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Original Article

Test-retest reliability and minimal detectable change of four functional tests in community-dwelling older adults with high risk of falls

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ABSTRACT

Objectives: This study aimed to quantify test-retest reliability and minimal detectable change (MDC) of the four commonly used functional tests in older adults with a high risk of falling.

Patients and methods: The cross-sectional study was conducted with 30 community-dwelling older adults (26 females, 4 males; mean age: 73.7±6.0 years; range, 65 to 88 years) with a high fall risk identified by the Thai falls risk assessment test between November 2018 and May 2019. Data from the 10-m walk test at a comfortable gait speed (CGS) and fast gait speed (FGS), timed up and go (TUG) test, five times sit to stand test (FTSST), and 6-min walk test (6MWT) were collected twice for each participant. The interval between test sessions was one week. Test-retest reliability was analyzed by the intraclass correlation coefficient (ICC). Standard error of measurement (SEM) and MDC at the 95% confidence interval (MDC_{95}) were also calculated.

Results: The four functional tests had ICC in the range of 0.92 to 0.97. The SEM values of the CGS, FGS, TUG, FTSST, and 6MWT were 0.06 m/sec, 0.04 m/sec, 1.10 sec, 1.30 sec, and 20.60 m, respectively. The MDC_{95} values of the CGS, FGS, TUG, FTSST, and 6MWT were 0.16 m/sec, 0.12 m/sec, 3.00 sec, 3.50 sec, and 57.20 m, respectively.

Conclusion: All functional tests demonstrated excellent test-retest reliability. The SEM and MDC_{95} of all functional tests were established. These findings can help clinicians interpret the effectiveness of interventions and determine changes in functional ability over time in older adults at high risk of falls.

Keywords: Falls, functional performance, measurement error, older adults, reproducibility of results.

The aging process leads to the impairment of functional abilities, which manifests in poor gait performance and balance ability and reduction in muscle strength.[1-3] These parameters are associated with independence in daily activities and closely linked to fall risk.[3,4] Falls are the leading cause of injury among people aged 65 years and older, where the frequency and risk of falls increase with age.[5] Each year falls occur in approximately 30 to 40% of community-dwelling older adults, and half of such falls result in physical injuries.[6] Falls markedly erode self-confidence, restrict activities of daily living,[6-8] and further lead to functional impairment, hospitalization, and increased healthcare costs.[9-11]

Previous studies assessing functional abilities commonly employed the 10-m walk test (10MWT), timed up and go (TUG) test, five times sit-to-stand test (FTSST), and 6-min walk test (6MWT) to reflect gait

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speed, balance ability, lower extremity muscle strength, and functional endurance, respectively.[3,10,12,13] These tests provide objective data and are practical for both clinical and community settings because of the brief duration of each test and since only simple instruments such as a stopwatch, a standard armless chair, and a tape measure are needed.[3,10,14]

Test-retest reliability and interpretability of each test should be established to accurately determine whether changes in functional impairment tests are the result of measurement error or real changes. Test-retest reliability demonstrates the consistency of the value measured over repeated tests over time under stable conditions.[15,16] The interpretability of the test is characterized by minimal detectable change (MDC), which indicates the magnitude of change needed to confirm actual changes.[16] Previous studies have reported test-retest reliability and MDC values of the 10MWT, TUG, FTSST, and 6MWT in older adults under various conditions;[17-19] however, no study to date focused specifically on older adults with high risk of falls. Since the reliability and MDC values depend on the type of population under investigation, the aim of this study was to quantify test-retest reliability and MDC of four functional tests (10MWT, TUG, FTSST, and 6MWT) in community-dwelling older adults with high risk of falls.

PATIENTS AND METHODS

This cross-sectional study conducted with community-dwelling older adults living in rural or semirural areas in the northeastern region of Thailand between November 2018 and May 2019. The inclusion criteria were as follows: *(i)* age ≥65 years, *(ii)* a body mass index between 18.5 and 29.9 kg/m^2, *(iii)* a Thai falls risk assessment test (Thai-FRAT) score of at least 4 points,[20] *(iv)* being able to understand simple commands to complete the study protocol. The exclusion criteria were as follows: *(i)* lower extremity joint or muscle pain with a score ≥5 on the numerical rating scale, *(ii)* concurrent neurological diseases (e.g., stroke or Parkinson's disease), *(iii)* being unable to perform the tests without a walking device, *(iv)* dizziness, visual or auditory problems, acute illness, and symptomatic heart disease, such as angina pectoris, which may preclude the completion of the test. The number of participants was derived from previous research,[21] which suggested that the investigation of reliability of the tests should include at least 30 individuals. Consequently, 39 participants were enrolled in the study; however, nine participants missed the second session. Thus, data from 30 participants (26 females, 4 males; mean age: 73.7±6.0 years; range, 65 to 88 years) were included for final analysis (Figure 1).

