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Walking Skill Can Be Assessed in Older Adults: Validity of the Figure-of-8 Walk Test

Rebecca J. Hess, Jennifer S. Brach, Sara R. Piva, Jessie M. VanSwearingen

Background. The Figure-of-8 Walk Test (F8W) involves straight and curved paths and was designed to represent walking skill in everyday life.

Objective. The purposes of this study were to validate the measure in older adults with walking difficulties and to explore correlates of the curved-path walking measure not represented by a straight-path walking measure.

Design. Fifty-one community-dwelling older adults with mobility disability participated in 2 baseline visits as part of an intervention study.

Methods. The F8W time, steps, and smoothness and measures of gait (gait speed, modified Gait Abnormality Rating Scale [GARS-M]), physical function (Late Life Function and Disabilities Index [LLFDI], Survey of Activities and Fear of Falling in the Elderly [SAFFE], Gait Efficacy Scale [GES], Physical Performance Test [PPT], and fall history), and movement control and planning (gait variability, Trail Making Test B [Trails B]) were recorded in each test session. Bivariate correlations for the F8W with each variable were conducted to examine concurrent and construct validity. Adjusted linear regression analyses were performed to explore the variance in mobility explained by F8W independent of gait speed.

Results. Figure-of-8 Walk Test time correlated with gait (gait speed, $r = -.570$; GARS-M, $r = .281$), physical function (LLFDI function, $r = -.469$; SAFFE restriction subscale, $r = .370$; PPT, $r = -.353$), confidence in walking (GES, $r = -.468$), and movement control (step length coefficient of variation, $r = .279$; step width coefficient of variation, $r = -.277$; Trails B, $r = .351$). Figure-of-8 Walk Test steps correlated with step width variability ($r = -.339$) and was related to fear of falling ($t = -2.50$). All correlations were significant ($P < .05$).

Limitations. This pilot study had a small sample size, and further research is needed.

Conclusions. The F8W is a valid measure of walking skill among older adults with mobility disability and may provide information complementary to gait speed.

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Walking is a complex motor skill, involving interactions between brain and body systems to walk and rapidly adapt to changes in conditions and the intent for walking.¹⁻³ Subtle changes in walking skill (ie, slowing, greater variability) have been associated with fall risk,⁴⁻⁶ mobility and disability in activities of daily living,^{7,8} nursing home placement, and death.⁸ Most clinical measures of walking skill consist of straight-path walking,⁸⁻¹¹ yet activities of daily living in the home and community require curved-path walking ability (eg, walking around a table, avoiding obstacles, navigating street corners).¹²

Straight- and curved-path walking differ in gait characteristics and the distribution of body mass with respect to the base of support.^{12,13} In curved-path walking, shorter stride lengths occur for the inner leg than for the outer leg compared with straight-path walking, with the outer leg traversing a longer distance to round the curve.¹² During curved-path walking, the body's center of mass shifts to the inner foot, with an increase in stance time for the inner foot.¹² For circular walking in a counterclockwise direction, medial balance (center of mass distributed over the medial aspect of the foot) is the predominant pattern for the outer foot. Walking in a clockwise direction results in balance over the lateral aspect of the inner foot, whereas for straight-path walking, balance is more equitably shared by the medial and lateral aspects of both

feet.¹³ Such gait adaptations for curved paths may be difficult for the older adult with mobility problems. Current gait assessment methods provide little or no account of the motor skills necessary for curved path walking.

Daily life walking often involves the added complexity of walking while doing other activities (ie, dual-task or multi-task walking). A complex walking task may require a greater proportion of physical and mental capacity, resulting in decrements in gait performance not seen for simple walking tasks.¹⁴ Older adults with mobility problems may dedicate greater attention to gait while walking under challenging conditions, with the potential consequence of the competing cognitive demand for brain resources (eg, limited information-processing capacity) under complex, dual-task walking being a marked decline in walking performance for some older adults.^{11,14,15} In a previous study,¹⁶ walking while carrying objects or responding to visual or auditory signals has been a typical method of testing walking under complex, dual-task conditions; however, the dual-task walk tests occurred over straight paths. Navigating everyday life environments requires creating an internal (mental) map of the environment, planning the path and executing the walk (eg, walking through a grocery store, walking to a table to be seated in a restaurant). As such, daily life walking even without objects to carry or signals to respond to is, by nature, a dual-task or even multi-task activity.¹⁵ In the newly developed Figure-of-8 Walk Test (F8W), we combined curved-path walking and navigation to better test the complex walking abilities necessary for independence in daily walking activities.

Mobility measures previously described, such as the Timed "Up &

Go" Test (TUG),¹⁷ the Emory Functional Ambulation Profile (E-FAP),¹⁸ and the Dynamic Gait Index (DGI),¹⁹ involve walking about a curve. However, the curved path in the previous mobility measures is either a single turn or one task embedded in a composite measure,¹⁷⁻¹⁹ whereas the curved-path walking of the F8W involves curves in clockwise and counterclockwise directions and is the single mobility task of interest represented by the score.

