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The Walking Speed Questionnaire: Assessing Walking Speed in a Self-Reported Format

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STRUCTURED ABSTRACT

OBJECTIVES—The literature increasingly demonstrates the importance of gait speed in the frailty assessment of patients 60 years and older. Conventional gait speed measurement, however, may be contraindicated in settings such as trauma where the patient is temporarily immobilized. We devised a Walking Speed Questionnaire (WSQ) to allow assessment of pre-injury baseline gait speed, in meters per second, in a self-reported manner, to overcome the inability to directly test the patients' walking speed.

DESIGN—Four questions comprise the WSQ, and were derived using previously published questionnaires and expert opinion of six physician-researchers.

SETTING—Four ambulatory clinics.

PARTICIPANTS—Ambulating individuals aged 60 to 95 (mean age 73.2 ± 8.1 , 86.1% female, N = 101).

INTERVENTION—Participants completed the WSQ and underwent gait speed measurement for comparison.

ANALYSIS—WSQ score correlation to true gait speed, receiver operating characteristics, and validation statistics were performed.

RESULTS—All four questions of the WSQ independently predicted true gait speed significantly ($P < 0.001$). The WSQ sufficiently predicted true gait speed with $r = 0.696$ and $\rho = 0.717$.

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Declarations of Conflicts of Interest

For the remaining authors, no conflicts of interest or additional sources of funding were declared.

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CONCLUSION—The WSQ is an effective tool for assessing baseline walking speed in patients 60 years and older in a self-reported manner. It permits gait screening in health care environments where conventional gait speed testing is contraindicated due to temporary immobilization, and may be used to provide baseline targets for goal-oriented post-trauma care. Given its ability to capture gait speed in patients who are unable to ambulate, it may open doors for frailty research in previously unattainable populations.

Keywords

Walking; Gait; Questionnaire; Speed; Self-Report

INTRODUCTION

Gait is a commonly used physical indicator for quality of life and functional independence.¹ In older populations, gait speed (GS) is associated with healthcare-related outcomes and is a major determinant of physical frailty.^{2, 3}

GS measurement can be easily incorporated into clinical settings, is quick to administer, and requires minimal equipment and personnel training.^{4–6} However, despite strong correlation with physical function and health outcomes,^{2, 5, 7–11} measuring GS is not always feasible, especially in cases of acute trauma, in survey-based research, or in retrospective GS analysis. Furthermore, physical frailty measures such as the Cardiovascular Health Study Frailty Index³ (CHS-FI) cannot be administered in immobilized subjects, temporarily or otherwise. Gait assessment and frailty research has thus been limited in these areas.

This study introduces the Walking Speed Questionnaire (WSQ) as a new tool to assess GS in meters per second (m/s) and identify slowness in gait, in a self-reported format, for the urban-dwelling geriatric population. The WSQ may prove to be useful in substituting the physical gait test in settings where conventional GS tests are contraindicated, and may be the only tool capable of providing a valid measure of pre-injury GS in lower-extremity (LE) trauma patients. The WSQ may thus open doors for patient care and medical research in previously unattainable populations.

PATIENTS AND METHODS

Study Population

This was a prospective study involving individuals aged 60 or older that visited one of four outpatient clinics between September 2013 and May 2014. The clinics include a metabolic bone clinic, an orthopedic clinic, a geriatric primary care clinic, and a physical medicine and rehabilitation (PM&R) clinic. This study was approved by two institutional review boards. Subjects were recruited consecutively and informed consent was obtained. Exclusion criteria included: 1) difficulty with the English language; 2) surgery or procedure affecting the LE in the previous 90 days; 3) any condition in the previous 90 days affecting current walking speed; 4) a Mini Mental State Exam 2 – Brief Version (MMSE2:BV) score of <13/16. We included subjects with chronic LE functional deficits who have not had acute changes in

their LE function in the previous 90 days, and subjects with LE trauma and/or surgery >90 days ago.

Study Design

First, we designed the WSQ based on expert opinion from six physician-researchers from three academic centers with backgrounds in geriatrics and orthopedic surgery, and from a literature review on questionnaire-based gait assessment.

