

Assessing the Accuracy of the Figure-of-Eight Walk Test in Distinguishing Between Household and Community Ambulation in Post-Stroke Individuals

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ABSTRACT

Introduction: Traditional post-stroke walking assessments often prioritize linear trajectories, failing to capture the complexity of everyday ambulation. Navigating the intricacies of everyday life requires adaptability that extends beyond the confines of linear paths. It involves addressing dynamic challenges, such as turns, varied terrains, and unexpected obstacles, which are often not adequately captured by traditional post-stroke walking assessments. The Figure-of-Eight Walk Test (F8WT) compensates for this limitation by assessing walking ability in varied scenarios. However, investigations into its accuracy for differentiating walking capabilities post-stroke are notably lacking. This study aimed to investigate the precision of the F8WT in distinguishing between household and community walkers among individuals post-stroke.

Methods: Sixty-two stroke participants, capable of walking independently or with minimal assistance (one assistant at most), were categorized into household and community walkers based on gait speed measurements. The F8WT was then administered, with its discriminative accuracy assessed using the area under the receiver operating characteristic (ROC) curve. Additionally, an optimal cutoff value distinguishing the two categories was calculated.

Results: The F8WT demonstrated robust discriminative potential, achieving the area under the curve (AUC) of 0.96 (95% CI = 0.91–1.00) on the ROC curve analysis. It registered a sensitivity of 97.60% and a specificity of 84.20%. A critical cutoff point was established at >11.20 seconds for effective categorization.

Conclusions: The F8WT is a potent assessment tool, successfully differentiating between household and community walking abilities among stroke survivors. This precise demarcation underscores its applicability in individualized post-stroke rehabilitative planning.

Keywords: Figure-of-Eight Walk Test, post-stroke assessment, Walking ability, Gait categorization, Rehabilitation

Introduction

Impaired walking function post-stroke significantly hinders individuals' independence both within their homes and the broader community [1, 2]. Coupled with this impairment is a heightened risk of falls, making the recovery of autonomous ambulation a critical rehabilitation target [3]. While approximately 60-80% of stroke survivors regain independent walking abilities within six months, many continue to face limitations in autonomous ambulation and community mobility [4, 5]. A substantial percentage, ranging from 20.7% to 82.3%, find themselves restricted to walking

independently and ambulating in a community setting [4, 5]. Hence, comprehensive assessments of walking capabilities, encompassing both home-based and community environments, are essential for these individuals.

Community ambulation refers to the ability and confidence required to navigate various environments, from indoor and outdoor public spaces to more challenging terrains [6]. This form of mobility is not merely a physical action but a key determinant of participation in meaningful activities, self-perceived health status, mental well-being, social engagement, and

overall quality of life [7-9]. Factors influencing community ambulation include gait speed, balance, and endurance, with gait speed often serving as a primary indicator [10].

Traditional assessment tools focus predominantly on linear walking activities, neglecting the more nuanced aspects of daily mobility such as turning, maneuvering through confined spaces, and safely navigating various obstacles and terrains [11, 12]. Real-world ambulation, particularly in home and community settings, requires not only straightforward walking but also the ability to navigate turns and curved paths [13]. Navigating these complex pathways requires specific gait characteristics and body adjustments [14], with any asymmetry in posture or movement particularly impacting stroke survivors' ability to execute precise turns or coordinate movements effectively, thereby increasing their fall risk [15, 16].