The purpose of this research was to determine the concurrent and construct validity of the F8W, which was designed to be used to assess curved-path as well as straight-path walking skill necessary for daily life walking in older people with walking difficulties. We determined the concurrent validity of the F8W with established measures of gait and construct validity with measures of physical function in activities of daily living and measures of movement control and planning. Secondarily, we explored whether the F8W measure of curved-path walking reflects components of physical function in daily life not represented by the gait speed measure of straight path walking by describing the relationships in common and different for the 2 measures with the constructs of mobility performance. We expected the F8W to correlate with established clinical measures of gait and with measures of physical function in daily living, especially instrumental activities of daily living, which include tasks that require curved-path walking ability. We also expected the F8W to correlate with measures of movement control and planning (ie, tasks requiring timing and coordination to adapt muscle activation and movements to changes in the task or conditions for performance, the ability to smoothly alternate movement direction, and the ability to recognize the demands of the task^{1,20}), such as gait variability and executive function.



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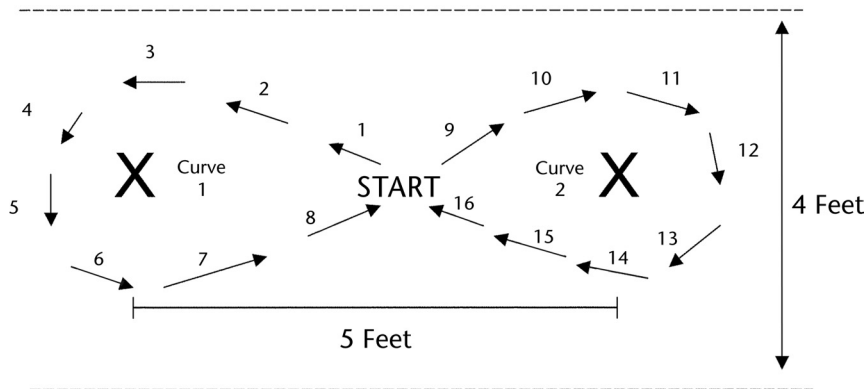


Figure 1.

Figure-of-8 Walk Test design. Visual schematic of the test layout illustrating an example of a completed test. Cones are represented by the large Xs. Arrows illustrate steps taken and the direction of the walking path. Numbers correspond to steps taken (straight steps: 1, 2, 7, 8, 9, 15, and 16; curve steps: 3, 4, 5, 6, 10, 11, 12, 13, and 14).

Method

Development of a Measure of Walking Skill: The F8W

The F8W (Fig. 1) requires a person to walk a figure-of-8 around 2 cones placed 5 ft (1 ft=0.3048 m) apart. A figure-of-8 was chosen because: (1) the task is readily recognized by name alone; (2) the pattern consists of walking on curved paths, clockwise and counterclockwise, with straight-path walking between the curved paths; (3) alternation between straight and curved paths requires switching motor strategies, including biomechanical and movement control adjustments; and (4) motor planning is needed to navigate the straight and curved paths.

Designed to be a measure of walking skill, we based scoring for the F8W on 3 components of skilled movement²⁰: (1) speed (time for completion), 2) amplitude (number of steps taken), and 3) accuracy (a tight versus an overly wide curved path). The accuracy component was defined as follows: F8W completed within a 2-ft surround of the cones (yes or no) (Fig. 1). The 2-ft boundary was chosen to impose some level of difficulty and to constrain the task to a space believed to fit the confined space of clinical settings (eg, a hallway).

Highly skilled movement or walking also has been described as smooth.²¹ We included a rater-based score for “walking smoothness” (ie, the consistent, continuous forward progression and regular pattern of steps during walking) to explore this descriptor of motor skill in walking. The harmonic ratio of trunk acceleration has been used to quantify smoothness in laboratory measures of gait.²¹ We defined an observational, rater-based, 3-item smoothness component scale as completion of the F8W without stopping, hesitating, or changing pace. The 3 smoothness items are each scored as 0 (any difficulty) or 1 (no difficulty), for a total smoothness score ranging from 0 (not smooth) to 3 (smooth). Higher smoothness scores represent better performance.

The F8W requires minimal equipment (2 cones [we also have used plastic cups as markers], stopwatch, tape measure), training, and time to complete and to score. The 5-ft distance between the cones was determined by asking individuals to walk a figure-of-8 around cones placed 4, 5, and 6 ft apart. The distance of 5 ft proved to be challenging but similarly completed by adults of different sizes and ages.

Administration of the F8W

The F8W was verbally explained and demonstrated to the participants prior to performance. The participants were instructed: (1) to stand midway between the cones, facing outward from the plane of the cones; (2) to begin walking at their usual pace when ready, choosing the direction of the figure-of-8 walking path about the cones; and (3) to stop upon return to the start position. Recording of test measures began with the first step and continued until the last step brought the performer to side-by-side stance of the feet at the start position. We did not mark a start (or stop) position or the walking path in order to avoid influencing the movement planning for the task. Longer time and greater number of steps to complete the task and walking outside of the 2-ft surround from the cones correspond to poorer performance. The 2-ft surround test boundary was not marked on the course. The tester determined the 2-ft boundary area for the test setup and the relationships of the boundary to the testing space (eg, distance from the hallway walls, floor markings, or landmarks) prior to testing, and estimated whether the test was completed within the boundary by comparison with the tester’s mental map of the testing space.

