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A Comparison of Straight- and Curved-Path Walking Tests Among Mobility-Limited Older Adults

Charles A. Odonkor,[1] Julia C. Thomas,[2] Nicole Holt,[3] Nancy Latham,[4] Jessie vanSwearingen,[5] Jennifer Sokol Brach,[6] Suzanne G. Leveille,[7] Alan Jette,[8] and Jonathan Bean[3]

[1]Yale University School of Medicine, New Haven, Connecticut.
[2]Wake Forest School of Medicine, Winston-Salem, North Carolina.
[3]Spaulding Rehabilitation Hospital, Boston, Massachusetts.
[4]Boston University School of Public Health, Massachusetts.
[5]McGowan Institute for Regenerative Medicine, Pittsburgh, Pennsylvania.
[6]School of Health and Rehabilitation Sciences, University of Pittsburgh, Pennsylvania.
[7]Department of Nursing, University of Massachusetts, Boston.
[8]Health & Disabilities Research Institute, Boston Rehabilitation Outcomes Center, Boston University School of Public Health, Massachusetts.

Address correspondence to Charles A. Odonkor, MA, Yale University School of Medicine, 367 Cedar Street, New Haven, CT 06511. Email: charles.odonkor@yale.edu

Background. Habitual gait speed (HGS) and the figure-of-8 walking test (F8WT) are measures of walking ability that have been associated with mobility outcomes and disability among older adults. Our objective was to contrast the physiologic, health, and behavioral attributes underlying performance of these two walking tests among older adults with mobility limitations.

Methods. HGS and F8WT were the primary outcomes. HGS was measured as time needed to walk a 4-m straight course at usual pace from standstill position. F8WT was measured as time to walk in a figure-of-8 pattern at self-selected usual pace from standstill position. Separate multivariable linear regression models were constructed that predicted walking performance. Independent variables included physiologic, cognitive–behavioral health attributes, and demographic information.

Results. Of 430 participants, 414 completed both walking tests. Participants were 67.7% female, had a mean age of 76.5 ± 7.0 years and a mean of 4.1 ± 2.0 chronic conditions. Mean HGS was 0.94 ± 0.23 m/s and mean F8WT was 8.80 ± 2.90 seconds. Within separate multivariable linear regression models (HGS: R^2 = .46, p_{model} < .001; F8WT: R^2 = .47, p_{model} < .001), attributes statistically significant within both models included: trunk extension endurance, ankle range of motion, leg press velocity at peak power, executive function, and sensory loss. Cognitive and physiologic attributes uniquely associated with F8WT were cognitive processing speed and self-efficacy, and reaction time and heel-to-floor time. Pain and peak leg press strength were associated with only HGS.

Conclusions. Both HGS and F8WT are useful tests of walking performance. Factors uniquely associated with F8WT suggest that it may be well suited for use among older adult patients with balance problems or at risk for falls.

Key Words: Walking—Mobility—Performance—Rehabilitation—Physiological attributes.

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MOBILITY limitations affect 25% of adults more than 65 years and impede walking and physical activity in this population (1). A number of studies suggest that limitations in mobility are of increasingly greater concern among elderly adults because this ability remains central to maintaining functional independence (2). Therefore, tools that allow for early screening of those at risk for decline in mobility and performance-based walking are indispensable for both geriatric research and clinical care (3). Key among these tools is habitual gait speed (HGS), a measure of straight-path walking, and a predictor of subsequent morbidity and mortality (4). Another important measure and a recently validated test of walking skill, the figure-of-8 walking test (F8WT), is theorized to more accurately assess walking during activities that require navigating around curved paths and avoiding obstacles (5). Some reports indicate that F8WT and HGS performance may be linked to tests of executive function (5). However, most of the studies evaluating the attributes that underlie walking performance have been completed among relatively small samples (N < 150 participants) and have not directly compared HGS and the F8WT across a wide array of attributes that may influence performance (6). Consequently, it remains unclear whether the two tests reflect different health attributes that