The Figure-of-Eight Walk Test (F8WT) has been designed to address these complexities by assessing walking function over straight and curved paths, requiring directional changes [17, 18]. The F8WT entails walking a figure-eight pattern between two cones spaced five feet apart [17, 18]. It precisely measures dynamic aspects of walking, including agility, balance, and adaptability [17-19]. Unique to the F8WT is its emulation of everyday walking challenges, providing a more comprehensive picture of an individual's functional walking capacity than straight-path assessments [19]. Although widely used in various populations, including older adults, individuals with Parkinson's disease, and stroke survivors [17-19], the F8WT's applicability for differentiating walking abilities among stroke patients in home and community settings has not been explored. This study aimed to fill the existing research gap by examining the accuracy of the Figure-of-Eight Walk Test (F8WT) in classifying the walking capacities of post-stroke individuals, specifically focusing on distinguishing between household and community walkers. The methodology involved analyzing the area under the curve (AUC) of the Receiver Operating Characteristic (ROC) curve. This analysis was complemented by assessing walking ability using the 10-Meter Walk Test (10MWT), a reference standard in this field. It was hypothesized that the F8WT would prove to be a reliable and precise tool in differentiating walking capacities, reflecting the true functional mobility levels in individuals post-stroke.

Methodology

Study Design

A cross-sectional study was conducted to evaluate the efficacy of the Figure-of-Eight Walk Test (F8WT) in accurately assessing the walking abilities of stroke. This research initiative was sanctioned by the Institutional Research Ethics Review Committee for Research Involving Human Subjects, conforming to the

standards outlined in COA No. 227/65. The study was centered on validating the F8WT's precision in differentiating functional mobility levels among post-stroke individuals, contributing critical insights for enhancing rehabilitation methodologies.

Participants

Individuals who had experienced a stroke were recruited for the study through a combination of advertisements and community outreach initiatives in Kanchanaburi, Thailand. The recruitment period spanned two months, from February to March 2023. The required sample size was established based on statistical calculations using MedCalc software (version 20.110), setting the parameters for a type I error at 0.05 and a type II error at 0.20 [20]. These thresholds were chosen to maintain a balance between statistical rigor and practical feasibility. The anticipated area under the receiver operating characteristic (ROC) curve (AUC) was projected at 0.7, with a null hypothesis value of 0.5. These considerations necessitated a sample size of 62 participants for the study.

Out of 66 individuals screened, 62 met the study's inclusion criteria and were subsequently enrolled. Informed written consent was obtained from each participant, ensuring they understood the study's scope, procedures, and their rights within the research context.

The study established several benchmarks for inclusion criteria for participation selection: (i) diagnosis of the individual's first stroke, either ischemic or hemorrhagic, by a clinician, with accompanying hemiparesis; (ii) participants aged between 18 and 80 years; (iii) the capability to walk independently or with minimal assistance (one assistant at most); and (iv) adequate cognitive function to understand and respond to simple commands.

Those Individuals were excluded from participation if they: 1) Presented with other neurological impairments that could interfere with stroke-related outcomes; 2) Had severe orthopedic conditions impacting their ability to walk, unrelated to their stroke history; 3) Were dealing with visual or vestibular disorders that could affect balance or navigation; 4) the Thai Mental State Examination (TMSE) < 23 scores; 5) Were managing serious concurrent medical issues like unstable angina or uncontrolled hypertension, which could pose health risks during testing procedures.

Procedures

Upon enrollment in the study, individuals underwent an initial interview and screening process. During this phase, baseline demographic and clinical data were meticulously recorded. The collected variables included age, sex, height, weight, type of stroke, duration since the stroke occurred, the affected

side of the body, the use of any walking aids, and scores on the Modified Rankin Scale (mRS), which evaluates the degree of disability or dependence in daily activities.

This study was constructed as a single-blind experiment to ensure an unbiased outcome. The first stage of practical assessment involved an assessor, uninformed about the participants' subsequent evaluations, administering the 10-Meter Walk Test (10MWT). Performance on this test was employed to categorize participants into two distinct groups: community walkers and household walkers. This categorization was based on their demonstrated walking ability over a short distance. After the 10MWT, participants' walking skills were further assessed using the Figure-of-Eight Walk Test (F8WT). A different assessor, blinded to the groups established by the 10MWT, conducted these tests. This method ensured that preconceived notions did not influence objective assessment. The F8WT requires the participant to walk in a straight line and then along a figure-of-eight trajectory, testing not only the straight-line walking ability but also the capacity to navigate turns and directional changes [17, 18].