Second, a pilot study was performed using a preliminary draft of the WSQ with 23 inclusion criteria-appropriate subjects to demonstrate internal consistency of the questionnaire and to identify areas for improvement.

Finally, for the main study, 101 subjects underwent standardized patient evaluations by four independent examiners who were trained by demonstration prior to their first subject evaluation. Standardized subject evaluations comprise (in this order): 1) Evaluation of inclusion and exclusion criteria by interview and MMSE2:BV; 2) Independent completion of the paper form of the revised WSQ (Appendix, Supplemental Digital Content 1) by the subject, allowing requests for clarification from examiners only if absolutely necessary, and 3) GS measurement.

Gait Speed Measurement

True GS was measured in a similar manner as in the Cardiovascular Health Study (CHS).³ Specific guidelines were adapted from Afilalo et al.:⁸

“A well-lit, unobstructed hallway with tape markings at zero and 15 feet (zero and 4.57 meters) was used for the test. Subjects were instructed to walk at a ‘comfortably fast speed for you, as if you are crossing a street,’ beginning with their toes on the zero line going past the 15-foot (4.57-meter) line. Subjects were permitted to use usual walking aids including walkers or canes, but were discouraged from wearing high-heeled footwear. Smartphone-based timers were used to time the travel between the first footfall after the zero line and the first footfall after the 15-foot (4.57-meter) line. This sequence was repeated three times with no rest periods provided. The average of the three times was used to determine true GS in feet/s and m/s.”

Questionnaire Design

The preliminary draft of the WSQ, which included items 2-5 (Q2-5), demonstrated good internal consistency among items (Standardized Cronbach’s alpha: 0.825; raw alpha: 0.687). Wording and stylistic changes were made and two additional items (Q1, Q6) were included to form the revised WSQ (Appendix, Supplemental Digital Content 1), which was used to survey the 101 subject cohort.¹² Four items (Q1-4) comprise the final WSQ; Q5-6 were relegated to correlation testing only.

Q1 of the WSQ was added as no previous literature has examined the ability for patients to accurately and directly predict their own GS in conventional speed units. Reference points were given for crawling, normal adult walking speed, and race walking.^{13, 14}

Q2 and Q3 capture the patients' GS in a visual analog scale (VAS) and in an ordinal fashion, respectively, by assessing their ability to cross avenues within the time allowed by pedestrian crosswalk signals. According to the United States Department of Transportation guidelines, crosswalks are standardized nationally and must accommodate slow walkers with GS as low as 3.5 to 4.0 feet/s (1.07 to 1.22 m/s), for a total crossing time of at least 7 seconds.¹⁵ Using this information, we reasoned that the act of crossing wide avenues is the most well-standardized activity in distance and timing (relative to other daily walking speed frames of reference), and thus provides the best subjective measure of daily GS.

Q4 of the WSQ was adapted from Mahe et al,¹⁶ asking subjects to compare their walking speed to relatives or friends. Q5 and Q6 were modified from the *Speed* section of the Walking Impairment Questionnaire (WIQ)^{16–19} and the Estimating Ambulation Capacity by History Questionnaire (EACH-Q),²⁰ respectively.

Answers to all WSQ items were assigned a numerical score, with a minimal score of 0 for the *slowest* answer for each item. Scoring formulas for Q5 and Q6 were adapted from their respective publications.^{20, 21} Though Q3 and Q4 are scored discretely, any in-between answers received from subject evaluations were analyzed as half-points; rounding of scores was avoided for testing purposes.

Statistical Modeling and Analysis

To score the WSQ, we evaluated seven additive and multiple regression scoring algorithms with differential item weighting. The multiple regression method demonstrated minimally higher correlation between WSQ score and true GS, and was excluded because of high calculation burden and likelihood for multicollinearity.²² Instead, we focused our analyses on a simple additive score out of a total of 19 points. Since each item of the WSQ assesses walking speed invariably, we halved the weight of Q2 in order to approximate equal weighting of the items. This boosted score correlation with true gait speed, without impacting ease of scoring.