Reliability of the F8W

The F8W’s interrater and between-sessions test-retest reliability were determined in a pilot study of gait variability in older adults with mobility disability (N=18; mean age [SD]=83.9 [4.1] years; mean gait speed [SD]=0.90 [0.20] m/s, range=0.60–1.24 m/s).²² Participants were residents of a senior living community who had consented to participate in a study of walking ability.³⁶ Two trials of the test were performed in both the initial baseline testing visit and the repeat baseline testing visit about 1 week later. The 2 trials in the initial visit were admin-

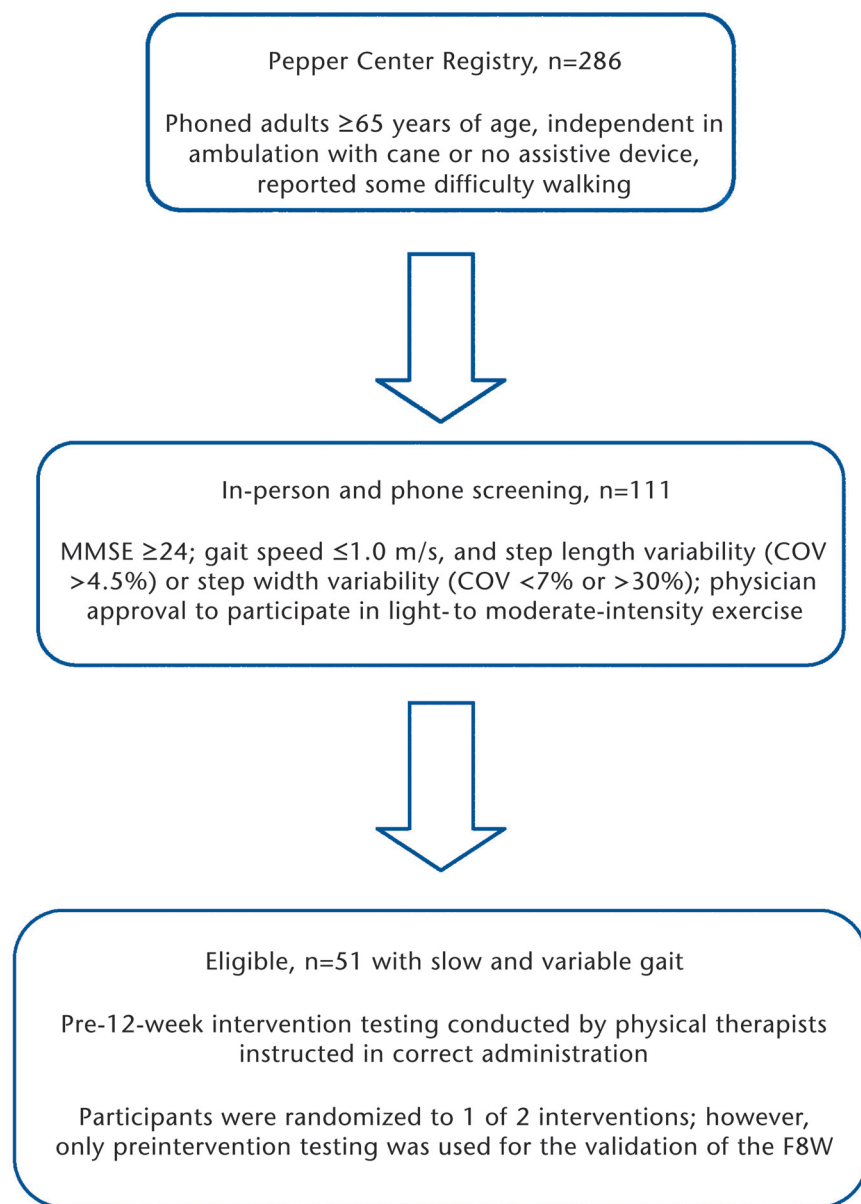


Figure 2. Study flow chart. MMSE=Mini Mental State Examination score, COV=coefficient of variation, F8W=Figure-of-Eight Walk Test.

istered by 2 different assessors and were used to determine interrater reliability. The first trials of the initial and repeat visits were used to calculate test-retest reliability.