Both the 10MWT and F8WT were conducted across three trials to account for variability in performance and ensure consistency in the results. After each trial, a rest period of one minute was instituted, and following each full test, a longer break of five minutes was observed. Additional resting time was provided as required, based on each participant's fatigue levels and personal needs, to prevent any test-induced strain. To optimize performance and ensure safety, participants were instructed to wear attire and footwear that provided comfort and did not restrict movement.

Measurements

(i) 10-Meter Walk Test

The 10MWT, a standardized assessment of gait speed, required participants to walk 14 meters at a comfortable pace upon a verbal cue. The total distance included 2 meters each for acceleration and deceleration, ensuring that the actual timed 10-meter distance was free from these variables' influence [21]. Each participant performed three trials, with the average time recorded. Gait speed was calculated by dividing the distance by the time taken to walk the middle 10 meters. The results of the 10MWT led to the classification of participants into two groups: those with a walking speed of less than 0.8 m/s were categorized as home walkers, and those achieving speeds above 0.8 m/s were identified as community walkers [22].

(ii) Figure-of-Eight Walk Test

The F8WT evaluated the ability to navigate straight and curved paths. Participants initiated the test from a standing position between two cones set 5 feet apart and were instructed to walk around the cones in a

figure-eight pattern until they returned to the start [18]. The test comprised three trials with rest periods in between. The primary outcome measure was the time taken to complete the course, measured from the first step until the participant returned to the starting position [17].

Statistical Analysis

Statistical analyses were conducted using GraphPad Prism version 9.5.1 (GraphPad Software, La Jolla, CA, USA). The D'Agostino–Pearson test verified demographic data normality. To describe participant characteristics, descriptive statistics were employed. The participant characteristics were presented as means compared between groups using the independent t-test for continuous data and the Chi-squared test for non-continuous data. For all analyses, a p-value of less than 0.05 was considered statistically significant.

The accuracy of the tests was evaluated using the Receiver Operating Characteristic (ROC) curve, illustrating the trade-off between sensitivity (true positive rate) and specificity (false positive rate). The area under the ROC curve (AUC) values were employed for categorizing the accuracy of the tests into the following: high accuracy (AUC >0.9), moderate accuracy (0.7–0.9), low accuracy (0.5–0.69), or non-informative (AUC <0.5) [23].

Additionally, Youden's index was utilized to determine the optimal cutoff score for each test, calculated as the maximum sensitivity plus specificity minus one [24]. This study also scrutinized the sensitivity, specificity, positive likelihood ratios (LR+), and negative likelihood ratios (LR-) at the determined cutoff points. Sensitivity reflected the ability of the test to correctly identify true positives (household walkers at risk), while specificity represented the accurate detection of true negatives (community walkers not at risk) [25].

Further, LR+ and LR- were calculated to assess the probability of positive and negative test results in household walkers relative to community walkers. LR+ was derived by dividing sensitivity by the complement of specificity (1-specificity), while LR- involved dividing the complement of sensitivity (1-sensitivity) by specificity. Test results were considered more indicative of household walkers when LR+ was greater than 1.0 and LR- was less than 1.0 [26]. The effectiveness of the tests in confirming or ruling out a diagnosis was evaluated based on LR+ and LR-. Specifically, ratios greater than 10 for LR+ or less than 0.1 for LR- were considered highly effective. The impact of the LRs on diagnostic probability was interpreted as follows: Large and often conclusive shift in diagnosis probability: LR+ >10 or LR- <0.1; Moderate shift: LR+ = 5–10 or LR- = 0.1–0.2; Small but potentially important shift: LR+ = 2–5 or LR- = 0.2–0.5; Minor change in diagnosis probability: LR+ = 1–2 or LR- = 0.5–1; No change in

probability: LR+ and LR- values not meeting the above criteria [27, 28].