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underlie mobility limitations among community-dwelling older adults. We therefore sought to compare the physiologic, cognitive, and health attributes underlying performance of HGS and F8WT to better understand how the two tests contrast. Direct comparison of the two tests allows us to better understand the relationships among the attributes that influence mobility performance among elderly adults. To address this aim, we conducted an analysis of baseline data collected as part of the Boston Rehabilitative Impairment Study of the Elderly (Boston RISE). Boston RISE is a prospective cohort study among 430 primary care patients aged 65 and older, who are at risk for mobility decline and disability. Because F8WT consists of both curvilinear and straight patterns of walking, we expected that the Boston RISE study results would help delineate the contexts of care in which the respective walking tests would be most useful.

Methods

All data were collected as part of the Boston RISE at the Spaulding Rehabilitation Hospital in Boston, Massachusetts. Boston RISE is a prospective cohort study of 430 primary care patients aged 65 and older (7). Details regarding the aims, recruitment, and methods employed within Boston RISE have been published elsewhere and will be briefly summarized (7). Recruitment for the study was initiated in December 2009 and was completed in 2012. Participants were recruited through primary care practices based at Massachusetts General Hospital and Brigham and Women's Hospital, which are Partners HealthCare Medical Centers, located in Boston, MA. Eligibility criteria included aged 65 or older, ability to understand and communicate in English, and presence of preclinical disability defined as self-reported limitation or modification in the ability to walk half mile or climb one flight of stairs (10 steps), or limitations in performing these mobility tasks due to underlying health conditions (8). Exclusion criteria were the presence of a terminal disease, an episode of major surgery or myocardial infarction in the past 6 months, a planned major surgery, an anticipated move from the Boston area within 2 years, major medical problems interfering with safe and successful testing, mini-mental status exam score less than 18, and Short Physical Performance Battery score less than 4 (7).

To address our aims, we performed a cross-sectional analysis of baseline data from the Boston RISE cohort. We included only those individuals (N = 414, 96%) who completed both HGS and F8WT and were able to do so without the use of a walker. These measures served as our primary (dependent) outcome measures. Both HGS and F8WT measures were verbally explained and demonstrated to study participants prior to performance. Time needed to walk a 4-m straight course at usual pace from a standstill position was recorded using a stopwatch (timed to 0.1 second) and was defined as the time between the first footfall after the 0-m mark and the first footfall after the 4-m mark. HGS was computed as the distance (4 m) divided by the time to complete the walk (9). F8WT was measured as the time to walk in a figure-of-8 pattern around two cones placed 5 ft apart (1.525 m), at usual pace from a standstill position (5). Participants started the walk from midway between the cones, facing outward from the cones, and asked to stop on return to the starting position. To avoid influencing movement planning for the F8WT, there was no mark to indicate the start or stop position or the specific direction to start the walk (clockwise vs anticlockwise). We measured time from the first step and continued till the last step brought the participant to side-by-side stance of the feet at the original start point between the two cones (5). The time to complete the task was the focus of our test, but others have measured the amplitude (number of tests taken) and the accuracy (the tightness or wideness of the curved path) (5). Intraclass correlation coefficient for test–retest reliability for time to complete F8WT is .84 (95% CI: 0.62–0.94) (5), and intraclass correlation coefficient for HGS is .78 (95% CI: 0.63–0.92) (10,11).

Health and cognitive–behavioral attributes assessed included pain severity via the severity subscale of the Brief Pain Inventory (12), depression as manifested by a score greater than or equal to 10 on the Patient Health Questionnaire 9-item scale (13), self-efficacy via the Activities-specific Balance Confidence scale (14), and executive function and psychomotor speed via the Trails-making test A and B. The Trails A test primarily assesses visuoperceptual and psychomotor speed, whereas Trails B assesses switching of attention, working memory, and cognitive flexibility (all executive functions), as well as psychomotor speed and visuoperceptual abilities. A derived trails score (Trails B – A) was used to emphasize executive function by diminishing the influence of psychomotor speed (15).

