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Straight and Curved Path Walking Among Older Adults in Primary Care: Associations with Fall-Related Outcomes

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Abstract

Background—Most falls among community-dwelling older adults occur while walking. Simple walking tests that require little resources, and can be interpreted quickly are advocated as useful screening tools for fall prone patients.

Objective—To investigate two clinically feasible walking tests, consisting of straight- and curved-path walking and examine their associations with history of prior falls and fall-related outcomes among community-living older adults.

Design—A cross-sectional analysis was performed on baseline data from a longitudinal cohort study.

Setting—Participants were recruited through primary care practices.

Participants—Participants included 428 primary care patients 65 years of age at risk for mobility decline. Participants had a median age of 76.5 years, 67.8% were women, and 82.5% were white.

Methods—Straight-path walking performance was measured as the time needed to walk a 4 meter straight path at usual pace from standstill using a stopwatch (timed to 0.1 second). Curved-path walking performance was timed while participants walked from standstill in a figure-of-8 pattern around two cones placed 5 feet apart.

Main Outcome Measurements—Multivariable negative binomial regression analyses were performed to assess the relationship between straight-path walking or curved-path walking and

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self-reported history of number of falls. For fall-related injuries, and fall-related hospitalizations, logistic regression models were used.

Results—In the fully adjusted model, an increase of 1 second in straight path walking time was associated with 26% greater rate of falls (RR=1.26, 95% CI: 1.10–1.45). An increase in curved-path walking time was associated with 8% greater rate of falls (RR=1.08, CI: 1.03–1.14). Neither walk test was associated with history of fall-related injuries or hospitalizations.

Conclusions—Poor performance on straight- and curved-path walking performance was associated with a history of greater fall rates in the prior year, but not with a history of fall-related injuries or hospitalizations. This information helps inform how prior fall history is related to performance on walking tests in the primary care setting.

Keywords

Falls; Injurious Falls; Fall-Related Hospitalizations; Walking; Performance Test

INTRODUCTION

Approximately 35–40% of community-dwelling older adults over age 65 fall annually.¹ The yearly cost of falls in the older adult population is approximated at 19.2 billion dollars due to related injuries and hospitalizations.² Given that the United States older adult population is growing at a faster rate than the total population itself, understanding falls and screening for these events is of the utmost importance.³

Walking performance tests are advocated for facilitating risk stratification of fall prone patients. Previous research shows that most falls among community-dwelling older adults occur while walking.⁴ For clinical applications, walking tests that require little resources, and can be interpreted quickly are needed. Three tests that meet these criteria include the Timed Up and Go test (TUG), the 4 meter Walk Time test (4mWT), and the Figure of 8 Test (F8WT). The TUG requires the older adult to stand up from a chair, walk 3 meters, turn around, walk back, then sit down in the starting position.⁵ The 4mWT is a walking test currently advocated for use in the clinical setting that requires simple walking in a straight path at a usual pace. The test assesses the time needed for the older adult to walk a 4 meter path from standstill.⁶ Finally, the F8WT is a newer walking test, thought to be more representative of everyday walking. It assesses the time required to navigate a curved path in a figure-of-8 shape from standstill.⁷ Prospective studies demonstrate the predictive ability of TUG and 4mWT on the occurrence of a future fall in older adults.^{8–12} The F8WT has yet to be evaluated in this context.

In order to understand how walking tests predict a future fall, it is important to also understand how a patient's baseline performance on such tests relates to a prior fall history, fall-related injury, or fall-related hospitalization. For example, previous studies have shown an association between TUG performance and a prior fall history.^{13–17} Evidence exists to support a relationship between 4mWT performance and fall history.^{9,18} No study has linked F8WT performance with fall number history. Previous work identified that the attributes most associated with F8WT performance were fall-related risk factors such as processing

speed, self-efficacy, reaction time, and rapid leg coordination. Such evidence suggests that F8WT performance and fall-related outcomes may be associated.¹⁹

In the present study, our aim was to identify associations between performance on straight- or curved-path walking (4mWT or F8WT) with fall outcomes in the prior year (self-reported recall of fall numbers, fall-related injuries, and fall-related hospitalizations). This information will inform the design and interpretation of future studies evaluating these walking tests and their ability to predict fall outcomes prospectively. Also it will inform clinicians considering use of either or both tests for patient screening. Clinical experience would suggest that F8WT may provide more information than 4mWT about falls and fall-related outcomes because it includes motor planning, navigating obstacles, and turns. Our hypothesis was that poorer performance on curved path walking would show a stronger association with self-reported fall outcomes than straight path walking.