Intraclass correlation coefficients (ICCs) (95% confidence interval [CI]) for interrater reliability were .90 (.71-.97), .92 (.77-.97), and .85 (.64-.95) for time, number of steps,

and smoothness, respectively. All participants completed the walk within the 2-ft surround of the cones with no difficulty. Subsequently, we eliminated scoring the accuracy component (eg, within the 2-ft boundary) because the score: (1) did not discriminate performance among participants, and (2) the number of steps to complete the F8W would account for a walking path

outside of the 2-ft boundary area. The ICCs (95% CI) for test-retest reliability were .84 (.62-.94), .82 (.59-.93), and .61 (.19-.84) for time, number of steps, and smoothness, respectively. Although the components of the F8W smoothness score are criterion-based, we justified the use of the ICC for determining agreement of the total smoothness score because the total score is rank ordered. However, we also provide Cohen kappa statistics for agreement for the smoothness scores: interrater agreement, kappa value=.40; test-retest agreement, kappa value=.25. The low kappa values for interrater and test-retest reliability reflect the ambiguity of the 3 components of the smoothness score (hesitancy, stopping, and changing pace). The assessors rating smoothness reported difficulty distinguishing hesitancy and changing pace. For example, slowing of gait around a curve could be scored as hesitancy, or changing pace, or both. As a result of the pilot study trial of the F8W, the smoothness components were defined in greater detail: hesitancy=submovements, or extra movements, made to adjust position or to complete the curve about a marker; changes in pace=a timing issue, or the interruption of a consistent pace of stepping for the entire walk pattern.

Overview of Procedures

An overview of the procedures is shown in Figure 2. Participants were volunteers recruited from the Pittsburgh Claude D Pepper Older Americans Independence Center Registry of older adults interested in studies of mobility and balance between February 2006 and March 2007. A registry sample of older adults over the age of 65 years who reported walking independently, but with some difficulty, and using a straight cane or no assistive device were contacted by telephone about participating. Interested individuals, who ob-

tained approval of their personal physician to engage in low- to moderate-intensity exercise, were scheduled for clinical screening and baseline testing at the Senior Mobility Aging Research and Training Center of the Pittsburgh Claude D Pepper Older Americans Independence Center, University of Pittsburgh, Pittsburgh, Pennsylvania. Eligible individuals participated in preintervention testing and 1 of 2 interventions, followed by immediate postintervention reassessment. Testing sessions were conducted by the study research physical therapists experienced in assessment and treatment of older adults with mobility problems. All assessors were trained in the administration of all measures, with a manual of operations, including printed directions and reference citations for the method of administering the tests, available for reference. All measurements were collected as a part of the baseline data collection for a randomized controlled trial of walking in community-dwelling older adults with mobility disability.²³

Participants

Community-dwelling older adults were eligible to participate if they were cognitively intact (Mini Mental State Examination²⁴ score of ≥ 24) and demonstrated walking difficulty. *Walking difficulty* was defined as having gait that was slow (walking speed of ≥ 0.6 m/s and ≤ 1.0 m/s)²⁵ and variable (coefficient of variation [COV] of $>4.5\%$ for step length variability⁵ or COV of $<7\%$ or $>30\%$ for step width variability⁴). We excluded older adults with: (1) persistent lower-extremity pain or muscle weakness (<4 out of 5 on manual muscle testing for the ankle dorsiflexor and plantar-flexor, knee extensor and flexor, and hip flexor, extensor, and abductor muscle groups), such as residual deficits associated with a stroke, fixed or fused joints, amputation, and prosthetic lower

limb; (2) hospitalization for 3 days or more in the past 6 months; (3) acute or chronic cardiopulmonary or metabolic conditions not well controlled with medication; (4) progressive neuromotor disorder (eg, multiple sclerosis, Parkinson disease); or (5) uncontrolled hypertension in the resting state. Gait speed and variability to determine eligibility were derived at self-selected walking speed in 2 passes over an instrumented walkway. Of the participants screened ($n=111$), 52 met the inclusion criteria, and 51 individuals had complete data and were included in the study (Fig. 2). The participants' mean (SD) age was 76.8 (5.5) years, their mean height was 165.1 (9.8) cm, and their mean weight was 80.5 (18.4) kg. The sample consisted of 17 men (33.3%) and 34 women (66.7%). Forty-five participants (88.2%) were white, and 6 (11.8%) were African American.

Measures of Gait

Figure-of-8 Walk Test. Participants walked a figure-of-eight at their self-selected usual pace around 2 cones placed 5 ft apart. Time and number of steps to complete the F8W and smoothness were recorded as described above.

Gait speed. Participants walked at their usual speed on a 4-m instrumented walkway (GaitMat II*)²⁶ with 2-m noninstrumented sections at either end to allow for acceleration and deceleration. After 2 practice walks, 2 walks were used for data collection. Gait speed was averaged over the 2 walks. Gait speed has demonstrated test-retest reliability (ICC=.78),²⁷ validity by comparison with other gait characteristics,⁹ and predictive validity for mobility disability.⁸

Modified Gait Abnormality Rating Scale. The modified Gait Abnormality Rating Scale (GARS-M),¹⁰ a 7-item, criterion-based, observational rating of gait abnormalities associated with fall risk,^{10,28} was used to assess gait characteristics. Reliability is excellent (ICC=.95-.99) among experienced assessors. Each item is scored 0 to 3, for a total score of 0 to 21. Higher scores reflect poorer performance.¹⁰

Measures of Physical Function in Activities of Daily Living

Late-Life Function and Disability Instrument. We used the Late-Life Function and Disability Instrument (LLFDI)^{29,30} function scale to assess perceived physical function related to walking ability. We used the LLFDI disability scale to assess perceived limitations in ability to perform socially defined life tasks in the home and community.³⁰ The LLFDI function and disability scales both have a possible score range of 0 to 100, with higher scores indicating better function and less disability (reproducibility of the scores, ICC $>.80$).^{29,30}

Survey of Activities and Fear of Falling in the Elderly.

