDS-30 item).

Medical comorbidity index scores (range 0–9) were obtained from dichotomous rating (presence or absence) of physician diagnosed diabetes, chronic heart failure, arthritis, hypertension, depression, stroke, chronic obstructive pulmonary disease, angina, and myocardial infarction [see also 18,19]. This scale typically includes ratings for Parkinson's disease (PD), but as previously mentioned PD was an exclusion criterion.

All participants were required to successfully complete a visual and sensory screening exam. Visual acuity was reported as the lowest (i.e., worst) monocular value on the Snellen eye chart in decimal notation (from 0.20 (or 20/100) to 1.00 (or 20/20)), and participants with acuity < 0.20 were excluded. Sensation in the lower extremities was measured at the big toe using a 128 Hz tuning fork by the study clinician, and rated as either normal or impaired with normal performance defined as the ability to feel the tuning fork struck moderately hard for 10 s or longer; while sensation was used as a covariate in our statistical models, it was not used as exclusion criteria.

2.2. Trunk sway measurements

Trunk sway was measured using the SwayStar™ device system (Balance International Innovations GMBH, Switzerland) that contains sensors to record angular deviations of the trunk in both the medio-lateral (roll) and anterior-posterior (pitch) planes at a sampling frequency of 100 Hz [10,12]. The SwayStar system includes a lightweight device (750 g) that is mounted on an adjustable belt and sits securely near the center of mass on the participant's lower back (L3-5 vertebral body; see Fig. 1). Participants were asked to wear the Swaystar device and keep their eyes open while standing still with feet shoulder width apart on a firm flat surface for a period of 10 s. Quantitative trunk sway measurements were simultaneously recorded. Participants were not required to be tethered with cables as wireless Bluetooth communication was employed between the SwayStar device and the recording computer.

Peak-to-peak measures of angular displacement in both planes were measured and bias was removed using a 90% range of excursion values as described in the Swaystar manual (see [20]). The peak-to-peak range of the participant's excursions was divided into 40 bins. Each 10 ms sample was assigned to one of these bins depending on its amplitude. With all samples binned, a histogram was created and the lower 5% and upper 95% limits were removed to minimize effects of outlying values. The SwayStar system has been reported to have good test-retest reliability [r = 0.69 and r = 0.81 for roll and pitch respectively; [see 12].

2.3. Fall interviews

Falls data was ascertained via structured telephone interviews and at yearly in-house visits. Falls were operationalized as unintentionally coming down to the floor or to a lower level not due to a major intrinsic or extrinsic event [21]. Participants were asked a baseline visit whether they experienced a fall during the past one year, of which 45 elders endorsed a fall. Trained research assistants contacted participants by telephone every 2–3 months and asked a series of questions, using a standardized form to reduce inter-tester-variability. Falls were ascertained by the question: "Have you fallen since we last spoke?" If the participant endorsed a fall, further information regarding the location of the fall and whether an injury was sustained from each fall was also collected. In order to be included in the current study, participants were required to partake in systematic falls interviews over a one-year period. As it is not feasible for every participant to be contacted at exactly 365 days post-baseline visit, we allowed the time-window for the one-year fall interview to extend up to 30 days post-baseline visit. The one-year follow-up interval was selected, as this was a clinically relevant period for over which clinicians could make prognostications and that would inform patients about their fall risk over a relatively short period of time. Sixty-six individuals reported a fall during the 12-month follow-up period, of which only twelve participants reported a previous fall at baseline.

Fig. 1. Depicts a CCMA participant with the wireless Swaystar device system fastened around their lower back.

2.4. Statistical approach

Data were inspected descriptively and graphically and the normality of model assumptions was formally tested. Angular displacements for both pitch and roll planes had skewed distributions and were log transformed to achieve normality. Descriptive statistics (mean and standard deviation (SD)) were calculated for continuous variables, including demographics and trunk sway. Separate Cox proportional hazards models were used to compute hazard ratios (HR) with 95% confidence intervals (CI) to predict incident falls based on trunk sway angular displacement for both the pitch and roll planes. In terms of the time scale, if the participant reported a fall at any time during the one-