Correlation of WSQ scores to true GS was tested by Ordinary Least Squares (OLS) analysis, based on a linear-relationship assumption. Predictive validity was demonstrated using 10-fold cross-validation. Since the WSQ can be scored continually from 0 to 19, we identified optimal score cut-points for detecting slowness below certain GS thresholds using Receiver Operating Characteristic (ROC) statistics. This allows binary stratification of patients into “slow” and “non-slow” categories for research and clinical applications.

Statistical analysis was performed by the primary author. Cross-validation, homoscedasticity, ROC and Youden's index calculations were performed using *R*, version 3.1.0, 64-bit with *DAAG*, ver. 1.20, *lmtest*, ver. 0.9–33, and *pROC*, ver. 1.7.3 statistics packages (R Foundation for Statistical Computing, Vienna, Austria). OLS, ANOVA, and Intra-class correlation analyses were performed using *SPSS Statistics*, ver. 21 (IBM, Armonk, NY). All remaining analyses were performed using *Office Excel 2010* (Microsoft, Redmond, WA).

RESULTS

Descriptive Statistics

A total of 218 age-appropriate, English-speaking patients were screened for participation in this study (Table 1). 33 were excluded due to surgery that affected the LE within 90 days, 39 were excluded due to any condition within the previous 90 days affecting current walking speed, 7 were excluded due to a MMSE:BV score of <13/16, and 38 patients refused to participate. The final study cohort included 101 subjects. Fourteen (13.9%) subjects were male and 87 (86.1%) were female. Mean age for the total cohort was 73.2 ± 8.1 (mean $\pm$ SD). The sex bias reflects that of the patient population. The majority of patients (69) were recruited from the metabolic bone outpatient clinic, with the remainder from the geriatric (21), orthopedic (9), and PM&R (2) clinics. Mean BMI of 98 subjects with completed weight data was 24.1 ± 4.9 (mean $\pm$ SD). GS among all participants was 1.18 ± 0.33 m/s (mean $\pm$ SD), with no statistical difference between males and females at $p < 0.01$ using a two-tailed Student's t-test.

Statistical Analyses

Reliability Analysis—Standardized Cronbach's alpha for the final WSQ (Q1-4) is 0.827 (raw alpha; 0.750), suggesting better internal consistency when compared to the draft used in the pilot study.

Regression and Agreement Analysis—OLS regression was used to generate an equation for estimating GS from WSQ scores, using a linear relationship assumption. Studentized Breusch-Pagan test demonstrated a p -value of 0.43 suggesting sufficient homoscedasticity. Review of score distributions for WSQ items Q1-4 demonstrates a ceiling effect in item Q2 (Table 2). Nevertheless, histogram analysis of total WSQ score distributions demonstrates sufficient normality of data (not shown). Outlier analysis led to the removal of one case out of 101 that demonstrated a regression residual greater than 3 standard deviations from the mean, forming a sub-cohort of 100 subjects which was used for all nondescriptive statistical analyses. These tests support robustness of the OLS method. The regression equation is:

$$\text{Estimated Gait Speed} = 0.0631 \times (\text{WSQ score}) + 0.381, \quad (\text{Equation 1})$$

with a standard error (SE) of estimate of 0.225 m/s for the estimated GS (see Figure, Supplemental Digital Content 2). Using Equation 1, estimated cohort GS was 1.17 ± 0.22 (mean $\pm$ SE, range 0.59 to 1.58). Per Intraclass Correlation Coefficient (ICC) analysis, single-administration of the WSQ produces a 66% absolute agreement between the WSQ-estimated GS and the true GS (ICC(3,1) coefficient: 0.655 [95% CI; 0.527, 0.754]).²³

Cross-Validation—Ten-fold cross-validation demonstrated a Mean Square Error of Cross-Validation (MSECV) of 0.051 for the WSQ scoring algorithm. Minimal difference was seen in the MSECV as compared to the ANOVA Mean Square Error (MSE; Table 3).