The Survey of Activities and Fear of Falling in the Elderly (SAFFE) questionnaire⁴³ consists of 11 activities of everyday life necessary for independent living. Three subscale scores are derived: (1) SAFFE activity—the number of activities performed; (2) SAFFE fear—the average “worried about falling” rating on a 4-point rating scale, from 0 (not worried) to 3 (very worried), for each item performed; and (3) SAFFE restriction—the number of activities performed less compared with the past 5 years. Internal consistency (Cronbach alpha=.91) and validity are established for the ability of the SAFFE to differentiate between adults who are afraid and those who are not afraid of falling in daily activities.³¹

*EQ Inc, PO Box 16, Chalfont, PA 18914-0016.

Gait Efficacy Scale. The Gait Efficacy Scale (GES)³² is a self-report, 10-item scale of perceived confidence in walking with a range of challenges, from level walking to walking on uneven surfaces, curbs, or stairs. Item scores range from 1 (no confidence) to 10 (complete confidence), with a possible total score of 10 to 100.³²

Physical Performance Test. The 7-item Physical Performance Test (PPT)³³ is a performance-based measure of basic and instrumental activities of daily living. Time to complete 6 items and the observation rating for 1 item are converted to a score of 0 to 4 (0=unable, 4=fastest time or best completion), with a summary score for the 7 items of 0 to 28; higher scores represent better performance. The PPT has established reliability and construct validity for activities of daily living and predictive validity for nursing home placement and death.^{33,34}

Fear of falling and fall history. We used a fall history survey questionnaire with specific questions about fear of falling and history of falls in the past year.³⁵ Scores are dichotomized for, fear of falling (yes or no) and number of falls in the past year (≥ 1 , yes or no).

Measures of Movement Control and Planning

Gait variability. Gait variability^{7,36} was assessed from the gait data recorded using the GaitMat II instrumented walkway. Step length, step width, and stance time variability were calculated as the standard deviation of the measure and as the COV, based on the average standard deviation of all right and left steps over the 2 walks divided by the mean step length, step width, or stance time.⁷ The number of steps used to estimate variability is somewhat less than that used by some other authors,^{6,37} but allows for measures of

spatial and temporal variability during natural walking (ie, not on a treadmill) and has acceptable reliability.³⁸ We used both the standard deviation and the COV for variability to be able to compare our findings with those of previous reports of gait variability in older adults in which both statistics have been used.⁵⁻⁷ Validity of gait variability has been established for fall risk⁵⁻⁷ and as a measure of movement control by association with measures of executive function³⁹ and brain vascular abnormalities in older adults.⁴⁰

Trail Making Test B. The Trail Making Test B (Trails B)⁴¹ is a neuropsychological test of executive function, specifically the ability to shift attentional resources (set shifting) in the visuomotor domain.⁴¹ Reliability and validity of the Trails B have been established, and a known normative sample has been described.⁴² Poorer scores, representing longer time to complete the test, have been associated with functional decline (odds ratio=1.34) and a higher risk of mortality (hazard ratio=1.48).⁴³

Data Analysis

Descriptive statistics (mean and CI) for each measure were used to describe characteristics and performance of the participants. The appropriate correlation, Pearson product moment correlation (r) or Spearman rank order correlation (ρ), was used to define the bivariate relationships of each of the variables with the F8W scores. We interpreted the associations as strong (.7-1.0), moderate (.4-.69), and weak (<.39).⁴⁴ An independent-sample t test or Mann-Whitney U test was used to compare mean F8W variables between participants categorized by history of falls and fear of falling. Lastly, we described the pattern of correlations of F8W time and gait speed with the constructs of gait, physical function, and movement control and planning. Linear

regression analyses were used to correlate each dependent variable with gait speed or the F8W time, with each adjusted for the other to determine the independent contributors (gait speed, F8W time) to the constructs.

Role of the Funding Source

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Results

Descriptive Characteristics

The older adults studied walked slowly (mean [SD] gait speed=0.89 [0.15] m/s), compared with the usual adult walking speed of 1.2 to 1.3 m/s.⁴⁵ The older adults had a moderate number of abnormalities of gait related to fall risk, with a mean GARS-M score (SD) of 6.69 (2.58) (Tab. 1). A GARS-M score of ≤ 3 signifies little or no risk for falling, and scores of ≥ 9 are associated with risk for recurrent falls among community-dwelling older adults.^{10,28}

The older adults with walking difficulties exhibited a mean (SD) for F8W time and steps of 10.49 (2.60) s and 17.51 (3.94) steps (Tab. 1) and a median (interquartile range) of 2.0 (1.0) for the smoothness rating. Specific difficulties for the component of smoothness included problems of hesitancy and pace. Almost all participants (92%) completed the F8W without stopping.

