Archives of Gerontology and Geriatrics 66 (2016) 54–61

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics

journal homepage: www.elsevier.com/locate/archger

Challenging the motor control of walking: Gait variability during slower and faster pace walking conditions in younger and older adults

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ARTICLE INFO

Article history:
Received 6 February 2016
Received in revised form 12 April 2016
Accepted 2 May 2016
Available online 9 May 2016

Keywords:
Gait variability
Motor control
Older adults
Faster
Slower

ABSTRACT

Background: Gait variability is a measure of motor control of gait. Little is known about age-related changes in the motor control of gait (gait variability) during challenging walking conditions, such as slower and faster pace walking.
Objective: The purpose of this study was to examine the impact of challenging walking conditions (slower and faster speeds) on gait variability in younger and older adults.
Design: This study was a cross-sectional, observational design.
Methods: Forty younger (mean age = 26.6 ± 6.0 years) and 111 community-dwelling older adults (mean age = 77.3 ± 6.0 years), independent in ambulation, were studied. Gait characteristics were collected using a computerized walkway (GaitMat II^{TM}). Step length, step width, step time, swing time, stance time and double support time variability were derived as the standard deviation of all steps across the 4 passes.
Results: Compared to younger, older adults had a significant change in their gait variability from usual to slower in step width (-0.006 ± 0.003), step time (0.028 ± 0.006), swing time (0.023 ± 0.004), stance time (0.042 ± 0.008), and double support time (0.024 ± 0.005). Changes in gait variability from usual to faster were not significantly different between younger and older adults.
Limitation: Gait variability was examined during self-selected over-ground walking, where subjects directed to walk "slower", "usual" and "faster".
Conclusions: Walking slowly is more challenging to the motor control of gait and may be more sensitive to age-related declines in gait than usual and faster speed walks.

1. Introduction

Gait variability, defined as fluctuations in spatio-temporal gait characteristics from one step to the next, is a measure of the motor control of gait (Gabell and Nayak, 1984). Under normal conditions within a testing session, the values of these fluctuations are relatively small reflecting remarkable consistency and stability within the locomotor system (Hausdorff, 2005). However, the fluctuations in spatio-temporal gait characteristics are altered in normal aging (Maki, 1997; Herman, Giladi, & Gurevich, 2005; Hollman, Kovash, & Kubik, 2007), in certain disorders that are largely considered having difficulties in the motor control of gait (i.e. Parkinson's and Alzheimer disease) (Baltadjieva, Giladi, & Gruendlinger, 2006; Webster, Merory, & Wittwer, 2006) as well as in subclinical conditions (Gabell & Nayak, 1984; Montero-Odasso, Muir, & Hall, 2011). Assessment of the alterations in gait variability may provide additional insights about mobility dysfunction and fall risk, above and beyond mean values of gait parameters such as average gait speed or step time (Brach, Berlin, & VanSwearingen, 2005; Brach, Studenski, & Perera, 2007; Hausdorff, 2005; Lord, Howe, & Greenland, 2011).

Measures of gait variability are commonly used to study age-related gait changes (Brach et al., 2005; Hausdorff, Edelberg, & Mitchell, 1997; Hausdorff, Rios, & Edelberg, 2001; Herman et al., 2005; Moe-Nilssen & Helbostad, 2005). Although some studies have found gait variability to be greater in older adults compared to younger adults (Grabiner, Biswas, & Grabiner, 2001; Owings & Grabiner, 2004a), others have reported no differences in gait variability between younger and older adults (Gabell & Nayak,

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http://dx.doi.org/10.1016/j.archger.2016.05.001
0167-4943/

1984; Hausdorff et al., 1997; Stolze, Friedrich, & Steinauer, 2000; Thies, Richardson, & Ashton-Miller, 2005). The majority of the studies that did not find a difference in gait variability between younger and older adults (Gabell & Nayak, 1984; Hausdorff et al., 1997; Stolze et al., 2000), investigated gait variability during usual pace unchallenged walking where energy cost of walking is minimized (Holt, Jeng, & Rr, 1995). This optimization of walking at usual speed might be due to the inherent interaction of neural and biomechanical mechanisms, with only minimal active control of high-level sensory feedback control (Wuehr, Schniepp, & Pradhan, 2013).

Little is known about age-related changes in gait variability during challenging walking conditions such as slower and faster pace walking. It is likely that these challenging walks are more sensitive to age-related declines in gait compared to usual walking speed (Ko, Hausdorff, & Ferrucci, 2010; Nascimbeni, Minchillo, & Salatino, 2015). Healthy younger adults become more variable when they walk at slower speed (Dingwell and Marin, 2006; Yamasaki, Sasaki, & Torii, 1991). Slowing of walking speed is one of the most consistent reported age-related changes in gait (Winter, Patla, & Frank, 1990). Therefore, increased gait variability in healthy older adults may be simply related to their slow walking speed. Alternatively, several studies suggest that the alterations in gait variability with older adults are a reflection of underlying subclinical pathology in important neural locomotor regions, and not simply a manifestation of slow walking speed. Slower speed of walking might be a challenging task to their motor control of gait (Hausdorff, 2004, 2005, 2007). Another study suggested that increased gait variability seen in older adults may exist from other causes such as loss of strength or flexibility than from their slower speeds (Kang & Dingwell, 2008). In addition, faster walking speed has been previously reported in the guidelines for clinical spatio-temporal gait analysis in older adults as a highly stressful walking condition that may challenge older adults and optimize the detection of high-level gait impairment (Ko et al., 2010; Kressig et al., 2006).