Physiologic attributes assessed in the baseline exam included heel-to-floor time, reaction time, trunk muscle endurance, limb joint range of motion, sensory loss, and leg press strength, power, and velocity.

Peak Leg Press Strength, Power, and Velocity

We measured each attribute separately for each leg using a computerized pneumatic leg press machine (Keiser A420 Pneumatic Leg Press, Keiser Co., Fresno, CA). We determined the one repetition maximum (1RM) as previously described (16) and then measured leg muscle power and strength for five repetitions performed at 40% and 70% 1RM. We computed leg velocity at peak power by inspecting the respective analog graphs of power and force and dividing the recorded peak power by the peak force at peak power. We also recorded the peak velocity (highest value on velocity analog graph generated by the computer software) during the repetition at which peak power was recorded. We determined the

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velocity value for each leg at resistances that corresponded to 40% and 70% 1RM. The highest value regardless of side or percent 1RM was recorded as peak velocity.

Asymmetry of Leg Strength and Leg Power

We measured asymmetry of leg strength as the ratio of the higher of the leg press strength values over the corresponding value of the other side. Similarly, asymmetry of leg power was measured as the ratio of the peak leg press power in a similar fashion (17).

Heel-to-Floor Time and Reaction Time

Heel-to-floor time is a test of rapid leg coordination and was measured in a seated position as the time to complete 10 repetitions in which the heel of one foot was placed just below the opposite knee and then back to the floor (7). Reaction time was measured using a validated computer-based test in which participants pressed a mouse button after the appearance of a bright light on a computer screen, which appeared at random intervals. Participants were given five practice trials, and reaction time was recorded as the mean of 10 subsequent measurement trials (18).

Trunk Muscle Extension Endurance

Trunk muscle extension endurance was measured as previously described (19). Extension endurance was measured while the participant was lying prone on a specialized plinth positioned 45° from vertical with feet fixed in position on a footplate and the body supported below the waist by the table. The participant maintained their trunk in a neutral position within the sagital plane in line with their pelvis and legs for as long as possible with arms across the chest. The test was terminated when the participant was no longer able to maintain the unsupported position. Time was recorded in seconds for all measures (20).

Kyphosis

We measured kyphosis using a flexicurve ruler by a validated and reliable technique (21).

Joint Range of Motion

We measured knee range of motion, ankle dorsiflexion, and ankle plantarflexion using a goniometer (10). To evaluate reduced ankle range of motion, decreases in dorsiflexion and plantarflexion were defined as the inability to dorsiflex past 90° and plantarflex past 110°, respectively.

Sensory Loss

Sensory loss was measured by the validated Semmes-Weinstein monofilament test for peripheral sensation (22). Sensory loss was dichotomized as sensory loss present or absent (23).

Other covariates included age, gender, education (number completing ≥ high school grade 12), number of chronic conditions (via the standardized comorbidity questionnaire) (24), and body mass index in kilograms per square meter (estimated from participants' height and weight). All study procedures were approved by the Spaulding Rehabilitation Hospital Institutional Review Board and were well tolerated by study participants without occurrence of any associated injuries or serious adverse events.