METHODS

We conducted a cross sectional secondary analysis of baseline data from an ongoing longitudinal cohort study. The cohort consists of 430 older adult patients, age 65 years, recruited through primary care physicians' offices. The overall aim is to evaluate an array of neuromuscular attributes associated with mobility status at baseline and predictive of functional decline and disability after 2 years of follow up. More detailed aims and methods have been published elsewhere.^{20,21} Written informed consent took place before the first baseline visit during the eligibility screen.

Inclusion criteria for the study consisted of adults aged 65 or older, with the ability to understand and communicate the English Language, no planned major surgery, and expectation of living in the area for at least 2 years. The presence of preclinical disability was an additional inclusion factor, defined as a self-reported limitation or modification in the ability to walk half a mile or climb one flight of stairs (10 steps), or limitations in performing these mobility tasks due to health conditions.²² Only those individuals who answered baseline questions related to falls were included in the study (n=428); see falls assessment below. Exclusion criteria included the presence of a terminal disease, an episode of major surgery or myocardial infarction in the 6 months prior to enrollment, a planned upcoming major surgery, an anticipated move from the regional area within 2 years, major medical problems interfering with safe and successful testing, a mini-mental state exam score less than 18, and a Short Physical Performance Battery score less than 4.^{23,24}

The overall aim of this secondary analysis was to identify associations between performance on straight- or curved-path walking (4mWT or F8WT) with fall outcomes in the prior year. Thus fall history and performance measures collected at baseline were assessed. A visual demonstration was provided for all performance based tests before study participants completed them.

Falls Assessment

Our primary outcome measures included self-reported number of falls in the year prior to enrollment, self-reported occurrence of an injury from a fall (yes/no), and overnight stay in

the hospital due to a fall (yes/no). The falls questionnaire was developed based on a population based study of community dwelling older adults.²⁵ Baseline questions related to falls included: “How many times have you fallen to the ground in the past year? (n=428); As a result of your worst fall, were you injured? (answer yes, n=88); Did you stay overnight in the hospital because of a fall in the last year? (answer yes, n=19).” A fall was defined as an unexpected event in which any part of the participant’s body above the ankle came to rest on the ground, floor, or lower level.²⁶

Four Meter Walk Time

Time needed to walk a 4 meter straight path at usual pace from standstill was recorded using a stopwatch (timed to 0.1 second). 4mWT was defined as the time between the participant’s first initiated movement of the feet and the first foot-fall after the 4 meter mark. Consistent with the study methods, the 4mWT is performed twice, and the fastest of the two trials is recorded. Intraclass correlation coefficient for test-retest reliability has been reported as 0.78 (95% CI: 0.63–0.92).²⁷

Figure of 8 Walking Test

Two cones were placed 5 feet apart (1.525 meters) and participants were instructed to start from midway between the cones, facing outward from the cones, and asked to stop on return to the starting position. Participants were instructed to walk in a figure-of-8 pattern around the two cones from standstill. Specific instructions given to participants were to “Complete the figure of 8 as quickly as you can while trying to complete the walk smoothly without any hesitation or stopping.” Time was measured from the first initiated movement of the feet until the last step brought the participant’s feet to a side-by-side stance at the original starting point.⁷ Intraclass correlation coefficient for test-retest reliability has been reported as 0.84 (95% CI: 0.62–0.94).⁷

All study procedures were approved by the 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 9.3 (SAS Institute, Inc., Cary, NC). Descriptive statistics were used to describe demographic characteristics, health characteristics, indicators, and outcomes in Table 1. Participants were grouped by reported fall status in the past year (positive recall of a fall in the past 12 months/no recall of a fall in the past 12 months). Associations between characteristics and fall status were tested using chi-squared tests for categorical variables (male/female gender, white/non white race, education<high school/education<high school) and non parametric Wilcoxon 2 sample approximation t-tests for continuous variables (age, body mass index [BMI], mini mental state exam [MMSE], chronic conditions, 4mWT, and F8WT).