Previous studies which examined gait variability at different walking speeds in younger and older adults obtained conflicting results, as some failed to find any relationship (Kang and Dingwell, 2008; Owings and Grabiner, 2004b), while others reported either linear or a non-linear relationship (Jordan, Challis, & Newell, 2007; Beauchet, Annweiler, & Lecordroch, 2009). Additionally most of these studies examined gait variability with fixed walking speeds on a treadmill. The imposed constant speed of a treadmill may artificially impose motor control of gait and impede the natural variation that occurs during over-ground walking and therefore minimize gait variability (Owings & Grabiner, 2004a; Dingwell, Cusumano, & Cavanagh, 2001).

The association between over-ground challenging walking conditions (slower and faster speeds) and gait variability remains unclear. Therefore, the purpose of this study was to examine the impact of challenging over-ground walking conditions (slower and faster speeds) on gait variability in younger and older adults. We expected gait variability would be greater under challenging walking conditions of slower and faster speeds compared to usual speed, and the impact would be greater in older adults compared to younger adults. To explore the impact of age-related changes on gait variability independent of walking speeds, we also compared gait variability by challenging walking condition for a subgroup of older adults who had similar walking speeds as the younger adults (i.e. speed-matched older adults). The assessment of gait variability during challenging walking conditions such as walking slower or faster may uncover motor control deficits among older adults that are not identified during usual walking testing.

2. Methods

2.1. Participants

Forty younger and 111 older adults participated in the study. The younger adults were recruited through fliers posted throughout the University of Pittsburgh.The younger participants were between the ages of 18 and 50, ambulated independently, and had no diagnosed neuromuscular, cardiopulmonary, or orthopedic conditions that would affect walking. The younger participants were first screened over the phone to determine initial eligibility. Subjects who passed the phone screen were scheduled for a one hour clinic visit which included a physical exam (range of motions and muscle testing) to determine final eligibility followed by measurement of gait characteristics using a computerized walkway.

Older participants were identified from a previous prospective longitudinal study of gait and balance in older adults (Brach, Perera, & VanSwearingen, 2011a). The inclusion criteria for the older adults were age 65 or older; self-reported ability to tolerate a five-hour session (with rest periods) of answering questionnaires and performing walking tests; ability to independently walk a household distances (approximately 50 ft) at a minimum, with or without an assistive device and without the assistance of another person. Also, the older adults had to be free of (a) neuromuscular disorders that impaired movement (including but not limited to Parkinson's disease, stroke, and multiple sclerosis); (b) cancer with active treatment (specifically radiation or chemotherapy) within the past 6 months; (c) non-elective hospitalization for a life-threatening illness or major surgical procedure in the past 6 months; (d) severe pulmonary disease requiring supplemental oxygen or resulting in difficulty breathing at rest or with minimal exertion (such as walking between rooms in their home); and (e) chest pain with activity or a cardiac event, such as heart attack within the past 6 months. The older participants were first screened over the phone to determine initial eligibility. Subjects who passed the phone screen were scheduled for a clinic visit which included a physical exam to determine final eligibility. Older adults completed 5 h of testing, including a measurement of gait characteristics which occurred within the first hour of testing. Both studies of younger and older adults were approved by the University of Pittsburgh Institutional Review Board, and all participants provided informed consent prior to participation.

2.2. Gait characteristics

Spatial and temporal gait characteristics were collected using acomputerized walkway (GaitMat II^{TM}) (EQ Inc, Chalfont, PA) (Craik & Oatis, 1995). The GaitMat II is an automated gait analysis system, based on the opening and closing of pressure sensitive switches on the walkway that are displayed on the computer screen as footprints when the participant walks.The GaitMat II is providing a temporal resolution of 5 msec and a spatial resolution of 15 mm in both the longitudinal and transverse directions.The reliability and validity of the computerized walkway has been established for quantification of the spatial and temporal mean gait characteristics for a variety of populations including children (Thorpe, Dusing, & Moore, 2005), healthy young adults (Menz, Latt, & Tiedemann, 2004), healthy older adults, (Brach, Studenski, & Perera, 2008; Menz et al., 2004) individuals with Parkinson's disease (Nelson, Zwick, & Brody, 2002) and Huntington disease (Rao, Quinn, & Marder, 2005).

For younger adults, the GaitMat II was approximately 12 m in length. The initial and final 2 m were inactive sections to allow for acceleration and deceleration of the participant. The middle 8 m were active and used for data collection. For older adults, the