Statistical Analysis

All statistical analyses were performed using SAS version 9.1 (SAS Institute, Inc., Cary, NC). All data were initially inspected using descriptive statistics. Time to complete the F8WT and the HGS were treated as continuous variables (5). Lower limb strength and trunk muscle extension were normalized per body weight in kilograms. Body mass index was treated as a categorical variable based on the standard National Heart, Lung, and Blood Institute cut points for body mass index: normal, less than or equal to 25; overweight, 25–29.9; obese greater than or equal to 30 (25). Comparison of the calculated leg press velocity with the actual measured peak leg press velocity showed the former explained more of the variance in both walking tests, so calculated leg velocity was used in all subsequent data analyses. We separately examined the bivariate association between each of the independent variables and both outcomes. In addition, we tested for the contribution of different aspects of cognition (Trails A, Trails B, Trails B − A) to HGS versus F8WT. All potential variables were evaluated for collinearity. For variables in which collinearity was present ($r \geq .4$), decisions for inclusion were based upon clinical relevance and strength of association with the outcomes (eg, asymmetry of leg strength was chosen over asymmetry of leg power due to its higher association with the walking tests). Separate multivariable linear regression models for HGS versus F8WT were generated by including all potential variables and then employing a manual backward elimination process, advocated by Sun and colleagues (26). Based on predefined criteria, iterative models were evaluated after individually removing nonsignificant predictors ($p \geq .05$) and inspecting to ensure that their removal did not meaningfully alter the estimates or standard errors of the retained values (ie, >10% change in the estimates or standard errors). Age, gender, education, overweight status, and obese status were retained in both models because they were deemed to be clinically relevant adjustment variables. To evaluate the relevance of the different aspects of cognition, Trails A, Trails B, and Trails B − A were evaluate within separate multivariable models for each walking test in order to understand their respective association with the outcomes. Finally, each multivariable model was reevaluated to ensure that each satisfied all statistical assumptions of regression modeling (normal

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distribution of residuals, no outliers, no relationship between residuals and explanatory variables, no multicollinearity, and no heteroscedasticity). An alpha level less than .05 was used to determine statistical significance.

Results

Participant baseline characteristics are presented in Table 1. The study population was 67.7% female, had a mean age of 76.5 ± 7.0 years and manifested 4.1 ± 2.0 chronic medical conditions. The mean HGS of participants with complete data was 0.94 ± 0.23 m/s, and mean time to complete the F8WT was 8.8 ± 2.9 seconds (Table 1). The mean HGS of participants with missing data was 0.82 ± 0.23 m/s, and the mean time to complete the F8WT was 10.4 ± 4.1 seconds. Demographic and clinical characteristics of participants with missing values compared with those of participants with complete data showed that both groups were not significantly different in age, gender, body mass index categories, college education, pain severity, or reaction time (Table 2). However, those with missing data tended to be sicker (higher number of chronic conditions), had more kyphosis, lower self-efficacy scores, and were 1.8 seconds slower on F8WT and 0.12 m/s slower on the HGS test, compared with those with complete data.

The F8WT and HGS were strongly correlated with each other (Pearson correlation coefficient, $r = -.67$, $p < .0001$). Table 3 presents the results of bivariate linear regression analyses between each of the independent variables and each of the outcomes.

The adjusted R^2 reflects the variance in HGS and F8WT explained by each model. Physiologic and health attributes that explained greater than 10% of the adjusted variance in HGS and F8WT were peak leg press velocity (at peak power), peak leg press strength, trunk muscle extension endurance, ankle range of motion, executive function, and self-efficacy (Table 3). Bivariate analysis evaluating contribution of different aspects of cognition showed that Trails A explained 12% of variance in F8WT and 6% variance in HGS. Although Trails B explained 14% of the variance in both walking tests, Trails B − A explained 12% variance in HGS and 9% variance in F8WT (Table 3). Separate multivariable linear regression models were constructed to determine which physiologic and health/behavioral attributes contributed to HGS (R^2 = .44, p_{model} < .001) and F8WT (R^2 = .45, p_{model} < .001) performance (Table 4). Attributes that achieved statistical significance in the final model for both walking outcomes were Trails B, trunk extension endurance, ankle range of motion (reduction in dorsiflexion and plantarflexion), leg press velocity at peak power, and sensory loss. Attributes that uniquely achieved statistical significance with F8WT were reaction time, heel-to-floor time, self-efficacy, and cognitive processing speed (Trails A). Pain and peak leg press strength were significantly associated with HGS performance (Table 4). In separate models, the derived trails score (Trails B − A) was associated with HGS but not with F8WT (Table 4).

