Gait & Posture 44 (2016) 94–99

Contents lists available at ScienceDirect

Gait & Posture

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

The test–retest reliability and minimal detectable change of spatial and temporal gait variability during usual over-ground walking for younger and older adults☆

Maha Almarwani [a,c,*], Subashan Perera [b], Jessie M. VanSwearingen [a], Patrick J. Sparto [a], Jennifer S. Brach [a]

[a] Department of Physical Therapy, University of Pittsburgh, Pittsburgh, PA, United States
[b] Division of Geriatric Medicine, Department of Medicine, University of Pittsburgh, Pittsburgh, PA, United States
[c] Department of Rehabilitation Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia

ARTICLE INFO

Article history:
Received 1 April 2015
Received in revised form 18 November 2015
Accepted 23 November 2015

Keywords:
Reliability
Gait
Variability
Younger
Older

ABSTRACT

Gait variability is a marker of gait performance and future mobility status in older adults. Reliability of gait variability has been examined mainly in community dwelling older adults who are likely to fluctuate over time. The purpose of this study was to compare test–retest reliability and determine minimal detectable change (MDC) of spatial and temporal gait variability in younger and older adults. Forty younger (mean age = 26.6 ± 6.0 years) and 46 older adults (mean age = 78.1 ± 6.2 years) were included in the study. Gait characteristics were measured twice, approximately 1 week apart, using a computerized walkway (GaitMat II). Participants completed 4 passes on the GaitMat II at their self-selected walking speed. Test–retest reliability was calculated using Intra-class correlation coefficients ($ICCs_{(2,1)}$), 95% limits of agreement (95% LoA) in conjunction with Bland-Altman plots, relative limits of agreement (LoA%) and standard error of measurement (SEM). The MDC at 90% and 95% level were also calculated. ICCs of gait variability ranged 0.26–0.65 in younger and 0.28–0.74 in older adults. The LoA% and SEM were consistently higher (i.e. less reliable) for all gait variables in older compared to younger adults except SEM for step width. The MDC was consistently larger for all gait variables in older compared to younger adults except step width. ICCs were of limited utility due to restricted ranges in younger adults. Based on absolute reliability measures and MDC, younger had greater test–retest reliability and smaller MDC of spatial and temporal gait variability compared to older adults.

1. Introduction

Gait variability is a quantifiable feature of walking defined as fluctuations in the spatial and temporal gait characteristics from one step or stride to the next [1–3]. Gait variability has recently gained much attention in research and clinical studies. Measures of gait variability might provide additional insights into the neuromotor control of walking, assist in identifying mobility dysfunction and fall risk in older adults, above and beyond mean values of gait parameters such as average gait speed or step time [4–6]. In this sense, measures of spatial and temporal gait variability are becoming important clinical tools.

Test–retest reliability is a fundamental psychometric requirement for any measure. However, the reliability of spatial and temporal gait variability is not well established [1,6–8]. The reliability of gait variability has mainly been examined in community dwelling older adults with a mean group age in the 8th decade. The reliability of gait variability in older adults is inconsistent; ranging from poor to excellent, with intra-class correlation coefficients (ICCs) ranging from 0.11 to 0.98 depending on the variables reported [6,7]. Lack of knowledge of the reliability of gait variability measures limits the interpretation of gait

☆ This work was supported by a National Institutes on Aging and American Federation of Aging Research Paul Beeson Career Development Award (grant no. K23 AG026766); and the University of Pittsburgh Older American's Independence Center (P30 AG024827); and the University of Pittsburgh, School of Health & Rehabilitation Sciences Research Development Fund. Maha Almarwani was supported by King Saud University, Riyadh, Saudi Arabia. A portion of this work was presented as an abstract at the Aging Institute Research Day, March 2015, Pittsburgh, PA.