Relationships between 4mWT or F8WT and self-reported total fall numbers in the prior year were statistically modeled. The Poisson distribution for fall counts assumes the mean equals the variance; however, this assumption is not usually met. Since the variance was higher than

the mean, negative binomial regression models were used to correct for overdispersion. After the models were constructed, rate ratios were calculated by exponentiation of the estimates, thus, a higher rate ratio would indicate a higher rate of falls based on walking performance. Multivariable logistic regression models were used to evaluate relationships between 4mWT or F8WT and the occurrence (yes/no) of a fall-related injury or hospitalization in the prior year. All multivariable models satisfied statistical assumptions. An alpha level of less than 0.05 was used to determine statistical significance. Models were adjusted for age, gender (male, female), race (white, non-white), MMSE, education level (grade 11 or below, completed high school or general education development test, college, graduate or professional school), BMI in kilograms per square meter (calculated from participants' height and weight), and chronic conditions (heart/lung/kidney/liver disease, diabetes, ulcers, anemia, cancer, and arthritis).

RESULTS

Table 1 shows the baseline characteristics for participants who did and did not experience a fall. The overall study sample had a median age of 76.0 with an interquartile range (IQR) of 70 to 82 years of age. The sample was 67.8% female, 82.5% white, with 87.4% completing high school. The median BMI was 28.2 (IQR 25.1–32.8), median MMSE was 28 (IQR 26–29), and the sample had a median of 4 chronic conditions. Of the 428 participants, 181 (42%) reported one or greater number of falls in the prior year. Among fallers in table 1, the median number of falls was 1 (inter quartile range: 1–2) with 88 participants (48.6%) reporting an injury due to a fall and 19 (11%) reporting a hospitalization due to a fall. Participants who experienced a fall did not significantly differ from nonfallers by age, gender, race, education level, MMSE, BMI, or number of chronic conditions. Fallers performance on 4mWT did not significantly differ from nonfallers performance 4.4 seconds (IQR 3.8–5.2) versus 4.3 seconds (IQR 3.9–5.6), respectively ($p=.24$). Likewise, fallers did not have a statistically significant difference from non fallers in their performance on F8WT, 7.9 seconds (IQR 6.9–9.7) versus 8.4 seconds (IQR 6.6–10.8) ($p=.29$).

Within the multivariable models, poorer performance on each walking test was associated with a greater rate of reported falls ($p<.01$). Figure 1 presents rate ratios of the unadjusted and fully adjusted models, showing the relationships between 4mWT or F8WT and fall number. In univariate analyses, poorer performance of 4mWT by 1 second was associated with 18% greater rate of falls ($p<.05$; $RR=1.18$, 95% CI: 1.05–1.32). Poorer performance of F8WT by 1 second was associated with 7% greater rate of falls ($p<.05$; $RR=1.07$, 95% CI: 1.02–1.12). In the fully adjusted model, poorer performance of 4mWT by 1 second was associated with 26% greater rate of falls ($RR=1.26$, 95% CI: 1.10–1.45). For F8WT, poorer performance by 1 second was associated with 8% greater rate of falls ($RR=1.08$, CI: 1.03–1.14). Adjustment for gender, BMI, MMSE, and chronic conditions had little influence on the RR 's for 4mWT or F8WT. When modeling fall number with 4mWT, the adjustment variables that demonstrated an association that were statistically significant with fall number included: age ($RR=0.97$, CI: 0.94–1.00), race ($RR=2.23$; CI: 1.35–3.67), and education levels less than high school ($RR=0.41$; CI: 0.21–0.79). Those same adjustment variables were statistically significant in models evaluating F8WT and fall number: age ($RR=0.97$; CI:

0.95–1.00), race (RR=2.04; CI: 1.25–3.34), and education levels less than high school (RR=0.44; CI: 0.21–0.78).