Discussion

The major findings of our investigation comparing attributives predictive of HGS and F8WT were (i) that certain attributes were associated with performance on both tests (leg press velocity at peak power, trunk muscle extension endurance, executive function as measured by Trails B, and ankle range of motion) and (ii) other attributes were uniquely associated with each respective test. Specifically, whereas pain severity and peak leg press strength were associated with HGS performance, self-efficacy, reaction time, heel-to-floor time, and cognitive processing speed (as measured by Trails A) were uniquely associated with time to complete F8WT performance.

Table 1. Baseline Characteristics of Study Population (*N* = 414)

Demographic	Mean ± *SD* or *n* (%)	Range
Age (y)	76.4 ± 6.9	65–94
Female gender	278 (67.1)	
Education (≥high school grade)	225 (54.3)	
BMI (kg/m²)	29.4 ± 6.2	18.4–55.7
Normal (<25.0)	114 (27.5)	
Overweight (25.0–29.9)	162 (39.1)	
Obese (≥30.0)	154 (37.2)	
Outcomes		
F8WT (s)	8.8 ± 2.9	3.7–26.1
HGS (m/s)	0.94 ± 0.23	0.4–1.7

Notes. BMI = body mass index; F8WT = figure-of-8 walking test; HGS = habitual gait speed; *SD* = standard deviation.

Table 2. Physiologic and Health Attributes of Study Population

Physiologic Attributes	*N*	Mean ± *SD* or *n* (%)
Leg press strength (N/kg)	376	9.5 ± 2.5
Loss of ankle range of motion	414	122 (29.5)
Leg press velocity (m/s)	370	1.02 ± 0.25
Reaction time average (ms)	414	248.7 ± 51.5
Trunk extension endurance (s/kg)	393	1.3 ± 0.9
Knee flexion (°)	410	63 (15.4)
Knee extension (°)	407	20 (4.9)
Kyphosis ratio (*n*)	414	10.5 ± 3.1
Rapid leg coordination (s)	414	10.2 ± 4.1
Sensory loss	407	121 (29.7)
Health and Cognitive Attributes*	***N***	**Mean ± *SD* or *n* (%)**
Comorbid conditions (*n*)	414	4.1 ± 2.0
Vision impairment	414	18 (4.3)
Depression score (PHQ-9) > 10	414	16 (3.9)
BPI pain severity	414	2.5 ± 1.9
Self-efficacy/ABC	414	75.8 ± 17.0
Trails A test	414	51.1 ± 25.6
Trails B test	414	147.3 ± 82.6
Trails B − A	414	96.2 ± 69.2

Notes. ABC = Activities-specific Balance Confidence scale; BPI = Brief Pain Inventory; PHQ-9 = Patient Health Questionnaire-9; *SD* = standard deviation.

**N* = 414 for health and cognitive attributes.

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Table 3. Bivariate Analysis of Predictors of Performance on HGS and F8WT

