Self-selected and maximal walking speeds provide greater insight into fall status than walking speed reserve among community-dwelling older adults

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Abstract

Objective—To determine the degree to which self-selected walking speed (SSWS), maximal walking speed (MWS), and walking speed reserve (WSR) are associated with fall status among community-dwelling older adults.

Design—WS and one-year falls history data were collected on 217 community-dwelling older adults (median age=82, range 65-93 years) at a local outpatient PT clinic and local retirement communities and senior centers. WSR was calculated as a difference (WSRdiff=MWS-SSWS) and ratio (WSRratio=MWS/SSWS).

Results—SSWS ($p<0.001$), MWS ($p<0.001$), and WSRdiff ($p<0.01$) were associated with fall status. The cutpoints identified were 0.76 m/s for SSWS (65.4% sensitivity, 70.9% specificity), 1.13 m/s for MWS (76.6% sensitivity, 60.0% specificity), and 0.24 m/s for WSRdiff (56.1%

sensitivity, 70.9% specificity). SSWS and MWS better discriminated between fallers and non-fallers (SSWS: AUC=0.69, MWS: AUC=0.71), than WSRdiff (AUC=0.64).

Conclusions—SSWS and MWS appear to be equally informative measures for assessing fall status in community-dwelling older adults. Older adults with SSWSs less than 0.76 m/s and those with MWSs less than 1.13 m/s may benefit from further fall risk assessment. Combining SSWS and MWS to calculate an individual's WSR does not provide additional insight into fall status in this population.

Keywords

gait; aged; geriatric assessment

INTRODUCTION

Preventing falls in older adults is an important public health initiative. The Centers for Disease Control and Prevention recognizes falls as a "serious threat to the health and well-being" of older adults and has created a Stopping Elderly Accidents, Deaths, & Injuries (STEADI) tool kit for providers.[1] Included in the STEADI algorithm is assessment of an at-risk older adult's gait, strength, and balance. The measure recommended in the STEADI tool kit is the Timed Up & Go test. However, other measures that combine assessment of these constructs may also be informative regarding an older adult's fall risk. A novel assessment tool incorporating gait, strength, and balance is walking speed reserve (WSR).

Walking speed reserve can be quantified clinically as either the difference between an individual's self-selected walking speed (SSWS) and his or her maximal walking speed (MWS) or the ratio (MWS/SSWS) between the speeds. Both WSR values reflect an individual's capacity to increase their walking speed when needed. Increasing speed is more challenging than maintaining steady-state WS and requires strength and balance, components of neuromuscular control.[2,3] To maintain balance while increasing speed, proactive and reactive neuromuscular control are used to prepare for and react to the destabilizing forces that occur.[4] Therefore, quantifying an individual's ability to increase their WS may provide insight into their fall-risk, as a low WSR value may be indicative of impaired neuromuscular control and decreased capacity to increase WS in response to environmental demands. Research is needed to examine the association between WSR and fall risk and to determine whether this measure is more informative than SSWS or MWS measured alone.

Although evidence indicates that a relationship exists between both SSWS and MWS and predicted fall risk, the assumption of a linear relationship between these variables (e.g. as SSWS decreases predicted risk of falling increases), has been questioned. Emerging evidence suggests the relationship between WS and fall risk may actually be "U-shaped", with those at the slow and fast ends of the WS spectrum being at higher risk.[5,6]

We hypothesize that both individuals with slow SSWSs and fast SSWSs could have low WSRs. Compensatory strategies for impaired neuromuscular control include a reduction in step length and WS.[7,8] These compensatory strategies may hinder the individual's ability to

accelerate and achieve a MWS greatly above his or her SSWS, resulting in a low WSR. Thus, WSR could be used to identify those with slow SSWS due to neuromuscular impairments, rather than another factor (e.g. personal preference), who are at risk of falls.

Conversely, evidence indicates that a subset of individuals at the fast end of the SSWS spectrum are also at an increased risk of falling.[5] This may be due to these individuals ambulating at speeds that exceed their actual physical capabilities (e.g. ability to regain balance following an event such as a slip or a trip) due to an overestimation of their abilities.[9,10] Since these individuals are already walking "too fast", their SSWS may be close to their MWS, leaving little reserve. Speeding up is a compensatory strategy used to recover from perturbations such as slips and trips.[11] These individuals may be at increased risk for a fall compared to their peers with similar SSWSs, but who are not walking "too fast" and maintain the ability to increase their speed. Therefore, WSR may identify individuals at the fast end of the WS spectrum, who would have been missed using SSWS cutoff values, but may be at risk for adverse events, such as falls.