Results

The study evaluated 62 participants post-stroke, categorizing them into two distinct groups based on their walking abilities: household walkers (n=43, ranging from 23 to 80 years old) and community walkers (n=19, aged between 33 and 75 years) (Table 1). A comprehensive comparison of demographic and clinical characteristics between the groups is detailed in Table 1. While most attributes were consistent across both categories, notable differences were observed in the mRS scores and the prevalence of walking aid usage (Figure 1).

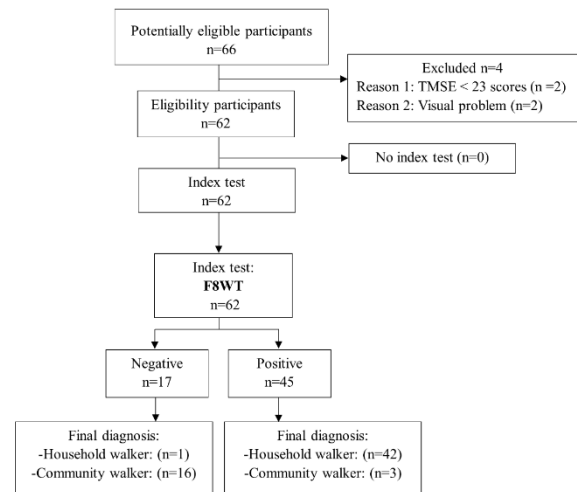


Figure 1 The flow of participants through the study

Table 1 Comparison of demographics characteristics and clinical characteristics among household and community walkers

Characteristics	Household walker (n=43)	Community walker (n=19)	p-value
Age (years) [mean (SD)]	62.42 (10.484)	59.74 (11.66)	0.373
Sex [n (%)]			0.469 ^b
Male	29 (67.4%)	11 (57.9%)	
female	14 (32.6%)	8 (42.1%)	
Height (cm) [mean (SD)]	162.16 (6.229)	161.58 (8.846)	0.767
Weight (kg) [mean (SD)]	66.28 (13.267)	64.24 (9.010)	0.544
Body mass index (kg/m ²) [mean (SD)]	25.19 (4.781)	24.73 (3.956)	0.715
Etiology [n (%)]			0.356 ^b
Infraction	36 (83.7%)	14 (73.7%)	
Hemorrhage	7 (16.3%)	5 (26.3%)	
Hemiplegic side [n (%)]			0.351 ^b
Left	24 (55.8%)	19 (100%)	
Right	19 (44.2%)	0 (0%)	
Stroke duration (months) [mean (SD)]	30.19 (38.668)	25.63 (32.833)	0.657
Modified Rankin Scale [n (%)]			< 0.001 ^{b*}
Grade 1	5 (11.6%)	18 (94.7%)	
Grade 2	24 (55.81%)	1 (5.3%)	
Grade 3	7 (16.3%)	0 (0%)	
Grade 4	7 (16.3%)	0 (0%)	
Grade 5	0 (0%)	0 (0%)	
Use of a walking aid [n (%)]			< 0.001 ^{b*}
No	15 (34.9%)	18 (94.7%)	
One-point cane	4 (9.3%)	1 (5.3%)	
Tripod cane	22 (51.2%)	0 (0%)	
Quad cane	2 (4.7 %)	0 (0%)	
Use of an orthosis [n (%)]			0.503 ^b
No	42 (97.7)	19 (100%)	
Yes	1 (2.3%)	0 (0%)	

^a T-test; ^b Chi-square test. *Statistical significance at $\alpha = 0.05$.