	HGS (m/s)			F8WT (s)		
Category	Estimate (*SE*)	R^2	*p* value	Estimate (*SE*)	R^2	*p* value
Age	−0.009 (0.002)	.07	<.0001	0.10 (0.02)	.07	<.0001
Gender	0.04 (0.02)	.003	.12	−0.20 (0.30)	.001	.5
Education	0.08 (0.02)	.03	<.0006	−0.70 (0.29)	.01	.02
BMI	−0.005 (0.002)	.02	.003	0.01 (0.02)	.002	.67
Health and cognitive attributes						
Trails A test	−0.002 (0.0004)	.06	<.0001	0.04 (0.005)	.12	<.0001
Trails B test	−0.01 (0.0001)	.14	<.0001	0.01 (0.002)	.14	<.0001
Trails (B − A)	−0.001 (0.0002)	.12	<.0001	0.01 (0.002)	.09	<.0001
Self-efficacy/ABC	0.006 (0.0006)	.17	<.0001	−0.07 (0.008)	.14	<.0001
Comorbid conditions*	−0.02 (0.005)	.03	<.0002	0.22 (0.07)	.02	.002
BPI pain severity	−0.03 (0.006)	.06	<.0001	0.18 (0.08)	.02	.02
Vision impairment	−0.13 (0.05)	.01	.01	0.01 (0.002)	.02	<.0001
PHQ-9 > 10	−0.10 (0.06)	.004	.09	0.23 (0.79)	.002	.77
Physiologic attributes						
Leg press strength	0.03 (0.004)	.15	<.0001	−0.34 (0.05)	.10	<.0001
Leg press power	0.05 (0.007)	.14	<.0001	−0.6 (0.08)	.14	<.0001
Ankle range of motion	−0.17 (0.02)	.11	<.0001	2.09 (0.31)	.10	<.0001
Leg press velocity	0.31 (0.04)	.12	<.0001	−3.76 (0.51)	.13	<.0001
Reaction time average	−0.01 (0.0002)	.05	<.0001	0.02 (0.003)	.08	<.0001
Trunk extension endurance	0.10 (0.01)	.16	<.0001	−1.06 (0.14)	.12	<.0001
Knee flexion	−0.07 (0.03)	.009	.03	0.94 (0.39)	.01	.01
Knee extension	−0.03 (0.05)	.002	.55	0.83 (0.66)	.001	.21
Kyphosis	−0.007 (0.004)	.006	.06	0.14 (0.05)	.02	.004
Heel-to-floor time	−0.004 (0.004)	.002	.19	0.06 (0.04)	.005	.09
Asymmetry leg strength	−0.006 (0.04)	.003	.15	1.21 (0.46)	.02	.01
Asymmetry leg power	−0.01 (0.02)	.002	.58	0.30 (0.26)	.002	.2
Sensory loss	−0.08 (0.02)	.02	<.0008	1.06 (0.31)	.02	.001

Notes. ABC = Activities-specific Balance Confidence scale; BMI = body mass index; BPI = Brief Pain Inventory; F8WT = figure-of-8 walking test; HGS = habitual gait speed; PHQ-9: Patient Health Questionnaire-9; *SE* = standard error.

*Comorbid conditions include diseases of the heart, lung, kidney, and liver, back pain, rheumatoid arthritis, arthritis, hypertension, ulcers, cancer, diabetes, and stroke.

One of the intriguing findings from our study concerned the differences with regard to cognitive testing. We observed that the Trails B test performance was associated with performance on both walking performance tests. Consistent with our findings, prior studies have linked certain aspects of cognition with performance on F8WT and HGS tests (27). The Trails-making test part B measures cognitive skills such as attention, working memory, and cognitive flexibility (all executive functions), as well as psychomotor speed and visuoperceptual abilities (15,28). Our study findings are unique in that when the derived trails test (Trails B – A) was utilized (see Table 4), executive cognitive function was no longer associated with F8WT. The Trails B − A was developed to diminish the component of processing speed and to emphasize executive function components (15,29). The one aspect of Trails B − A, which reflects processing speed, is more uniquely related to the switch demands of the Trails B test. Our results suggest that among the cognitive skills we tested, performance on the F8WT is most sensitive to speed of cognitive processing in general. This conclusion is supported by the fact that Trails A, which emphasizes cognitive processing speed and diminishes executive function, was significantly associated with F8WT but not with HGS. The association of straight-path walking with executive function is well established (30). Our results highlight that curved-path walking may be sensitive to other aspects of cognition and reinforce the connection between walking performance and cognitive processing previously highlighted in an important review article (30).

These findings with regard to speed of processing with cognitive tasks are also mirrored by our findings with regard to the other measured attributes that were uniquely associated with F8WT performance. Reaction time and heel-to-floor time (a test of rapid leg coordination) were both uniquely associated with F8WT performance. These tests measure rapid movements of the limbs and thus are also speed-dependent attributes. Our findings suggest that navigation of a curved path draws upon aspects of both central and peripheral components relevant to processing speed. The clinical implications of the finding should be interpreted in light of the fact that self-efficacy was also uniquely associated with F8WT. Reaction time, speed of movement, and self-efficacy are attributes that have all been linked to falls. For example, the ability to catch oneself quickly after a perturbation is considered to be a very important skill in preventing a fall or fall-related injury (30). Reaction time and heel-to-floor time as reflections of limb speed of movement are related to this ability as well (31). Reaction time has been directly