The Thai-FRAT, a validated tool to screen older adults with high risk of falls in Thailand, was used to determine high fall risk. The questionnaire comprises six items related to significant fall risk factors, including female sex, impaired visual acuity (inability to read more than half the letters in six of 12 lines on a Snellen chart), impaired balance ability (inability to hold a tandem stance position for 10 sec), medication use (e.g., sedatives/hypnotics, psychotropic drugs, antihypertensive drugs, diuretics, or simultaneously taking more than four other medications), a history of two or more falls within the past six months), and living in a Thai-style house (i.e., the first floor is 1.5 m or higher from the ground and has a traditional Thai-style staircase). A score of at least 4 out of a possible 11 points for these six factors indicates high fall risk.[20]

There were four testers (physical therapists), and one tester was responsible for one test. They had at least two years of experience in the standard functional test protocol to evaluate the performance of the participants. The intra- and inter-rater reliability among them was excellent (intraclass correlation coefficient [ICC]2,3=0.91 to 0.97, p<0.001 and ICC2,3=0.86 to 0.99, p<0.001, respectively). Participants attended two test sessions; each session was separated by at least seven days. Prior to each test, the participants were asked about their physical activity, exercise, and pain scale to confirm that there was no change in these parameters from the baseline session. The sequence of the tests was randomized to minimize the effect of learning and fatigue.

The 10MWT was used to reflect ambulatory status at a comfortable gait speed (CGS) and fast gait speed (FGS).[22] Participants were instructed to walk along a 10-m walkway at a comfortable pace and then at a fast but safe pace. The tester recorded the walking time at 4 m.[23] The test was repeated three times at each speed. The average time was converted to walking speed (m/sec).

Balance ability was assessed using the TUG while rising from a sitting position, walking, turning, and sitting.[3] Participants were instructed to stand up from a standard armrest chair (approximate seat height of 43 cm), walk 3 m, turn around a cone in front of the chair, walk back, and sit down on the chair at a fast but safe speed. The tester began recording the time at the command "go" and stopped when the participant sat

