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Gait characteristics associated with walking speed decline in older adults: Results from the Baltimore Longitudinal Study of Aging

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ABSTRACT

Background: Understanding the mechanisms that contribute to walking speed decline can provide needed insight for developing targeted interventions to reduce the rate and likelihood of decline.
Objective: Examine the association between gait characteristics and walking speed decline in older adults.
Methods: Participants in the Baltimore Longitudinal Study of Aging aged 60 to 89 were evaluated in the gait laboratory which used a three dimensional motion capture system and force platforms to assess cadence, stride length, stride width, percent of gait cycle in double stance, anterior–posterior mechanical work expenditure (MWE), and medial–lateral MWE. Usual walking speed was assessed over 6 m at baseline and follow-up. Gait characteristics associated with meaningful decline (decline $\geq$0.05 m/s/y) in walking speed were evaluated by logistic regression adjusted for age, sex, race, height, weight, initial walking speed and follow-up time.
Results: Among 362 participants, the average age was 72.4 (SD = 8.1) years, 51% were female, 27% were black and 23% were identified has having meaningful decline in usual walking speed with an average follow-up time of 3.2 (1.1) years. In the fully adjusted model, faster cadence [OR_{adj} = 0.65, 95% CI (0.43,0.97)] and longer strides [OR_{adj} = 0.87, 95% CI (0.83,0.91)] were associated with lower odds of decline. However age [OR_{adj} = 1.04, 95% CI (0.99,1.10)] was not associated with decline when controlling for gait characteristics and other demographics.
Conclusion: A sizable proportion of healthy older adults experienced walking speed decline over an average of 3 years. Longer stride and faster cadence were protective against meaningful decline in usual walking speed.

1. Introduction

Walking speed declines with age and slower walking speed has been associated with increased risk of falls, hospitalizations, and subsequent physical and cognitive decline (Mielke et al., 2013; Newman et al., 2006; Peel, Kuys, & Klein, 2013; Watson et al., 2010). Walking speed is also predicts five and ten year survival rates over and beyond age (Studenski et al., 2011). In fact, it has been suggested that evaluation of walking speed should become standard clinical measurement for older adults as it is easily evaluated in a clinic settings (Cummings, Studenski, & Ferrucci, 2014; Peel et al., 2013).

Although walking speed is a promising clinical measure, very few studies have tested the hypothesis that increasing walking speed could lead to less disability. Indeed, since the physiological mechanisms that lead to walking speed decline with aging are not completely understood, it is difficult to develop tailored preventive interventions. Age-related differences in biomechanical characteristics of gait may offer some clue on the mechanisms underlying gait speed decline with aging. Older adults have slower walking speeds compared to younger adults and tend to have shorter stride lengths (Judge, Davis, & Ounpuu, 1996; Samson et al., 2001). There are also differences between older and younger participants in stride width and time spent in double support (Gabell & Nayak, 1984). It has been suggested that movements in the sagittal plane,

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greater lateral movement and even double stance time, are related to compensatory strategies to address progressive balance impairments, and may result in slower gait speeds (Gabell & Nayak, 1984). Interestingly, even among older adults, those who are older have slower walking speed, slower cadence, shorter stride lengths and higher MWEs (Ko, Stenholm, Metter, & Ferrucci, 2012; Ko, Ling, Winters, & Ferrucci, 2009). Some studies reported that cadence was associated with age among older adults, while others report no age related differences in cadence (Ko, Tolea, Hausdorff, & Ferrucci, 2011; Samson et al., 2001).

Remarkably, most work examining gait parameters and walking speed is cross-sectional, and it is mostly unknown whether changes in gait biomechanical parameters emerge before or in parallel to the decline in speed. Thus, there is great need of studies that examine gait characteristics and test the hypothesis that they are predictive of future decline of walking speed in older adults. This includes determining if basic spatio-temporal gait parameters (i.e. stride length) and kinetic parameters (i.e. MWE, double stance) known to differ by and vary with age are predictive of walking speed slowing and decline. Attention to spatio-temporal gait parameters in concert with kinetic parameters may be especially important in generally healthy, well-functioning older adults in whom the start of the decline process may be particularly difficult to detect.