Walking speed reserve is a novel fall risk assessment tool, and evidence is limited regarding its capabilities. Previous research has shown that WSR is not associated with daily ambulatory activity in community-dwelling older adults,[12] but it is unknown whether the measure provides insight into fall risk. A better understanding of the relative utility of SSWS, MWS, and WSR for identifying fall status in older adults is needed. Therefore, the primary objective of this study was to determine the degree to which SSWS, MWS, and WSR are associated with fall status in community-dwelling older adults. "Fall status" refers to whether an individual is a faller or non-faller. We hypothesized that WSR would demonstrate a stronger association with fall status than SSWS or MWS. Findings will help clinicians and researchers select the most appropriate WS measure when fall risk is an outcome of interest.

METHODS

Study procedures were approved by the University of South Carolina's Institutional Review Board and all participants signed an informed consent form prior to participation. A cross-sectional, retrospective study design was used to investigate the relationship between SSWS, MWS, and WSR and fall status in community-dwelling older adults.

Walking speed and fall history data were collected at a local outpatient physical therapy (PT) clinic and at local retirement communities and senior centers. All data were collected by physical therapists trained on the standardized protocols. Walking speed tests were performed on pre-marked, straight walkways, and fall history questionnaires were completed in quiet rooms providing participants' privacy. Walking speed and falls data for each participant were collected at the same testing session.

Participants

To be eligible, participants had to be 65 years of age or older, community-dwelling, and able to complete the WS assessments. Individuals who presented with unresolved, but temporary musculoskeletal problems that affected ambulation (e.g. recent sprain or fracture); history of

a neurologic condition (e.g. stroke, traumatic brain injury, Parkinson's disease); or required a prosthetic device of any sort for ambulation were excluded. The goal was to have a sample representative of older adults living independently in the community.

Fall Status

Fall history was used to determine fall status. Participants were asked "Have you fallen in the last 12 months? A fall is an unplanned, unexpected contact with a supporting surface."[13] If the participant reported 1 or more falls, they were then asked to describe the circumstances for each fall. Only falls not resulting from an excessive external force (e.g. bumped by car) were counted. Individuals who reported 1 or more falls in the preceding 12 months were classified as "Fallers"; those with no reported falls were classified as "Non-fallers".

Walking Speed

Walking speed data were collected using either a 3 or 10 meter walk test. Due to space limitations at the outpatient PT clinic, a 3 meter walk test was performed in this setting to determine SSWS and MWS.[14] Two meters were provided prior to and following the timed portion to allow for acceleration and deceleration and ensure that steady-state WSs were captured for analyses. For assessment of SSWS, participants were instructed to walk at their "usual, comfortable speed". For MWS, the instructions were to walk as "quickly, but safely as possible". A stopwatch was used to time participants over the 3 meter path. Timing started when the participant's lead leg broke the plane of the marker at the beginning of the path and stopped when the lead leg broke the plane of the marker at the end of the 3 meter path. Three trials were performed under each condition and averaged to determine SSWS and MWS (m/s), respectively. Assistive devices and/or orthoses typically used during community ambulation were permitted during testing.

Self-selected WS and MWS were assessed at the local retirement communities and senior centers using a 10 meter walk test.[15] Participants performed 4 trials of the 10 meter walk test- 2 trials under 2 different conditions (SSWS and MWS). The SSWS instruction set was the same as the one used at the PT clinic; participants were instructed to walk at their "usual, comfortable speed". The MWS instruction set differed slightly from the one used at the PT clinic, as an example was provided. For MWS, the instructions were to walk as "quickly, but safely as possible, for example, as if you are hurrying to get somewhere." The 2 trials under each condition were averaged to determine SSWS and MWS (m/s), respectively. The timing procedure was identical to the protocol used at the PT clinic. Five meters were provided prior to and following the timed portion to allow acceleration and deceleration to occur outside the timed region and ensure that steady-state self-selected and maximal WSs were captured for analyses. Assistive devices and/or orthoses typically used during community ambulation were permitted during testing.

Data Analysis

Descriptive statistics (e.g. mean, SD, median, range, percentage) were calculated for demographic and WS variables. Normality of data were established using the Kolmogorov-

Smirnov test with Lilliefors correction along with visual inspection of plots.[16] Alpha was set at   0.05 for all significance testing.