Correlation and Convergent Validity—Correlations among individual WSQ items were determined using Spearman's rank-order correlation (ρ). For the total WSQ score,

Pearson's correlation (r) was also reported (Table 3) given the utility of assuming a linear relationship (Equation 1). Correlations in all item pairings were statistically significant (Table 4; $p < 0.01$). ρ between Q1-4 and Q5-6 ranged from 0.495 (between Q1 and Q5) to 0.690 (between Q3 and Q5) demonstrating reasonable correlation of Q1-4 against published measures.

In comparing item correlation with true GS, items Q1-4 correlated similarly as compared to Q5-6 ($\rho = 0.530$ to 0.632), demonstrating good convergent validity among these questions against published measures of GS. Q1 demonstrated the poorest correlation with true GS ($\rho = 0.530$), suggesting that subjects were less capable in estimating their own gait speed in an absolute manner than they were in a subjective manner.

Discriminant Validity—Literature reveals 1.0 m/s and 1.2 m/s as two important speed thresholds used as determinants for health outcomes. GS of < 1.0 m/s has been shown to be associated with higher risk for LE limitation, health decline, short-term mortality and hospitalization in the elderly,^{2, 7, 11} and a GS of < 1.0 m/s (approximately 3.3 feet/s) has been shown to be a determinant of independence and longer survival.^{9, 11} A speed of > 1.2 m/s (approximately 4 feet/s) has been used to predict longer life expectancy,¹¹ and as a threshold speed in pedestrian crosswalk timing – an important aspect of independent living.^{15, 24}

Using the 100-patient sub-cohort, we generated ROC curves for the 19-point WSQ to determine its sensitivity (Sn) and specificity (Sp) for detecting slowness defined as true GS of either < 1.0 m/s or < 1.2 m/s. Area Under the Curve (AUC) was 0.845 (95% CI 0.76, 0.93), for slowness defined as < 1.0 m/s and 0.897 (95% CI 0.84, 0.96), for slowness defined as < 1.2 m/s, suggesting that the WSQ correctly stratifies patients into slow and non-slow categories 85 to 90% of the time. Calculation of Youden's indices enabled determination of optimal WSQ score cut-points for maximizing Sn and Sp (Figure 1). Youden's index for a slowness definition of < 1.0 m/s was determined to be 12.7 points, achieving Sn of 87%, Sp of 76%, positive likelihood ratio ($LR+$) of 3.6 and negative likelihood ratio ($LR-$) of 0.18. Youden's index for < 1.2 m/s was 12.3 points, with Sn of 74%, Sp of 94%, $LR+$ of 12, and $LR-$ of 0.28.

DISCUSSION

Gait speed (GS) is an important variable in the clinical assessment of the elderly as a major independent predictor for health outcomes.^{2, 4, 5, 7, 8, 10, 11, 25, 26} The Walking Speed Questionnaire (WSQ) allows for GS assessment in a self-reported, non-ambulatory fashion. This quality makes the WSQ a valuable tool in situations where the conventional physical gait test cannot be performed, especially in trauma. In these cases, it may be used to assess baseline pre-injury walking speed and objectively guide post-injury medical care and physical therapy goals. GS is also a major component of measuring physical frailty – a modality increasingly used in the trauma and geriatric literature for outcomes prediction.^{3, 26}

The WSQ consists of four items (Q1-4). Though additional items (Q5 and Q6) were tested, higher user burden from these items, in combination with lower value in improving psychometric characteristics of the WSQ, caused them to be excluded from the final WSQ.

In our experience, the WSQ requires less than 1 minute to complete. The WSQ can therefore be useful in settings where brief, hand-scorable gait speed surveys are needed.

To improve the accuracy of the WSQ, subjectivity in the interpretation of gait instructions was minimized by designing the GS protocol and the items of the WSQ such that they both faithfully reflect the act of crossing a wide avenue. Our GS protocol is otherwise very similar to the 5-meter/15-foot gait speed test used in studies including the well-established CHS Frailty Index,^{3, 8, 27} but departs from longer-established GS tests in literature.^{28, 29} Given that this study required subjects to recall their walking speed using a wide avenue as a frame of reference, the WSQ may theoretically better reflect subjects' usual walking speeds in public spaces when compared to existing gait assessment tools. However, there remains the limitation that we have not explicitly demonstrated the accuracy of our GS protocol in reflecting GS outside of the clinic, which may impact the accuracy of the WSQ.