Important methodological work has identified walking speed declines as small as 0.03 to 0.06 m/s to be meaningful among older adults (Kwon et al., 2009; Perera, Mody, Woodman, & Studenski, 2006). Meaningful was defined using an anchor based approach to identifying the minimal change perceived as meaningful to the individual (Guyatt, Osoba, Wu, Wyrwich, & Norman, 2002). These small detectable changes in walking speed have been identified across demographic groups in healthy older adults and among older adults with clinical conditions (Kwon et al., 2009; Perera et al., 2006, 2014). Identifying early markers of decline among relatively healthy older adults could allow for timely intervention to slow the decline process.

This study examined the association between gait characteristics and decline in walking speed over an average follow-up of three years in generally high functioning older adults participating in the Baltimore Longitudinal Study of Aging (BLSA). Gait characteristics including stride length, stride width and MWE were assessed with a three dimensional motion capture system and force platforms. Usual walking speed was determined during a short corridor walk and change in walking speed was calculated between two study visits.

2. Methods

2.1. Participants

The BLSA is a continuous enrollment cohort study of normative aging conducted by the National Institute on Aging (NIA), Intramural Research Program (IRP). Eligibility at enrollment is restricted to persons free of cognitive impairment, functional limitations, chronic diseases, and cancer within the past 10 years. Participants receive regularly scheduled comprehensive health, cognitive, and functional evaluations over a 3-day visit to the BLSA clinic facility. Visits occur every two years for persons aged 60–79 and annually for persons aged 80 and older.

Participants in the current analyses were aged 60 to 89 years at the time of their gait laboratory and walking speed assessments. Exclusion criteria for gait evaluation included: hip or knee joint prosthesis; severe joint pain; severe obesity (i.e. body mass index >40 kg/m^2); history of Parkinson's disease; inability to walk safely without assistance. In addition, participants in the analytic sample had to have at least one follow-up assessment of walking speed either at the clinic or during a home visit. The BLSA protocol was approved by the standing Institutional Review Board either Medstar Research or the National Institute of Environmental Health Sciences depending on the date of data collection. All participants provided informed consent.

2.2. Demographics and anthropometrics

Demographic characteristics were self-reported and standardized procedures were used to assess height and weight.

2.3. Gait characteristics

Detailed procedures for gait evaluation in the NIA IRP Gait Laboratory have been reported previously (Ko et al., 2009) and are summarized here. Participants wore non-reflective tight-fitting spandex and reflective markers were placed directly on the skin at 20 anatomical landmarks. A Vicon three dimensional motion capture system with 10 digital cameras (Vicon 612 system, Oxford Metrics Ltd. Oxford, UK) using a 60 Hz sampling frequency recorded the markers during a 10 m walk at usual walking speed. In addition, three staggered force platforms (Advanced Mechanical Technologies, Inc., Watertown, MA, USA) assessed ground reaction forces (1080 Hz sampling frequency). Spatiotemporal (e.g. cadence, stride length, stride width) and kinetic gait characteristics (e.g. MWE) were calculated as previously reported (Ko et al., 2009).

2.4. Usual walking speed

Usual walking speed in meters per second (m/s) was assessed while participants walked at their "usual, comfortable pace" from a standing start over a 6 m course in an uncarpeted corridor. Participants completed the task twice and the faster of the two trials was used for analyses. Follow-up walking speed was obtained from the next regularly scheduled BLSA visit which was conducted in the clinical unit for the majority of participants. A few individuals unable or unwilling to attend a clinic visit had a home visit where the walking course was 4 m.

2.5. Meaningful decline in usual walking speed

Meaningful decline in usual walking speed was defined as a walking speed decline of at least 0.05 m/s per year of follow-up (Kwon et al., 2009; Perera et al., 2006, 2014).

2.6. Statistical analyses

Age was expressed in years, height in centimeters, weight in kilograms, and race as either black or non-black. Usual walking speed was reported as m/s and both anterior–posterior and medial–lateral MWE were expressed as 100 J/kg. Cadence was reported in steps per minute and analyzed as 10 steps per minute. Both stride length and width were expressed in centimeters. Double stance refers to the percent of the overall gait cycle spent in double stance, that is, with both feet on the ground. Walking speed change was calculated (follow-up walking speed—initial walking speed) with negative values indicating decline. Follow-up time (date of second visit—date of first visit) was expressed in years. Meaningful decline was a dichotomous variable indicating if the participant had a decline in usual walking speed of at least 0.05 m/s/year.

Descriptive statistics were reported for demographic characteristics, walking speed, and gait characteristics at the initial visit for these analyses. Bivariate correlations were reported for age, usual walking speed, gait characteristics, and changes in walking speed. The associations of gait characteristics associated with