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Short report

Gait coordination impairment is associated with mobility in older adults

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ABSTRACT

Background: Impairments to body systems contribute to mobility limitations. The objective of this study was to determine whether impaired gait coordination, as measured by the Phase Coordination Index (PCI), is significantly associated with mobility limitations in older adults, even after adjusting for other gait features.
Methods: We conducted a cross-sectional analysis of performance-based measures of mobility in older adults (N = 164) 77–101 years of age, participants in the population-based MOBILIZE Boston Study. Mobility outcomes included the Short Physical Performance Battery (SPPB) and each of its three components. Multivariable linear regression models, adjusting for age and gender, were used to examine the associations of PCI and the coefficients of variation of stride length, width and time, stance time, and step width with each outcome.
Results: PCI accounted for more variance in SPPB score ($R^2 = 0.21$), gait speed ($R^2 = 0.17$), chair rise score ($R^2 = 0.10$), and balance score ($R^2 = 0.09$) than any of the other gait measures. Impaired gait coordination was significantly associated with performance on the SPPB and each of its component tasks, even after accounting for gait measures previously linked to mobility tasks (all $P < 0.05$). In multivariable linear regression modeling PCI accounted for an additional 9% of the variance in SPPB score ($P < 0.001$), after accounting for the other gait variables, age, and gender.
Conclusions: This study shows that impaired gait coordination is associated with poorer mobility performance in older adults, independent of other gait variables previously linked to mobility tasks.

1. Introduction

Mobility is classified by the World Health Organization as an activity that consists of moving by changing body position or location and may include activities such as walking and climbing stairs (Organization, W. H., 2001). Mobility limitations decrease participation in activities of daily living and can lead to loss of independence. These limitations contribute to falls (Hausdorff et al., 2001), disability, hospitalization and even death in older adults (Vermeulen et al., 2011). Mobility limitations affect over 15 million older adults and are expected to lead to a $42 billion increase in annual healthcare costs by the year 2040 (Hardy et al., 2011).

A number of body system impairments have been identified as risk factors for mobility limitations. These include cognitive (Montero-Odasso et al., 2012) and peripheral neuromuscular (e.g., reduced leg strength, trunk endurance, and range of motion) impairments (Bean et al., 2013). Alterations in gait characteristics that have been identified as risk factors for mobility limitations include measures of the amplitude (e.g., length, width) and the variability in the duration of spatial-temporal properties such as strides, steps and stance (Brach et al., 2008a; Brach et al., 2007; Hausdorff et al., 2001). The identification of new contributors to mobility limitations in older adults are needed to identify those at risk for mobility limitations and to improve rehabilitative outcomes, as currently known factors account for <50% of the variance in measures of mobility (Bean et al., 2013).

Another class of body movement measures is the timing of one body segment in relation to another, termed coordination (Kelso, 1995). Impairments in the coordination of the left-right stepping pattern during the gait cycle have not been well studied with respect to mobility

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limitations in older adults. The Phase Coordination Index (PCI) provides a means of evaluating gait coordination that combines the variability and asymmetry of the left-right step timing during locomotion. Prior research has shown that PCI distinguishes older from young adults even when gait speed and stride time variability do not (Plotnik et al., 2007). Poorer gait coordination (i.e., higher PCI values) has also been found post-stroke (Meijer et al., 2011), and in patients with Parkinson's disease with (vs. without) freezing gait (Peterson et al., 2012). The relationship of PCI to standard measures of mobility performance in older adults is not well established.

We view gait coordination, as measured by PCI, as a novel and potentially important gait impairment. Thus, while the association of standard mobility measures with gait impairment measures (i.e., gait variability) is known, the relative strength of association of PCI with mobility performance has not been evaluated. Therefore, we conducted a study of PCI and other gait impairment measures and their relationship with standard measures of mobility within the Maintenance of Balance, Independent Living, Intellect and Zest in the Elderly (MOBILIZE) of Boston study (MBS), a population-based study of older adults. The Short Physical Performance Battery (SPPB) is a measure of mobility performance that has been shown to be predictive of disability, nursing home admission, and mortality (Guralnik et al., 2000; Guralnik et al., 1994). The aim of this study was to examine the association of gait coordination with mobility performance in older adults. We hypothesized that, after adjusting for age and gender, PCI would be significantly associated with SPPB scores.