Self-reported measures are more influenced by pain than performance-based measures.³⁰ Although we attempted to isolate subjects' walking *speed* from walking *difficulty* (the latter presumably being more confounded by pain) in the design of the WSQ questions, pain may nevertheless be an unavoidable confounding variable.

In our literature review, the WSQ is the only survey of its kind that has been evaluated for its accuracy in directly estimating true GS in speed units (Equation 1). Our results suggest that the WSQ is capable of measuring gait speed to within ± 0.23 m/s in standard error. However it is important to consider the limitations of using a subjective survey to measure such an objective variable as GS. The WSQ, at its best, was only able to account for 49% of the variability in true GS measured using our protocol ($r=0.696$; Table 3). Also, the intraclass correlation coefficient calculated for the WSQ-estimated GS versus true GS was 0.655, suggesting mild item-to-item agreement between the WSQ scores and true GS. Inherent bias due to subjectivity, deficiencies in the design of the WSQ, and/or deficiencies in our true GS measurement protocol may contribute to this discrepancy. However, the theoretical ability for the WSQ to capture subjects' *perception* of their slowness as a psychologic component to GS may also play a part in the discrepancy between WSQ scores and true GS; patients' perception of street surface, crowd, noise, and the threat of passing vehicles can all influence patients' confidence in walking. For instance, a 2001 study demonstrated that subjects who were not fearful of falling had significantly higher average GS than did fearful subjects.³¹ Conventional gait tests, performed in the protected environment of a lighted hallway, may not elicit emotional and physiological responses to the perceived activity of crossing a "wide avenue" to the same degree. Applying the WSQ as a predictive variable in prospective health outcomes studies alongside true GS may unmask these potential benefits of the WSQ which we could not demonstrate.

For detecting slowness defined as <1.0 m/s, we recommend using a WSQ score cut-point of <12.7 (sensitivity (Sn) 87%; specificity (Sp) 76%). For <1.2 m/s, we recommend using a cut-point of <13 (Sn 82%; Sp 80%) (Figure 1). These cut-points offer good sensitivities without significantly sacrificing specificity, allowing the WSQ to be positioned as a screening tool.

Though the WSQ was designed to be applicable to adults of any age, we excluded the younger cohort because of lower relevance of the frailty syndrome and presumed lower prevalence of slow gait. We also excluded patients with limited mental function as a precaution against decreased reliability of gait speed reporting. As such, we have not proved reliability of the WSQ in these excluded cohorts, representing a significant limitation since younger age and altered mental status are common in the trauma setting. However, the utility of the WSQ arguably still resides in the geriatric realm, where mechanically simple injuries such as hip fractures can cause significant morbidity and mortality, with outcomes hinging on baseline frailty.³² Additionally, it may be possible to administer the WSQ on a surrogate basis for patients who have limited mental function, but this needs to be further evaluated.

As this study was performed in ambulating seniors in an urban setting, the WSQ is most valid when applied to urban-dwelling seniors. Using cross-validation instead of external cohort-validation for the GS-estimation model (Equation 1) is also a limitation. The validity of the WSQ in external cohorts needs to be established in future studies.

Despite the above limitations, the WSQ is a simple and the only available tool for assessing GS in m/s in settings where walking is not possible. Its potential utility in clinical and academic applications is promising, pending studies that further establish its validity and predictive value.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Receiver Operating Characteristic (ROC) curves demonstrating sensitivity and specificity for the 19-point Walking Speed Questionnaire (WSQ) in detecting slowness in gait. (A) ROC curve demonstrating the WSQ's ability to detect slowness below 1.0 m/s. Area under the curve is 0.845, 95% CI [0.76, 0.93]. (B) ROC curve demonstrating the WSQ's ability to detect slowness below 1.2 m/s. Area under the curve is 0.897, 95% CI [0.84, 0.96]. Representative sensitivity (*Sn*), specificity (*Sp*), positive and negative likelihood ratios (*LR*), and incidence counts of slowness (*n*) for the optimal score cut-points and bracketing whole-number cut-points are listed in the tables as shown.