Between group (Fallers versus Non-fallers) differences in age, sex, AD use, SSWS, MWS, WSRdiff, and WSRratio were assessed using independent t-tests (or a non-parametric equivalent) and chi-squared tests. Binary logistic regression models were constructed with previous falls (yes, no) as the dependent variable in order to determine which independent variables were associated with fall status. Unadjusted analyses were performed first to examine the main effects of the WS measures. Any of the aforementioned descriptive statistics (e.g. age, sex, AD use) found to differ significantly between the groups (Fallers and Non-fallers) were considered for entrance into the model as covariates. It was determined *a priori* that the number of covariates entered into the models would not exceed 10% of the smaller outcome (n of Fallers or Non-fallers).[17]

Receiver operating characteristic (ROC) curves were constructed for the WS measures associated with fall status in logistic regression. Area under the ROC curves (AUC) were calculated to examine the discriminative capabilities of the WS measures The ROC curves were also used to identify a cutpoint which maximized sensitivity and specificity for the included WS measure.[18] Positive and negative likelihood ratios (+LR = sensitivity/(1-specificity), −LR = (1-sensitivity)/ specificity) were calculated for the identified cutpoints. Likelihood ratios combine sensitivity and specificity into a single metric and can be compared to determine which measure is the most informative.[19] The larger the shift from pre-test to post-test probability that occurs when the LR for a test is applied, the more valuable the test is for differentiating between those who would benefit from intervention and those who do not require intervention. Likelihood ratios can be interpreted as follows: +LRs >10 and −LRs <0.1 result in shifts in probability that are "large and conclusive", +LRs between 5 and 10 and −LRs between 0.1 and 0.2 result in "moderate" shifts, +LRs from 2 to 5 and −LRs from 0.5 to 0.2 result in "small" shits, and +LRs from 1 to 2 and −LRs from 0.5 to 1 result in shifts that are "rarely important".[20] All data analyses were performed using IBM® SPSS 22, Armonk, NY and SAS® 9.3, Cary, NC.

RESULTS

Participants

Sample characteristics (n=217) are presented in **Table 1**. 150 participants were assessed at a local outpatient PT clinic and 67 participants at local retirement communities and senior centers. Participant ages ranged from 65 to 93 years (median=82 years), 70.5% were female, and 49.3% reported having experienced at least one fall over the previous year.

Walking Speed Measures and Falls

Self-selected WS (p <0.001), MWS (p <0.001), and WSRdiff (p <0.01) were associated with fall status in unadjusted logistic regression (**Table 2**). The only potential covariate measured that was significantly different between Fallers and Non-fallers was rolling walker (RW) use. Therefore, RW use was the only additional variable entered in multivariable analyses; however, RW use was not a significant predictor of fall status in any of the adjusted models

(SSWS+RW, MWS+RW, and WSRdiff+RW). Since addition of RW as a covariate did not improve the predictive capabilities of the models, results of the adjusted models are not presented, rather the focus is on the unadjusted models.

The AUCs for the unadjusted SSWS (0.69, 95% CI: 0.62-0.76), MWS (0.71, 95% CI: 0.64, 0.77), and WSRdiff (0.64, 95% CI: 0.56, 0.71) models imply that SSWS and MWS perform similarly in discriminating between Fallers and Non-fallers, while WSRdiff demonstrated the least utility (**Table 3**). The cutpoints identified on the SSWS, MWS, and WSRdiff ROC curves, which maximized sensitivity and specificity, along with the associated +LRs and −LRs are presented in **Table 3**. The LRs associated with all cutpoints produced only "small" or "rarely important" shifts in pre-test to post-test probabilities.

DISCUSSION

In our sample of community-dwelling older adults, SSWS, MWS, and WSRdiff were all associated with fall status. Although we hypothesized that WSR would demonstrate the strongest association, the measure provided the least utility for assessing fall status in our sample when compared to SSWS and MWS.

Self-selected WS and MWS demonstrated comparable capabilities for discriminating between fallers and non-fallers (AUC's of 0.69 and 0.71, respectively). The positive and negative LRs for both measures were also comparable. The similarity in findings indicate that when fall status is an outcome of interest, SSWS and MWS are equally informative. Clinicians can use the WS measure (SSWS or MWS) that is most appropriate for their patient and the purpose of the assessment without compromising insight into fall risk. Assessing both SSWS and MWS does not provide additional information on an older adult's fall risk, as WSRdiff demonstrated the least clinical utility for discriminating between fallers and non-fallers (AUC of 0.64).