The older adults with mobility problems demonstrated moderate activity (mean SAFFE activity score=8.37, mean SAFFE restriction score=3.47) and mild to moderate deficits in physical function based on mean LLFDI function and disability limitations summary scores between 50 and 70 and the mean PPT score be-

tween the 50th and 75th percentiles for community-dwelling older adults.³³ The participants reported moderate confidence in their walking ability (mean GES scores of >70) (Tab. 1), yet the majority reported fear of falling (n=33, 64.7%), and almost half had fallen at least once in the past year (n=23, 45.1%).

Similar to physical function, the older adults demonstrated moderate problems in movement control and planning. Mean step length variability, step width variability, and stance time variability exceeded values of each associated with risk for falling.⁴⁻⁶ The mean stance time (0.04 second) was greater than the value of stance time variability associated with an increased risk for mobility disability (SD ≥0.037 second).⁴⁶ Mean time to complete the Trails B task (135.71 seconds) was well above the mean time previously demonstrated for older adults with a history of falls (70.65 seconds) and older adults without a history of falls (58.4 seconds).⁴⁷

Concurrent and Construct Validity

The F8W was correlated to gait, with time negatively correlated to gait speed and positively correlated to the GARS-M (*P*<.05) (Tab. 2). The F8W time was associated with physical function in daily life (LLFDI function), activity restriction (SAFFE restriction), and activities of daily living performance (PPT); a similar relationship was found for the number of steps to complete the test (Tab. 2). Confidence in walking skill (GES) correlated to all F8W variables (time, steps, and smoothness) (Tab. 2). The number of steps and smoothness scores of the F8W differed by fear of falling status (Tab. 3).

Construct validity for the F8W with movement control was established by the relationship of all F8W scores (time, number of steps, and smooth-

Table 1.

Figure-of-8 Walk Test, Gait, Physical Function in Daily Life, and Movement Control and Planning in Older Adults With Slow and Variable Gait (n=51)^a

Measure	Mean	95% CI
F8W time, s	10.49	9.78–11.21
F8W steps, n	17.51	16.43–18.59
F8W smoothness (0–3)	1.75	1.49–2.00
Gait speed, m/s	0.89	0.85–0.93
GARS-M (0–21)	6.69	5.99–7.39
SAFFE activity (0–11)	8.37	7.95–8.80
SAFFE fear (0–3)	0.56	0.43–0.68
SAFFE restriction (0–11)	3.47	2.74–4.20
PPT (0–28)	20.53	19.79–21.26
LLFDI disability (0–100)	69.28	66.45–72.11
LLFDI function (0–100)	54.70	52.93–56.48
Gait Efficacy Scale (0–100)	72.52	66.78–76.24
Step length SD, m	0.04	0.032–0.041
Step length COV, %	7.37	6.33–8.41
Step width SD, m	0.03	0.031–0.038
Step width COV, %	76.52	47.73–105.31
Stance time SD, s	0.04	0.038–0.045
Stance time COV, %	5.61	5.12–6.11
Trails B, s	135.71	117.77–153.65

^a CI=confidence interval, F8W=Figure-of-Eight Walk Test, GARS-M=modified Gait Abnormality Rating Scale, SAFFE=Survey of Activities and Fear of Falling in the Elderly, PPT=Physical Performance Test, LLFDI=Late-Life Function and Disability Instrument, Trails B=Trail Making Test B, SD=standard deviation, COV=coefficient of variation.

ness) with step width variability (COV). The F8W time correlated to step length COV, and the number of steps to complete correlated to step width standard deviation. Both F8W time and number of steps were associated with the Trails B measure of planning and navigation (Tab. 2).

The pattern of correlations of both the F8W time and gait speed with gait, physical function, and movement control and planning variables illustrated similarities and differences (Tab. 4, significant correlations only are shown). The F8W time pattern of associations was with measures of perception of walking difficulties in the environment (SAFFE restriction), confidence (GES), and planning (Trails B). The pattern of associations demonstrated

for gait speed was with measures of gait and physical function (GARS-M, PPT, LLFDI disability). For the variables to which the F8W and gait speed were both related, the regression analysis indicated F8W independently explained the variance in walking confidence, and gait speed was the independent contributor to gait abnormalities (GARS-M), physical function (PPT and LLFDI function), and step length variability (step length COV) (Tab. 4).

Discussion

The results support the validity of the F8W as a measure of walking ability in older adults with mobility disability for the constructs of gait (gait speed, GARS-M), physical function in activities of daily living (SAFFE restrictive, LLFDI function,

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Table 2.