*This value represent Youden's index, which maximizes the sum of sensitivity (*Sn*) and specificity (*Sp*).

Table 1

Descriptive Statistics

Size of study cohort, <i>n</i>	101
Sex	
Male	14
Female	87
Age, mean $\pm$ SD	73.2 $\pm$ 8.1 (Range 60–95)
Distribution among involved clinics, <i>n</i>	
Geriatric clinic	21
Metabolic bone clinic	69
Orthopedic clinic	9
PM&R clinic	2
Years of education, mean	17.3 (Range 7–24)
Mini Mental-State Exam 2 – Brief Version score, mean, out of 16	14.7 (Range 13–16)
* BMI, mean, $\pm$ SD	24.1 $\pm$ 4.9
Weight, mean, in kg $\pm$ SD	63.0 $\pm$ 13.3
Height, mean, in cm $\pm$ SD	161.5 $\pm$ 9.8
[‡] Gait speed, mean $\pm$ SD, in m/s	1.18 $\pm$ 0.33
Male	1.10 $\pm$ 0.30 (Range 0.58–1.78)
Female	1.19 $\pm$ 0.33 (Range 0.42–2.25)

* BMI, weight, and height are reported for 98 of 101 patients due to 3 cases having missing information.

[‡] Difference in gait speed between males and females is statistically insignificant at $p < 0.01$ (two-tailed).

Table 2

Score Distribution of Walking Speed Questionnaire for 101 Subjects

WSQ Item	Question Scores			
	Mean	Median	25% Quartile	75% Quartile
Q1. Speed in miles/hour	2.94	3.0	2.5	3.1
Q2. VAS – difficulty crossing avenue	4.11	4.75	3.4	5
Q3. Discrete – difficulty crossing avenue	3.10	3	3	4
Q4. Discrete – relative walking speed	2.32	2	2	3
WSQ Total Score	12.5	13	11	15

Table 3

Correlation and Regression Statistics for the Walking Speed Questionnaire Against True Gait Speed

Pearson Correlation Coefficient (r)	* Spearman's Rank-Order Correlation Coefficient (ρ)	Std. Error of Estimate	ANOVA MSE	MSECV	ANOVA Significance
0.696	0.717	0.225	0.051	0.051	$P < 0.001$

Note: One outlier case was removed (>3 SD). Total sample size for regression analyses was 100. OLS = Ordinary Least Squares regression; ANOVA MSE = Analysis of Variation Mean Square Error. MSECV = Mean Square Error of Cross-Validation, obtained using 10-fold cross-validation.

* Spearman's Rank-Order Correlation was performed in addition to Pearson's Correlation due to the possibility for a monotonic, but non-linear, relationship between WSQ scores and true gait speed.

Table 4

Item-to-Item Spearman's Rank Correlation (ρ) Matrix

WSQ Item	Q1	Q2	Q3	Q4	Q5	Q6	True Gait Speed (m/s)
Q1. Speed in miles/hour	1	0.405	0.401	0.534	0.495	0.569	0.530
Q2. VAS – difficulty crossing avenue	0.405	1	0.634	0.496	0.540	0.508	0.584
Q3. Discrete – difficulty crossing avenue	0.401	0.634	1	0.616	0.690	0.640	0.588
Q4. Discrete – relative walking speed	0.534	0.496	0.616	1	0.663	0.659	0.567
Q5. Walking Impairment Questionnaire – Speed section (WIQ)	0.495	0.540	0.690	0.663	1	0.767	0.591
Q6. Estimation of Ambulation Capacity by History Questionnaire (EACH-Q)	0.569	0.508	0.640	0.659	0.767	1	0.632

Note: One outlier case was removed (>3 SD). Total sample size for regression analyses was 100. All correlations are significant at the $p < 0.01$ level (2-tailed).