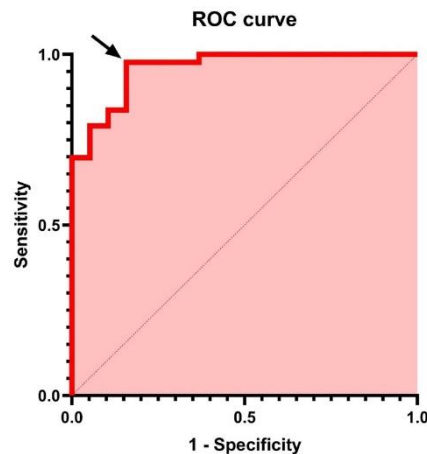
A crucial aspect of the evaluation involved the F8WT, the results of which are quantified in Table 2. Utilizing the Mann-Whitney U test for comparison, data revealed a significant disparity in the time taken to complete the F8WT between household and community walkers. Specifically, household walkers exhibited a prolonged completion time, indicative of diminished walking capabilities.

Table 2 The score of F8WT in household and community walkers

Test	Household walker (n=43) Median (IQR)	Community walker (n=19) Median (IQR)	p-value
F8W time (s)	22.30 (15.28 - 45.78)	9.15 (7.43 - 10.63)	< 0.001*

*Mann-Whitney test. IQR: interquartile range; F8W: the figure of eight walk test. *Statistical significance at $\alpha=0.05$.*

Subsequent analysis emphasized the diagnostic power of the F8WT in distinguishing between household and community walking statuses. The ROC curve analysis demonstrated that the F8WT was a highly accurate classifier with an AUC of 0.96 (95% CI= 0.91–1.00) (Figure 2). This impressive accuracy was further evidenced by a sensitivity of 97.60% and specificity of 84.20%, established at an optimal cutoff point of >11.20 seconds for the test duration. These metrics signify an excellent ability of the F8WT to differentiate participants' walking abilities accurately.


Figure 2 The receiver operating curve for comparing the accuracy of the Figure-of-Eight Walk Test (F8WT) to predict the walking classification of individuals with stroke between household and community walkers.

In further support of these findings, the likelihood ratios associated with the F8WT results underscored the test's effectiveness. Both LR+ and LR- confirmed the substantial evidential weight of the F8WT in correctly identifying participants as either household or community walkers, as detailed in Table 3.

Table 3 AUC, cut-off score, sensitivity, specificity, LR+, and LR- of F8WT for discriminating household and community walker

Indicator	F8W time (s)
AUC	0.96
SE	0.02
95%CI	0.91 - 1.00
p-value	<0.001*
Youden's index	0.82
Cut-off score	>11.2
Sensitivity	97.67
Specificity	84.21
LR+	6.19
LR-	0.03

*F8W: the figure of eight walk test; AUC: area under the ROC curve; SE: standard error; LR+: positive likelihood ratio; LR-: negative likelihood ratio. *Statistical significance (null hypothesis: AUC = 0.5) at $\alpha = 0.05$.*

The demonstrated high diagnostic accuracy of the F8WT in our study suggests its utility as an effective screening tool for walking impairments in post-stroke individuals. Early and accurate identification of walking difficulties using the F8WT can guide clinicians in making informed decisions about initiating appropriate rehabilitative interventions, potentially improving recovery trajectories.

Discussion

This study illuminated the critical role of the F8WT in differentiating walking abilities among post-stroke individuals, categorizing them into household or community walkers. The results underscore the test's substantial accuracy, with a notable AUC of 0.96, an impressive sensitivity of 97.60%, and a specificity of 84.20%. These metrics not only affirm the test's precision but also highlight its potential as a reliable tool in clinical and rehabilitative settings.

Contextualizing F8WT within Post-Stroke Recovery

Walking, a complex motor task, demands the integration of physical strength, balance, coordination, and cognitive function. For stroke survivors, these components often become disjointed, impeding efficient walking [11]. Particularly, the ability to navigate curved paths, essential for household and community ambulation, becomes compromised, leading to increased fall risk and limited functional independence [17, 18]. The F8WT's high sensitivity and specificity in this study accentuate its effectiveness in capturing these nuanced deficits, empowering clinicians with a precise tool for evaluating walking abilities in post-stroke individuals. The test, by incorporating straight and curved walking, challenges the individual's dynamic balance, weight shifting, and cognitive-motor interface, offering deeper insights into their walking proficiency and underlying neurological recovery [17].