In Table 2, odds ratios are reported from multivariable logistic regression models between fall-related injuries or fall-related hospitalizations and 4mWT or F8WT. For both of the resulting outcomes, neither unadjusted nor adjusted models were statistically significant. This was the case for 4mWT and F8WT.

DISCUSSION

The major findings of our analysis are that (i) poorer performance of 4mWT by 1 second was associated with 26% greater rate of falls in the prior year, (ii) poorer performance of F8WT by 1 second was associated with 8% greater rate of falls in the prior year; and (iii) neither 4mWT nor F8WT is associated with self-reported history of fall-related injuries or hospitalizations.

To our knowledge, this is the first study looking at both straight- and curved-path walking associations together with fall history in the prior year among community dwelling older adults. This is important for 2 reasons. First, it contributes to the understanding of how a prior fall history may relate to performance on walking tests, especially if clinical researchers wish to evaluate the predictive ability of these walking tests on fall related outcomes prospectively. It is known that walking speed may be used as a predictor of falls, whereas F8WT has not been examined prospectively in the same manner.⁹ Second, the findings highlight for clinicians how a prior history would relate to performance on walking tests in the primary care setting. While previous studies have shown that walking speed may stratify subjects into those with and without a fall history, fall history was measured more crudely.^{18,28,29} The data collected in this study, however, support these findings and expand on them by looking at history of fall counts. Furthermore, no previous work has been done to evaluate the relationship between F8WT and history of fall counts. This is the first study to evaluate F8WT and history of fall-related events (injuries and hospitalizations) of any type.

Contrary to our original hypothesis, F8WT did not have a stronger association than 4mWT with falls in the prior year. The association between 4mWT and F8WT with fall rates was significant; however, there was no observed association between the two walking tests and history of fall injuries or hospitalizations. Given that poorer performance by 1 second was associated with 26% greater rate of falls during 4mWT versus 8% during F8WT, at first look it may appear that straight path walking was more strongly associated with fall rates than curved path walking. However, on average, it took participants longer to complete the F8WT than the 4mWT, suggesting that an increase by one second in 4mWT performance may represent a greater incremental change than a one second increase in F8WT performance. Given that the mean performance of the study sample overall was 4.7 seconds for the 4mWT and 9.0 seconds for the F8WT, a one second increase in time to complete the 4mWT represents an average change of 21.3%, while a one second increase in time to complete the F8WT represents an average change of 11.1%. Thus, it may not be appropriate to draw the conclusion that poorer 4mWT performance by one second has a stronger association with

fall rates in the prior year than F8WT performance. Specifically, the findings were unable to identify if one walking test is superior to the other. The adjustment variables which were significantly associated with higher fall rates in the negative binomial regression models included older age, white race, and education levels (less than high school). These results are consistent with prior studies, which have demonstrated that each of these factors is associated with falls.^{30,31}

Our findings, demonstrating an association between prior fall rates and performance on these walking tests, are important for future prospective studies evaluating these walking tests as predictors of risk for fall-related outcomes, since they show the importance of considering prior fall rates when assessing these relationships. Our findings suggest that prospective analyses of walk tests may need to control for prior fall rates, but if fall injuries and hospitalizations are the outcome of interest that prior history of these events may be less of a concern.

The absence of an association between performance on the 4mWT or F8WT with fall-related injuries or hospitalizations may be due to a number of reasons. First, there were a small number of hospitalization events reported, which may have made it difficult to achieve discrimination. Second, one year may not have been a sufficient amount of time for these events to occur. Third, the occurrence of an injury or hospitalization event (yes/no) was recorded, rather than the number of times the event happened. This lesser amount of information may have limited the statistical power to detect an association. The fourth possibility is that there was no relationship between the walking tests and prior fall-related injuries or hospitalizations.