2. Methods

2.1. Participants

Community dwelling older adults aged 77–101 years were recruited for the current follow-up assessment wave of the MBS. Details of the original design, recruitment and assessment for the MOBILIZE Boston Study have been previously published (Leveille et al., 2008). When the MBS began in 2005 to 2008, participants were recruited door to door in Boston and 5 surrounding communities. Eligibility criteria included age 70 years or older, ability to speak and understand English, ability walk 20 ft without personal assistance, sufficient vision to read written material, and the expectation of living in the area for at least the subsequent 2 years. Exclusion criteria were a Mini-Mental State Exam score of <18, severe language, visual or hearing deficits, or having a terminal disease. Interested spouses and domestic partners of participants were allowed to join the study if they were aged 65 or older and met other eligibility criteria. All participants completed a new written informed consent form for the current follow-up that was approved by the Hebrew Senior Life Institutional Review Board.

2.2. Measures

2.2.1. Gait analysis

Participants were instructed to walk at their usual pace across a 16 foot long GAITRite Electronic Walkway (Menz et al., 2004). The participants performed 2 walking trials that consisted of 3 passes each across the gait walkway and an additional 3 ft on either end of the walkway. Variables calculated from gait walkway data were the mean gait speed, PCI and the coefficient of variation (CV = SD / Mean) of the: 1) stride time; 2) stride length; 3) stride width; 4) step width; and 5) stance time; expressed as percentages. Participants who completed a total of 6 passes across the walkway and with a sufficient number of strides to determine at least 15 data values for each gait variable were included in the analysis (N = 164; 120 female).

Data from the first 15 strides for each participant were used to calculate each gait variable. The stride time, length and width, step time, width and stance time data time series were determined by the GAITRite software. The speed of individual strides was calculated as the stride distance divided by the stride time. The 15 stride speeds were then averaged to determine the mean gait speed for each participant. The PCI (as described below) and the CV (SD/Mean) of stride time, length and width, the step width and stance time were calculated using custom written MATLAB software. Inferential statistical analysis was conducted using IBM SPSS software (version 22) using a Type I error rate of 0.05.

PCI was determined from the first 15 gait phase (ϕ) values for each participant. The gait phase (ϕ) for individual strides is determined by dividing step times by stride times and multiplying by 360°. Gait coordination that is perfectly symmetrical would have step times that are one half of stride times and gait phase values of $\phi = 180°$. PCI was calculated as previously recommended (Plotnik et al., 2007) using the absolute deviation of the gait phase from 180° ($\phi\ ABS$) and the coefficient of variation of gait phase ($CV\ \phi = SD\ \phi\ /\ Mean\ \phi$). Increments in PCI values indicate increments in the variability of ϕ and/or the deviation of ϕ from symmetrical coordination (180°). As mean gait phase values fell within a narrow range we used standard linear, rather than circular, statistics for analysis.

2.2.2. Short Physical Performance Battery

Participants performed the SPPB, which consists of usual walking speed, standing balance, and a five-repetition chair stand test (Guralnik et al., 1994). Scores from each component are scored between 0 and 4 which when summed creates a total score ranging from 0 to 12, with higher scores indicating better performance. SPPB score was calculated in the standard manner, including scores for gait speed, balance and chair rise time (Guralnik et al., 1994).

2.2.3. Gait speed

The gait speed score included in the total SPPB score was determined by having participants walk at their usual pace across a 4-meter course. The faster of two trials was used to determine the gait score according to the following criterion: a score of 0 was assigned to participants who could not perform the task; 1 for task completion in >5.7 s; 2 for completion between 4.1 and 5.7 s; 3 for completion between 3.2 and 4.09 s; 4 for completion in <3.2 s.

2.2.4. Repeated chair stands

While seated in a chair participants were instructed to stand and sit 5 times as quickly as they were able with their arms crossed. The chair stand score was determined according to the following criterion: a score of 0 was assigned to participants who could not perform the task; 1 for task completion in >16.7 s; 2 for completion between 13.7 and 16.69 s; 3 for completion between 11.2 and 13.59 s; or 4 for completion in <11.2 s. In linear regression modeling of individual SPPB component tasks chair rise score, rather than time, was used for analysis so data for participants who were unable to perform the chair rise test could be included.

2.2.5. Standing balance

Balance was assessed with three 10-second stands: standing with the feet touching side-by-side, semi-tandem stand with the side of one heel touching the side of the big toe of the other foot, and full tandem (heel to toe) stand. If a participant was unable to perform one of these stands for 10 s they were not requested to perform the subsequent more challenging standing tests. Balance score was determined by the following criterion: 0 = side-by-side balance time of 0–9 s or unable to perform; 1 = side-by-side stand time of 10 s and <10 s for semi-tandem stand; 2 = semi-tandem stand time of 10 s and full tandem stand time 0–2 s; 3 = semi-tandem stand time of 10 s and tandem stand for 3–9 s; 4 = full tandem stand for 10 s.