Interpreting the Cutoff Point

The introduction of a cutoff point of >11.20 seconds in the F8WT is a pivotal finding of this study. This threshold is practical, helping to distinguish between household and community walkers. In a clinical context, this cutoff point simplifies decision-making for practitioners. It acts as an indicator necessitating more intensive, targeted rehabilitation strategies for individuals struggling with ambulation post-stroke, particularly those surpassing this time limit.

It is important to recognize that this cutoff is not just a number but a significant demarcation guiding patient categorization. It aids in identifying stroke survivors who are in a transitional phase of recovery, indicating a potential readiness to navigate more complex environments beyond the household. This distinction is crucial, as it helps in tailoring therapy, setting realistic goals, and providing motivation for patients undergoing rehabilitation.

Moreover, this cutoff can facilitate consistent monitoring of progress, enabling therapists to objectively measure improvements in walking ability over time and adjust interventions accordingly. It standardizes a component of stroke recovery, ensuring that individuals receive appropriate, evidence-based care aligned with their recovery trajectory.

F8WT and Cognitive Function

Walking, especially on curved paths, is not purely a motor task but involves significant cognitive input, requiring attention, planning, and visuospatial awareness [29]. Post-stroke deficits often blur this cognitive-motor interface, making tasks like the F8WT more challenging and thereby more revealing of a person's functional and cognitive recovery scope. The relationship between F8WT scores and cognitive function underscores the need for comprehensive post-stroke care, integrating cognitive rehabilitation and physical therapy.

Biomechanics of Curved Walking

Curved walking post-stroke is biomechanically demanding, requiring asymmetrical adjustments, inner leg loading, and continual rebalancing [30]. These requirements, disrupted by stroke-induced motor and balance impairments, prolong the F8WT completion time, reflecting the individual's struggle to maintain stability [31]. Rehabilitation programs, thus, need to address these specific biomechanical demands, possibly through targeted interventions like weight-shift training, strength building, and neuromuscular re-education. Numerous investigations have explored the efficacy of curved-path gait training. Kim et al. (2012) discovered that eight-way curved-path gait training significantly improves balance and ambulation in stroke patients [32]. Richard (2010) further noted that altering the center of gravity and pelvis rotation during training enhances adaptability in motor control on the affected side, improving curved-path gait performance and the ability to provide sensory information and support during walking [33]. In addition, Jin et al. (2023) found that curved-path gait training significantly improves gait ability, resulting in a more balanced walking pattern compared to general gait training. This highlights the potential of curved-path gait training as a meaningful intervention for improving the asymmetrical gait ability of stroke patients with hemiplegia [34].

Strengths and Limitations

While the study heralds new understanding, certain limitations temper its implications. Its cross-sectional design precludes observing longitudinal recovery, necessary for understanding how walking abilities evolve post-stroke. Additionally, focusing on command-compliant participants excludes insights from those with cognitive impairments, a significant post-stroke cohort.

Future Directions

Given the F8WT's demonstrated efficacy, future studies should explore its predictive validity over longer-term recovery and its applicability across diverse stroke populations, including varying stroke severities, and cognitive statuses. Additionally, integrating technological advancements like motion analysis systems could offer objective insight into the biomechanical aspects of curved walking post-stroke.

Conclusion

In conclusion, the F8WT emerges as a potent tool for discerning walking capabilities in individuals recovering from a stroke, with profound implications for targeted rehabilitation strategies. This aspect of the study is particularly important because it provides new information that can inform clinical practice and rehabilitation programs for individuals with stroke. Its robust association with both the physical and cognitive facets of post-stroke recovery necessitates its consideration in future research and clinical practice, ultimately contributing to enhanced quality of care and life for stroke survivors.

Declarations of interest

The authors report no conflicts of interest.

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