* Corresponding author at: Department of Physical Therapy, University of Pittsburgh, 470 Bridgeside Point 1, Pittsburgh, PA 15219, United States.
Tel.: +1 412 383 6533.
E-mail address: mma46@pitt.edu (M. Almarwani).

http://dx.doi.org/10.1016/j.gaitpost.2015.11.014
0966-6362/

variability from evaluative, diagnostic, prognostic and intervention studies [3,6]. In this regard, it is important to know the minimal detectable change (MDC) to support the use of gait variability as an outcome measure in clinical or research settings. The MDC allows investigators to determine if an observed change is a true change or simply a result of a measurement error [9].

Healthy older adults exhibit greater variability in basic spatial and temporal measures of gait when compared to healthy young adults [10–12]. Gait variability is thought to be a function of the neurological integration of numerous sensory inputs (e.g. visual, auditory, vestibular, proprioceptive, etc.) and feedback processes that take place during the generation of each gait cycle [13]. An increase in gait variability is indicative of a decline in the coordination of the locomotor control system and its complex integration of interdependent components [14]. Older adults may fluctuate in their walking from hour to hour, day to day, week to week which could impact the reliability of gait variability whereas walking in younger adults is more stable (fluctuates less), thus potentially leading to more consistent measurements or greater test/retest reliability. In older adults, it is possible that underlying subclinical pathology in important neural locomotor regions might contribute to inconsistent walking over time and low reliability estimates [10].

The purpose of this study was to (i) compare the test–retest reliability and (ii) determine the minimal detectable change (MDC) of spatial and temporal gait variability in younger and older adults over one week. Younger adults are more stable and fluctuate less in their walking over time compared to older adults [10]. Therefore, we hypothesized that younger adults will have greater test–retest reliability and smaller MDC of spatial and temporal gait variability compared to older adults.

2. Methods

2.1. Participants

Forty younger and 46 older adults were included in the study. The younger adults were recruited through fliers posted throughout the University of Pittsburgh. The younger participants were of age 19–47 years, 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 prospective longitudinal study of gait and balance in older adults [15]. 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 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 impair 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 a computerized walkway (GaitMat II) (EQ Inc., Chalfont, PA) [16]. 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 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 [17], healthy young adults [18], healthy older adults [1,18], and individuals with Parkinson's disease [19] and Huntington disease [20].

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 GaitMat II was approximately 8 m in length. The initial and final 2 m were inactive sections to allow for acceleration and deceleration of the participant. The middle 4 m were active and used for data collection.

Each participant completed two practice walks the length of the walkway to become familiar to walking on mat. Each walk was considered one pass. Four passes were collected at the subject's self-selected walking speed for data collection. Participants completed two test sessions approximately one week apart.

2.3. Data processing

GaitMat II data was inspected and cleaned for half foot-prints (footprints that occur at the beginning and the end of the mat) and extraneous points. Step length, step width, step time, stance time, swing time, and double support time were determined for each individual step. These spatial and temporal gait characteristics were commonly used in studies of gait variability [1,11,14,21,22]. Definitions of each of the spatial and temporal characteristics are listed below in Table 1. We first looked for asymmetries between left and right steps, as asymmetries can impact measures of gait variability [7]. There were no asymmetries between left and right steps, so left and right steps were combined and the standard deviation from all steps was calculated as the measure of gait variability.

2.4. Statistical analysis

All statistical analyses were conducted with SAS version 9.3. We computed appropriate descriptive statistics to describe the study sample. The mean and standard deviation of gait variability of spatial and temporal gait characteristics for younger and older adults were calculated. Absolute differences of gait variability between visit 1 and visit 2 were computed. Independent sample *t*-tests were used to compare the absolute differences between younger and older adults.

To assess test–retest reliability of gait variability in younger and older adults, intra-class correlation coefficients (ICCs) (2, 1 model) were computed. ICCs were interpreted as follows: less than 0.4, poor; 0.4–0.75, fair to good; and more than 0.75, excellent [23]. ICCs represent the relative reliability which is the degree to