Correlations of Figure-of-8 Walk Test With Measures of Gait, Physical Function in Daily Life, and Movement Control and Planning (n=51)^a

Measure	F8W Time <i>r</i> (P)	F8W Steps <i>r</i> ^b (P)	F8W Smoothness <i>r</i> ^b (P)
Gait measures			
Gait speed	-.570 (.000) ^b	-.503 (.000)	.144 (.315)
GARS-M	.281 (.045) ^c	.235 (.097)	-.146 (.308)
Physical function measures			
SAFFE activity	-.221 (.119) ^c	-.217 (.127)	.183 (.198)
SAFFE fear	.088 (.541) ^c	-.042 (.768)	-.030 (.835)
SAFFE restriction	.370 (.008) ^c	.280 (.047)	-.183 (.199)
PPT	-.353 (.011) ^c	-.343 (.014)	.221 (.119)
LLFDI disability	-.259 (.067) ^c	-.160 (.261)	-.052 (.717)
LLFDI function	-.469 (.001) ^c	-.348 (.012)	.225 (.113)
Gait efficacy	-.468 (.001) ^c	-.435 (.002)	.304 (.032)
Movement control and planning measures			
Step length SD	.035 (.806) ^b	-.081 (.571)	.001 (.994)
Step length COV	.279 (.047) ^b	.149 (.295)	-.103 (.473)
Step width SD	-.205 (.150) ^b	-.339 (.015)	.052 (.718)
Step width COV	-.277 (.049) ^b	-.308 (.028)	.336 (.016)
Stance time SD	.072 (.613) ^b	-.012 (.935)	.013 (.925)
Stance time COV	-.050 (.729) ^b	-.027 (.852)	-.061 (.669)
Trails B	.351 (.012) ^b	.389 (.005)	-.267 (.059)

^a F8W=Figure-of-8 Walk Test, GARS-M=Gait Abnormality Rating Scale, SAFFE=Survey of Activities and Fear and Fall in the Elderly, PPT=Physical Performance Test, LLFDI=Late Life Function and Disability Instrument, SD=standard deviation, COV=coefficient of variation, Trails B=Trail Making Test B.

^b Pearson product moment correlation.

^c Spearman rank order correlation.

PPT, GES), and movement control and planning (step length COV, step width COV, Trails B). In clinical practice, we often have found that if older adults or their family complain about poor walking performance, the F8W exposes the walking difficulties not obvious during the straight path walk. Mild slowing and few abnormalities of gait during the straight path walk become short steps, uneven and hesitant steps rounding the corner of the figure-of-eight, pace changes with every change of path direction, markedly slower speed of gait, and unsteadiness.

Interestingly, individuals with less step width COV (ie, better gait control) performed worse on the F8W,

requiring more time to complete the test (Tab. 2). Mean step width may drive the association of the F8W time with step width COV. Gaybell and Nayak³⁶ suggested a wide step width may be a compensation for instability, whereas a narrow step width likely contributes to instability. In our experience, a wide step width usually yields a smaller step width COV and is associated with more time and steps to complete the F8W compared with a narrow step width. Individuals with a narrow step width may exhibit a shorter path around the curves of the F8W (less time), but test performance is characterized by stumbling; multiple adjustments to pace, path, and speed; and even near falls. A smoothness rating

may be useful to differentiate less skilled individuals from highly skilled individuals with a narrow step width, who could be considered skilled based on a fast F8W time.

Interrater reliability for F8W time (ICC=.90) and steps (ICC=.92) was slightly lower than for the composite measures of mobility that included a turn or curve,^{18,48} but acceptable for clinical measures. Test-retest reliability for F8W time (ICC=.84) and steps (ICC=.82), although acceptable for clinical measures, also was lower than for one composite measure of mobility with a curved-path walk (E-FAP).¹⁸

Although both the F8W and gait speed correlated to performance-based measures of gait (GARS-M, step length and step width variability) and to the LLFDI self-report of function in essential activities of daily living, many of which involve walking, the associations with curved- and straight-path walking differed for disability limitations and executive function. We expected curved-path walking to be a good representative of physical function in community-dwelling older adults. Such was the case for walking confidence and activities in specific conditions or when fulfilling certain roles in the environment, but the F8W was not related to disability limitations. The endurance aspect of walking performance represented by some LLFDI disability items may have led to the lack of association. The movement control required to walk under certain conditions or in certain environments may underlie the association of the GES and the SAFFE measures of walking activities with the F8W.

The association of the F8W with the Trails B executive function measure of cognition illustrates the planning and navigation aspects of mobility represented by the measure. In the

Table 3. Construct Validity: Mean Difference for Figure-of-8-Walk Test Scores Based on Fear of Falling and Fall History (n=51)

Measure	Fear of Falling				History of Falls (≥ 1 Fall in Past Year)			
	Yes, Mean	No, Mean	Mean Difference (95% CI)	t ^b (P)	Yes, Mean	No, Mean	Mean Difference (95% CI)	t ^b (P)
FW8 time, s	10.96	9.63	0.75 (-0.16, 2.83)	-1.79 (.08)	10.74	10.29	0.45 (-1.03, 1.93)	-.61 (.54)
FW8 steps, (#)	18.33	16.00	1.12 (0.09, 4.58)	-2.50 (.02)	17.78	17.29	0.50 (-1.75, 2.74)	-.45 (.66)
Measure	Median (IQR)	Median (IQR)	Median (IQR)	U ^c (P)	Median (IQR)	Median (IQR)	Median (IQR)	U ^c (P)
FW8 smoothness, (0-3)	1.00 (1.0, 2.0)	2.00 (1.75, 3.0)		211.00 (.075)	2.00 (1.0, 2.0)	2.00 (1.0, 3.0)		257.00 (.196)

^a FW8=Figure-of-8 Walk Test, IQR=interquartile range, CI=confidence interval.

