ORIGINAL ARTICLE

The Reliability and Validity of Measures of Gait Variability in Community-Dwelling Older Adults

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ABSTRACT. Brach JS, Perera S, Studenski S, Newman AB. The reliability and validity of measures of gait variability in community-dwelling older adults. Arch Phys Med Rehabil 2008; 89:2293-6.

Objective: To examine the test-retest reliability and concurrent validity of variability of gait characteristics.

Design: Cross-sectional study.

Setting: Research laboratory.

Participants: Older adults (N=558) from the Cardiovascular Health Study.

Interventions: Not applicable.

Main Outcome Measures: Gait characteristics were measured using a 4-m computerized walkway. SD determined from the steps recorded were used as the measures of variability. Intraclass correlation coefficients (ICC) were calculated to examine test-retest reliability of a 4-m walk and two 4-m walks. To establish concurrent validity, the measures of gait variability were compared across levels of health, functional status, and physical activity using independent *t* tests and analysis of variances.

Results: Gait variability measures from the two 4-m walks demonstrated greater test-retest reliability than those from the single 4-m walk (ICC=.22–.48 and ICC=.40–.63, respectively). Greater step length and stance time variability were associated with poorer health, functional status and physical activity ($P<.05$).

Conclusions: Gait variability calculated from a limited number of steps has fair to good test-retest reliability and concurrent validity. Reliability of gait variability calculated from a greater number of steps should be assessed to determine if the consistency can be improved.

Key Words: Gait; Rehabilitation; Reliability and validity.

GAIT VARIABILITY IS EMERGING as an important indicator of impaired mobility in community-dwelling older adults, among whom it has been shown to predict future falls and incident mobility disability.[1-4] An important quality of any measure is test-retest reliability, the consistency of repeated measurements for a subject. Measurements that do not have good test-retest reliability will have high measurement error and are likely to be imprecise, making it difficult to assess associations or change over time.[5] Although the test-retest reliability of gait speed and mean gait characteristics have been extensively assessed for reliability,[6-10] the test-retest reliability of gait variability measures is unknown.

Naturally, the number of data points or steps used in the calculation of gait variability are important in the consistency of the measure, with longer walks giving more stable variability estimates.[11,12] However, the optimal number of consecutive steps or data points needed to calculate a consistent measure of gait variability has yet to be determined, and such a recommendation must consider tradeoffs between maximizing consistency and the potential constraints of subject fatigue and space limitations.

Accuracy or validity of a measure is also essential for research. A measure is valid to the extent that it measures what it purports to measure. The predictive validity of gait variability for future falls[1,2] and incident mobility disability[4] has been reported. However, reports of concurrent validity have been limited by modest sample size and focus on only temporal aspects of gait variability.[13]

The purpose of this study was to examine reliability and validity of measures of temporal and spatial gait variability in a large sample of community-dwelling older adults. Specifically, we report test-retest reliability of measures of gait variability, and estimate the impact of the length of the walk on the consistency of the measure. The concurrent validity of temporal and spatial measures of gait variability is also examined by comparison to measures of health, functional status, and physical activity.

METHODS

Study Sample

Gait characteristics were assessed in ambulatory older adults from the Pittsburgh site of the CHS at the tenth follow-up visit (between 1998 through 1999). CHS is a population-based, ongoing longitudinal multicenter study of coronary heart disease and stroke risk in community-dwelling older adults age 65 years and older.[14,15] At the initiation of the CHS in 1989

List of Abbreviations

ADLs	activities of daily living
CHS	Cardiovascular Health Study
IADLs	instrumental activities of daily living
ICC	intraclass correlation coefficient

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through 1990, individuals were identified from the Health Care Financing Administration sampling frame. Individuals who were 65 years or older, noninstitutionalized, expected to remain in the area for 3 years, and able to give informed consent were included in the study. Individuals who were wheelchair-bound in the home or were receiving hospice care, radiation therapy, or chemotherapy for cancer were excluded.[14,15] In 1989 to 1990 an original cohort of 5201 predominately (>95%) white men and women were enrolled, and in 1992 through 1993 a cohort of 687 black men and women was added.

Participants in the current study included men and women who attended the tenth clinic visit in 1998 through 1999 at the Pittsburgh site, who could walk without the assistance of another person, and who could follow directions to complete the gait assessment (N=558). The University of Pittsburgh Institutional Review Board approved this study, and all study participants provided written informed consent prior to data collection.