Walking speed reserve is a fairly novel fall risk assessment tool. Callisaya et al. 2012, calculated a similar metric, the ratio between participants' (n = 155) preferred and fast walking speeds. Their sample was divided into 3 groups: no fall, single fall, and multiple falls. The WS ratio value was associated with cognitive outcomes, but not with risk of falls.[9] These findings are comparable to what was observed in this study; WSR calculated as a ratio was not associated with fall status.

Although the ratio values were not associated with fall status, the WSR values calculated as a difference demonstrated some utility for discriminating between fallers and non-fallers. This finding implies it is the absolute speed change an individual has available during ambulation that impacts fall-risk, rather than the relative speed change. In our sample, the inability to increase WS by 0.26 m/s or more was associated with increased likelihood that the participant had fallen over the previous year, regardless of their "starting" SSWS. These individuals may also be at increased risk of falls, as previous falls are a risk-factor for future falls.[21] However, the 0.26 m/s WSRdiff value does not discriminate between fallers and non-fallers as well as the SSWS cutpoint of 0.76 m/s or the MWS cutpoint of 1.13 m/s.

We had hypothesized that WSR would be the most informative of the WS measures for assessing fall risk. A possible explanation for why this was not observed may be the association between SSWS and MWS. To further explore this, we performed a post hoc correlation analysis examining the association between SSSW and MWS in our sample. The two speeds were strongly correlated (Spearman's rho = 0.91). The strong association indicates that the difference between SSWS and MWS is fairly consistent across participants. Those with slow SSWSs have slow MWSs and those with fast SSWSs have fast MWSs. The difference between SSWS and MWS (i.e. WSRdiff) is therefore not as informative as one of the measures alone. Greater variation in the ability to increase WS was expected in our sample. Walking speed reserve may be associated with fall risk among individuals with compromised ability to increase their WS, as the association between SSWS and MWS may not be as strong. Future research in populations with impaired neuromuscular control, such as individuals with stroke and Parkinson's disease, are needed.

Clinical Implications

Our findings indicate that older adults with SSWSs less than 0.76 m/s and those with MWSs less than 1.13 m/s are likely at increased risk for a fall, whether they have experienced one or not, and would benefit from further fall risk assessment. These findings support previous research reporting fall risk cutpoints of 0.7 m/s for SSWS and 1.0 m/s MWS for older adults.[22,23] Additionally, our findings add to available evidence by 1) comparing these two measures within the same sample and 2) examining a novel WS measure combining the 2 speeds. The clinical implications of our findings are that SSWS and MWS are equally informative regarding fall status in older adults and having a patient perform both measures does not offer additional insight.

Limitations

Measures that produce AUC values between 0.5 and 0.7 are considered to have "low" accuracy.[24] The AUC values reported in this study range from 0.64 to 0.71 (with all confidence interval upper bounds 0.71 to 0.77), falling into the upper range of this category. The purpose of the AUC analysis was to compare the relative utility of the WS measures for identifying fall status. To achieve this, we compared the diagnostic accuracy (AUCs) of the measures among themselves to determine which discriminated best. We acknowledge that the AUCs are low and findings must be interpreted with caution. The results provide insight into how these WS measures compare to each other in regards to their utility for identifying fall status in community-dwelling older adults. Other available outcome measures may provide higher accuracy at discriminating between fallers and non-fallers in this population.[25] The LRs for the WS measures should also be considered. All the LRs for the cutpoints identified in this study produced only "small" or "rarely important" shifts from pre-test to post-test probabilities. Other measures may be more informative for identifying fall status.

Another limitation is the use of fall history to dichotomize the sample. Although a prospective design would have protected against potential recall bias and strengthened results, asking an individual if they have fallen in the previous year is a recommended clinical strategy for identifying fallers.[26]

The protocol used to assess WS differed between testing locations. Those assessed in the community performed a 10 meter walk test, while those assessed at a local outpatient PT clinic performed a 3 meter walk test due to space limitations. The differing distances of the WS tests is acknowledged as a limitation in study design and needs to be considered when interpreting results. However, steady-state walking speed was assessed using both distances, which reduces differences between the protocols. Additionally, both are reliable methods of assessing walking speed and the assessments were performed by experienced physical therapists trained on standardized protocols, which further improves the reliability.[14,27] The instructions given during MWS testing also differed slightly between groups, as individuals assessed in community settings were provided an example. Although the use of 2 methods reduces internal validity of the study design, it improves the generalizability of our findings. Across clinical settings, WS is assessed using different methods.