^b Independent t test.

^c Mann-Whitney U test.

Table 4.

Pattern of Significant Correlations of Figure-of-8 Walk Test Time and Gait Speed With Dependent Variables (n=51)^a

Variable	F8W Time r (P)	Gait Speed r (P)	Independent Contributor ^b P<.05
Gait speed	-.570 ^c (.000)		
GARS-M	.281 ^d (.045)	-.526 ^d (.000)	Gait speed
SAFFE restriction	.370 ^d (.008)		F8W time
PPT	-.353 ^d (.011)	.378 ^d (.006)	Gait speed
LLFDI disability		.296 ^d (.035)	Gait speed
LLFDI function	-.469 ^d (.001)	.429 ^d (.002)	Gait speed
Gait Efficacy Scale	-.468 ^d (.001)	.321 ^d (.023)	F8W time
Step length COV	.279 ^c (.047)	-.414 ^c (.002)	Gait speed
Step Width SD		.337 ^c (.015)	Gait speed
Step Width COV	-.277 ^c (.049)		F8W time
Trails B	.351 ^c (.012)		F8W time

^a F8W=Figure-of-Eight Walk Test, GARS-M=modified Gait Abnormality Rating Scale, SAFFE=Survey of Activities and Fear of Falling in the Elderly, PPT=Physical Performance Test, LLFDI=Late-Life Function and Disability Instrument, SD=standard deviation, COV=coefficient of variation, Trails B=Trail Making Test B.

^b Independent contribution to the variance in the construct variable, determined by linear regression analysis with gait speed and F8W time, with each adjusted for the other variable.

^c Pearson product moment correlation.

^d Spearman rank order correlation.

F8W, the cognitive challenge (planning and navigation) of walking is embedded in the mobility task, similar to the Walking Trail Making Test of stepping accuracy.⁴⁹ The F8W and the Walking Trail Making Test differ from other dual-task and multi-task tests in which the cognitive task typically is distinct from the walking task and the cognitive challenge serves to distract from walking or compete for attention to the task. Because the F8W was associated with measures representative of walking in more complex conditions of the environment not associated with gait speed, we suggest the F8W can provide different information about mobility performance of older adults than that provided by gait speed alone.

Measures used to identify individuals with walking difficulties that predispose older adults to greater dependence and loss of independent community dwelling need to be representative of the complexity of mo-

bility tasks in home and community navigation.¹⁵ As individuals age, changes in cognitive and sensorimotor processing functions of the brain contribute to a decline in navigational skill for walking in some environments.¹⁵ A decline in motor skill with aging has been described previously for specific movements or motor functions. For example, older adults are slower initiating and performing movements,⁵⁰ their movements lack smoothness and are less consistent,⁶ and they hesitate when switching directions or motor tasks, such as changing from knee extension to knee flexion.⁵¹ We believe the F8W may capture similar deficits in motor skill but at the level of mobility performance for socially defined roles in the home and community. The F8W may be able to provide information complementary to the information obtained from straight-path walking measures and enhance current assessment and un-

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derstanding of mobility problems in older adults.

The limitations of the study are primarily related to sample selection, which restricts the ability to generalize the findings to a general population of older adults. We studied older adults recruited to participate in a clinical trial of interventions to improve walking. Thus, sample size was limited, powered for the intervention outcomes; the participants were volunteers interested in improving their walking; and the findings are relevant only for older adults with mobility disability, specifically slow and variable gait.

Conclusions

The findings provide evidence to support the validity of the F8W as a measure of walking skill among older adults with mobility disability. Future study of the F8W in a sample of older adults with a greater range of walking abilities and study of the responsiveness of the measure will be helpful in understanding the usefulness of the measure for assessing the mobility abilities of community-dwelling older adults.

Ms Hess, Dr Brach, and Dr VanSwearingen provided concept/idea/research design. All authors provided writing, data analysis, and consultation (including review of manuscript before submission). Ms Hess and Dr VanSwearingen provided data collection. Dr VanSwearingen provided project management, participants, and facilities/equipment.

This research was conducted in partial fulfillment of the thesis requirements for completion of Ms Hess' Bachelor of Philosophy degree.

This research was approved by the Institutional Review Board for Human Subjects Research, University of Pittsburgh.

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**Walking Skill Can Be Assessed in Older Adults:
Validity of the Figure-of-8 Walk Test**

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