It is important to understand the limitations of this study. Since cross-sectional data was used, causal relationships cannot be determined. While associations were found between walking performance and fall history, this was based on a self-reported recall of falls of older adults over one year, which for those participants with poorer memory may represent a source of error. This information is separate and distinct from future fall risk, which requires longitudinal data. Second, this was not a population based study; therefore, it may not be representative of all older adults. However, this is a study of older primary care patients at risk for decline in mobility skills. They were recruited to match the demographic characteristics of older adults residing in the greater regional area. Primary care patients at risk for decline in mobility skills is the exact population for which walking tests have been advocated.^{32,33} Furthermore, it is important to acknowledge that there was a variation in the instructions used when administering the F8WT in this study in comparison to the original publication describing the F8WT. We are unable to interpret how these differences may have impacted the study findings.

Our original hypothesis was based on clinical experience and prior studies that linked F8WT performance to attributes that are recognized fall risk factors.¹⁹ While we did not observe a stronger association between F8WT and prior fall history, it may be that a stronger association between F8WT and fall related outcomes is observed with prospective studies. Such studies have yet to be performed.

Despite the limitations, this study had a number of strengths. It included a well characterized cohort of older primary care patients. Also, the use of fall counts rather than fall occurrences (yes/no) allowed for a more rigorous analysis than prior studies²⁸ and these findings may be more applicable to mobility outcomes among older adults. Given the differences in performance of the study participants with higher fall rates, future longitudinal studies of performance based walking tests may need to account for prior rates of falls. Our future work will address the relationships between walking performance tests and fall outcomes prospectively and this preliminary work has informed the analytic approach we will undertake.

Conclusion

Poorer performance on straight- and curved-path walking tests are both associated with history of greater fall rates in the prior year among primary care patients at risk for mobility decline. Contrary to our original hypothesis, curved-path walking was not more strongly associated with prior fall outcomes than straight path walking; however, longitudinal data is needed to evaluate these relationships prospectively. Neither test was associated with fall injury or fall - related hospitalizations in the prior year. These findings among primary care patients will help inform the design of future studies and clinical programs wishing to evaluate the relationship between walking test performance and future fall outcomes.

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Figure 1.

Multivariable Negative Binomial Regression Modeling Fall Rate Ratios and Confidence Limits

Adjusted models included age, BMI, chronic conditions, MMSE, gender, race, and education level. 4mWT= Four meter walk time; F8WT= Figure of eight walk test; BMI = body mass index; MMSE = Mini Mental State Exam.

Table 1

Baseline Characteristics of Study Sample (N=428)

Demographic	Nonfallers (n=247)	Fallers (n=181)	p value
Median (IQR)			
Age	77 (71–82)	76 (70–82)	.96
BMI (kg/m ²)	28.1 (25.3–32.9)	28.5 (25.0–32.8)	.91
Chronic Conditions (0–11)	4 (3–5)	4 (3–5)	.77
MMSE (0–30)	28 (27–29)	28 (26–29)	.08
n (%)			
Female gender	169 (68.4%)	121 (66.9%)	.73
White race	197 (79.8%)	156 (86.2%)	.08
Education (high school)	213 (86.2%)	161 (89.0%)	.80
Indicators			
Median (IQR)			
4mWT (s)	4.4 (3.8–5.2)	4.3 (3.9–5.6)	.24
F8WT (s)	7.9 (6.9–9.7)	8.4 (6.6–10.8)	.29
Outcomes			
Fall number	0	1 (1–2)	(–)
n (%)			
Fall-Related Injuries	0	88 (48.6%)	(–)
Fall-Related Hospitalizations	0	19 (10.5%)	(–)

BMI = body mass index; SD = standard deviation; IQR= Interquartile Range; MMSE = Mini Mental State Exam; 4mWT= Four meter walk time; F8WT= Figure of eight walk test

Table 2

Multivariable Logistic Regression Modeling Fall-Related Injuries and Fall-Related Hospitalizations

Walk Test	Odds Ratio Estimate	95% Confidence Interval	p Value
Outcome: Fall-Related Injuries			
4mWT	0.87	0.67–1.13	.29
F8WT	1.07	0.97–1.18	.17
Outcome: Fall-Related Hospitalizations			
4mWT	0.94	0.61–1.45	.78
F8WT	1.06	0.92–1.23	.41

Adjusted for age, BMI, chronic conditions, MMSE, gender, race, and education level. 4mWT= Four meter walk time; F8WT= Figure of eight walk test