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Table 4. Multivariable Linear Regression Models Predicting HGS and F8WT Performance

Model HGS (N = 353, R^2 = .44, p < .001)	Characteristic	Estimate (*SE*)	95% CI	SE_{st}
	Age	−0.006 (0.001)	−0.008 to −0.003	−0.18
	Gender	0.004 (0.02)	−0.04 to 0.04	−0.006
	Education	0.01 (0.02)	−0.02 to 0.05	0.02
Health, Cognitive, and Behavioral Attributes*				
	Trails B − A	−0.0006 (0.0001)	−0.0008 to −0.0003	−0.21
	BPI pain severity	−0.01 (0.005)	−0.02 to −0.002	−0.12
Physiologic attributes				
	Trunk extension endurance	0.06 (0.01)	0.04 to 0.08	0.22
	Ankle range of motion	−0.10 (0.02)	−0.13 to −0.05	−0.20
	Leg press velocity	0.13 (0.04)	0.05 to 0.20	0.16
	Sensory loss	−0.05 (0.02)	−0.08 to −0.01	−0.11
	Leg press strength	0.01 (0.04)	0.002 to 0.02	0.14
Model F8WT (N = 353, R^2 = .44, p < .001)	**Characteristic**	**Estimate (*SE*)**	**95% CI**	**SE_{st}**
	Age	0.06 (0.02)	0.03 to 0.09	0.18
	Gender	0.22 (0.25)	−0.27 to 0.73	0.04
	Education	0.07 (0.21)	0.36 to 0.50	0.01
Health, Cognitive, and Behavioral Attributes*				
	Trails B − A	0.003 (0.002)	−0.0004 to 0.006	0.08
	Self-efficacy	−0.02 (0.07)	−0.03 to −0.004	−0.12
Physiologic attributes				
	Trunk extension endurance	−0.59 (0.13)	−0.84 to −0.34	−0.20
	Ankle range of motion	1.32 (0.24)	0.83 to 1.82	0.23
	Leg press velocity	−1.89 (0.48)	−2.83 to −0.94	−0.19
	Sensory loss	0.63 (0.24)	0.16 to 1.11	0.11
	Reaction time	0.009 (0.002)	0.004 to 0.01	0.16
	Heel-to-floor time	0.08 (0.03)	0.03 to 0.14	0.12

Notes. ABC = Activities-specific Balance Confidence scale; BPI = Brief Pain Inventory; F8WT = figure-of-8 walking test; HGS = habitual gait speed; PHQ-9: Patient Health Questionnaire-9; *SE* = standard error; SE_{st} = standardized estimate.

*Within separate multivariable models substituting Trails A for Trails B − A, Trails A was significantly associated with F8WT but not with HGS.

linked to falls and fall-related injuries (18). The heel-to-floor test has not yet been evaluated in this context. In addition, the scores on our self-efficacy measure (Activities-specific Balance Confidence scale) are predictive of falls (32). Taken together, our study results suggest that F8WT performance might be closely related to "central" cognitive–behavioral attributes (cognitive processing speed and self-efficacy) and "peripheral" physiologic attributes (reaction time, rapid coordination, and sensory loss), which are linked to falls and fall-related injuries (30,33). An evaluation of F8WT as a predictor of falls outcomes has not been reported, but would be justified based on these findings.

The findings with regard to leg velocity and leg strength contrast with our aforementioned results. Leg velocity was associated with both walking tests; however, leg strength was only associated with HGS. Both leg velocity and leg strength are components of leg power (power = force × velocity), an attribute linked to a variety of physical functional tasks (34). Leg velocity as measured in our study reflects peripheral generation of speed of movement at relatively slower speeds because it is generated against a more substantial resistance (~40% 1RM). It is likely that this attribute, which is derived from power generation of the hip extensors and quadriceps, represents biomechanical aspects of walking that are common to both tests. The fact that leg strength was uniquely associated with HGS and not F8WT may also be one explanation for the observed association of pain with HGS and not F8WT. For example, in HGS, when an individual has an arthritic or sore limb, they may experience greater pain because larger forces are being generated across that limb. Alternatively, the same individual may not have pain influence on F8WT performance to the same degree because force production is less influential on performance.