The percentage of individuals in our sample who reported having a fall over the previous year (49.3%) is higher than the 33% expected.[1] A possible explanation for this is the inclusion of older adults receiving PT. These individuals may be at higher risk for falls than their peers who are not receiving PT. Sample characteristics, such as fall rate, should be taken into consideration when interpreting and applying study findings.

Conclusions and Directions for Future Research

Self-selected WS and MWS are equally informative measures for assessing fall status in community-dwelling older adults. Older adults with SSWSs less than 0.76 m/s and those with MWSs less than 1.13 m/s may benefit from further fall risk assessment. Combining SSWS and MWS to calculate an individual's WSR does not provide additional insight into fall status, potentially due to the strong association between SSWS and MWS in this population. Future research is needed to determine the utility of WSR as a fall risk assessment tool in populations with mobility restrictions who may have difficulty increasing their WS. The utility of WSR as a predictor of other adverse events, such as institutionalization or mortality, also warrants further investigation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

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Table 1

Characteristics of Study Sample

Characteristic	All	Non-fallers	Fallers	p-value[*]
n (%)	217	110 (50.7)	107 (49.3)	
Age, median (min, max)	82 (65, 93)	81 (66, 93)	82 (65, 93)	0.62
Female, n (%)	153 (70.5)	81 (73.6)	72 (67.3)	0.31
AD,[**] n (%)				
Cane	31 (14.7)	12 (11.4)	19 (17.9)	0.18
RW	28 (13.3)	8 (7.6)	20 (18.9)	**0.02**
SSWS, mean ± SD	0.81 ± 0.28	0.90 ± 0.28	0.71 ± 0.24	**<0.001**
MWS, mean ± SD	1.10 ± 0.36	1.23 ± 0.36	0.96 ± 0.32	**<0.001**
WSRdiff, median (min, max)	0.26 (0.00, 0.99)	0.31 (0.03, 0.99)	0.22 (0.00, 0.67)	**0.001**
WSRratio, median (min, max)	1.39 (0.98, 3.36)	1.33 (1.03, 1.92)	1.33 (0.98, 3.36)	0.61

Abbreviations: min, minimum; max, maximum; AD, assistive device; RW, rolling walker; SSWS, self-selected walking speed; MWS, maximal walking speed; WSRdiff, walking speed reserve calculated as a difference (MWS – SSWS); WSRratio, walking speed reserve calculated as a ratio (MWS/SSWS)

Units of measure: age, years; SSWS, MWS, WSRdiff, m/s

[*] Between group differences analyzed with t-test (SSWS, MWS), Mann-Whitney U test (Age, WSRdiff, WSRratio) and Chi-square test (Female, Cane, Walker)

[**] AD data missing for 6 participants, total sample n = 211, Non-fallers n = , Fallers n =

Table 2

Unadjusted Logistic Regression

Model	OR	95% CI for OR	*p-value* for OR
SSWS	0.06	(0.02, 0.19)	**<0.001**
MWS	0.10	(0.04, 0.25)	**<0.001**
WSRdiff	0.05	(0.01, 0.34)	**<0.01**
WSRratio	1.20	(0.441, 3.26)	0.72

Abbreviations: OR, odds ratio; CI, confidence interval; SSWS, self-selected walking speed; MWS, maximal walking speed; WSRdiff, walking speed reserve calculated as a difference (MWS – SSWS); WSRratio, walking speed reserve calculated as a ratio (MWS/SSWS)

Table 3

ROC Analyses

	SSWS	MWS	WSRdiff
AUC	0.69 (0.62, 0.76)	0.71 (0.64, 0.77)	0.64 (0.56, 0.71)
Cutpoint (m/s)	0.76	1.13	0.24
Sensitivity	65.4%	76.6%	56.1%
Specificity	70.9%	60.0%	70.9%
+LR	2.25	1.92	1.93
−LR	0.49	0.39	0.62

Abbreviations: SSWS, self-selected walking speed; MWS, maximal walking speed; WSRdiff, walking speed reserve calculated as a difference (maximal walking speed – self-selected walking speed); AUC, area under the receiver operating characteristic curve; m/s, meters per second; +LR, positive likelihood ratio; −LR, negative likelihood ratio