Gait Characteristics

The GaitMat II system[a] was used for the gait analysis.[16] The GaitMat II consists of a 4-m long walkway on which the subject walks and a computer system that controls the GaitMat II and analyzes the data. In addition to the 4-m long walkway, there are initial and final 1-m inactive sections to allow for acceleration and deceleration of the participant. The GaitMat II is an automated gait analysis system based on the opening and closing of pressure-sensitive switches, which are represented on the computer screen as footprints when the participant walks on the walkway. Participants completed 2 practice passes on the GaitMat II followed by 4 passes at their self-selected walking speed for data collection.

We were primarily interested in variability of step length, step width, and stance time. Step length and width represent spatial characteristics in 2 different planes. Stance time was selected as the temporal gait characteristic. Step length, step width, and stance time were also specifically selected because they have been studied by other investigators.[1,2,17,18] Gait speed was determined by dividing the distance traversed by the time between the first and last step (eg, switch closure) and was recorded in meters/second. Step length was defined as the distance between 2 consecutive footprints, measured from the heel of 1 footprint to the heel of the next footprint and was recorded in meters. Step width was defined as the distance between the outermost borders of 2 consecutive footprints and was recorded in meters. Stance time was defined as the length of time that 1 foot was in contact with the floor (ie, from initial foot-floor contact until final foot-floor contact) and was recorded in seconds. The SDs of step length, step width, and stance time determined from all of the steps recorded over the passes of interest (1 pass for the 4-m analyses and 2 passes for the two, 4m analyses) were used as the measures of variability.

Other Measures

Measures used for the concurrent validity analyses included a measure of general health perception, self-reported difficulty with ADLs and IADLs, difficulty walking a half mile, and physical activity level.[19] Perception of general health was self-reported as excellent, very good, good, fair, or poor. The ADLs assessed were bathing, dressing, eating, using the toilet, walking around the home, or getting out of a bed or chair. The IADLs were heavy housework, light housework, shopping for personal items, preparing own meals, paying bills or managing money, or using the telephone. Self-reported difficulty walking a half mile was also recorded. Physical activity was measured as the self-reported number of blocks walked in the past week and the participants were classified as physically active (≥7 blocks) or physically inactive (<7 blocks).

Statistical Analysis

Step length, stance time, and step width variability calculated from the four individual passes and an ICC was calculated to determine test-retest reliability of a 4-m walk. Step length, stance time, and step width variability calculated from the first 2 passes and the last 2 passes were used to obtain an ICC to determine the test-retest reliability of two 4-m walks. ICCs were interpreted as follows: less than 0.4, poor; 0.4 to 0.75, fair to good; and more than 0.75, excellent.[20] Similar assessment of test-retest reliability was made for mean gait characteristics and gait speed to examine the consistency of the methodology for measuring gait characteristics in our sample compared with the methodology of other studies.

To establish the concurrent validity, the measures of step length variability, stance time variability, and step width variability (dependent variables) were compared across individuals with and without ADLs and IADLs difficulty, with and without difficulty walking a half mile, who were physically active (reported ≥7 blocks walked previous week) and inactive (reported <7 blocks walked previous week), who could and could not tandem stand for 10 seconds, and with different levels of health status (poor, fair, good, very good, and excellent) using independent samples *t* tests for comparison of 2 means (ADLs difficulty, IADLs difficulty, difficulty walking one-half mile, tandem stand, and physical activity) and 1-way analysis of variance for comparison of more than 2 means (health status).

RESULTS

Table 1 provides the participant characteristics. The mean age of the sample was 79.4 years. Approximately 18% of the sample reported having fallen in the previous year and only a small percentage of the participants (<10%) used a cane for ambulation. On average the participants demonstrated a mean gait speed that was slightly less than the desired gait speed of 1.2m.[21-24]

The gait variability measures from the two 4-meter walks demonstrated greater test-retest reliability than those from the single 4-m walk (table 2). When calculated from the single 4-m walk, step width and stance time variability demonstrated poor reliability (ICC=0.22 and 0.37, respectively) and step length variability demonstrated fair (ICC=0.48) test-retest reliability. When calculated from the longer two, 4-m walks, step width variability continued to demonstrate marginal (ICC=0.40) re-

Table 1: Participant Characteristics (N=558)

Characteristic	
Demographics and health status	
Age (y)	79.4±4.1
	n (%)
Women	339 (60.5)
Black	127 (22.7)
Use assistive device	42 (7.6)
Fallen past year	101 (18.3)
Gait characteristics	
Gait speed (m/s)	1.00±0.23
Stance time (s)	0.40±0.23
Step length (m)	0.36±0.17
Step width (m)	0.35±0.15

NOTE. Values are mean ± SD unless otherwise noted.