Other possible explanations exist for the unique association of pain with HGS. It is possible that different motor patterns involving hip joint loading, stride length, and stance adjustments during walking may explain this finding (35). With F8WT performance, the asymmetry of foot placement, stride length, and stance adjustments needed to achieve curvilinear walking, likely produces alterations in limb joint loading throughout the test. In comparison, during HGS performance, repetition of limb placement in straight-path walking leads to a repeated pattern of hip and lower limb joint loading. Thus, a repeated joint loading pattern within a painful joint may bring about a greater performance–pain association than what is observed in F8WT. Lastly, it is plausible that participants generally walk faster when going in a straight line but almost everyone slows down to walk in a curved path because it is a more complex task. Thus, walking faster (during HGS) may be more

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painful than slower walking (F8WT). A more detailed biomechanical assessment of these two walking tasks in future investigations may help explain many of the observed differences between HGS and F8WT.

Study Limitations

Our study is cross-sectional, and thus causation cannot be determined. A prospective study may allow us to better establish temporal relationships between physiologic attributes and measures of walking skill. Because we used baseline data, further understanding of these relationships will benefit from longitudinal analyses of the attributes influencing both tests, and importantly how these relate to mobility limitations among older adults. Additionally, we did not evaluate certain aspects of F8WT, which other studies have investigated. These include the amplitude and accuracy (wideness or narrowness) of the curved path traversed during the F8WT, which are components of F8WT that were not measured in the Boston RISE study. These other aspects of F8WT performance may also have clinical relevance, perhaps with regard to the associated cognitive tests utilized in this study. Thus, we confine our conclusions to a single aspect of F8WT performance (time for completion).

In addition, although this study screened out those with moderate to severe dementia, it is plausible that some participants had early dementia and this may have influenced findings with respect to the cognitive measures and the associated performance on the walking tests.

Finally, we did have missing data. The magnitude of missing data is consistent with other well-established cohort studies of community-dwelling older adults (7). Patients with missing data tended to be sicker (higher number of chronic conditions), had more kyphosis and smaller self-efficacy scores, compared with those with complete data. Importantly, patients with missing data were 1.8 seconds and 0.14 m/s slower on the F8WT and HGS test, respectively, compared with those with complete data. The difference in gait speed (>0.10 m/s) suggests that these individuals were at clinically meaningful lower levels of function (36). Thus, it may be challenging to extrapolate our findings to individuals at the lowest levels of functional performance.

The major strength of this study lies in the large number of attributes investigated that contribute to walking performance and the identification of those attributes that distinguish F8WT and HGS. Although heel-to-floor time is a relatively new test, first used on a large scale within a different study (37), both the Activities-specific Balance Confidence scale and the reaction time test have been linked to falls (31). Thus, in contrast to HGS, which is advocated for use among patients at risk for disability and mortality (4), F8WT may be useful among patients prone to balance and fall-related problems. Alternatively, given the observed association between pain and HGS performance, HGS may be useful in the assessment of older adults undergoing treatment for pain problems. These hypotheses are worthy of future study.

Conclusions

HGS and F8WT are performance-based walking tests that are dependent upon a number of different attributes. Although both tests are associated with tests of cognitive function, F8WT appears to be particularly sensitive to cognitive processing speed. Reaction time, heel-to-floor time, and self-efficacy are attributes that are uniquely associated with F8WT, and HGS is uniquely associated with pain severity. The use of F8WT or HGS should be considered based on the clinical context and in light of the attributes that are uniquely associated with each test. These contrasting findings have important implications for clinicians and researchers evaluating walking performance among older adults.

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Conflict of Interest

The authors have no conflicts of interest.

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