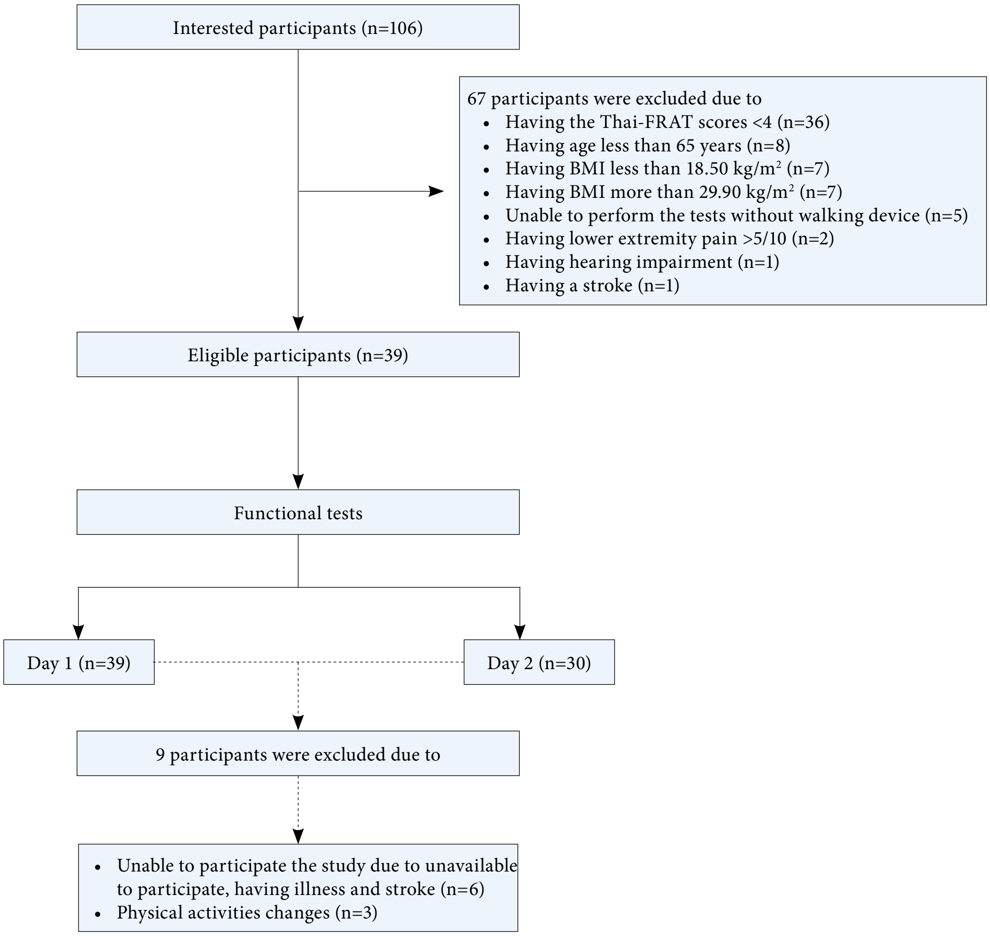

Figure 1. Participant flowchart.

down and their back touched the backrest of the chair. The test was performed three times, and the average time was recorded.

The FTSST was used to evaluate lower extremity muscle strength.[24] Participants were instructed to rise from a standard armless chair (seat height of 43 cm) with their arms at their sides, fully extending the hip and knee joints, and return to a sitting position as quickly as possible for five repetitions.[3] The tester recorded the time from the command "go" until the participant sat down and their back touched the backrest of the chair. The test was repeated three times, and the average time was recorded.

The 6MWT was applied to assess functional endurance.[25] Participants were instructed to walk as far as possible in 6 min around a 6×4 m rectangular walkway.[26,27] They were given standard encouragement during the test. The distance walked in 6 min was recorded.

Participants were allowed to rest between the trials as needed. Blood pressure and heart rate were monitored to ensure the participants' safety and that sufficient rest periods were taken. The time to complete all the functional tests, including the rest periods, varied between 30 and 45 min.

Statistical analysis

Statistical analysis was performed using the IBM SPSS Statistics for Window version 28 (IBM Corp., Armonk, NY, USA). Baseline characteristics of the participants are presented using descriptive statistics. The data of all functional tests at baseline and one-week follow-up were compared using a paired t-test. Test-retest reliability was quantified using the ICCs of a two-way random model (ICC2,3 for the 10MWT, TUG, and FTSST; ICC2,1 for the 6MWT). The standard error of measurement (SEM) was calculated using the following formula: SEM=(standard deviation [SD])$\times\sqrt{(1-r)}$, where SD is the pooled SD of two trials, and r is the test-retest reliability. The MDC at the 95% confidence interval (MDC_{95}) was calculated using the following formula: $MDC_{95}=1.96\times\sqrt{2}\times SEM$.[15] The statistical significance level was set at $p<0.05$.

RESULTS

The mean body mass index of the patients was 24.34±3.09 kg/m^2. The mean Thai-FRAT score was 6.0±2.5. More than half (56.7%) of participants had experienced a fall in the past six months (Table 1).

No statistically significant difference was found in all functional tests between baseline and one-week follow-up. The ICCs of all functional tests were in the range of 0.92 to 0.97 ($p<0.001$). The SEM values of the CGS, FGS, TUG, FTSST, and 6MWT were 0.06 m/sec, 0.04 m/sec, 1.10 sec, 1.30 sec, and 20.60 m, and the

TABLE 1
Demographic characteristics of participants (n=30)

Variable	n	%	Mean±SD	95% CI	Min-Max
Age (year)			73.7±6.0	71.42-75.91	65.00-88.00
Body mass index (kg/m^2)			24.34±3.09	23.19-25.49	8.91-29.12
Total Thai-FRAT (scores)			6.03±2.46	5.12-6.95	4.00-10.00
Sex					
Female	26	86.70			
Male	4	13.30			
Visual impairment					
Yes	18	60.00			
No	12	40.00			
Balance impairment					
Yes	28	93.30			
No	2	6.70			
Number of medication per day					
0	8	26.70			
1	4	13.30			
2	8	26.70			
≥3	10	33.30			
History of fall in the past 6 month					
0	13	43.30			
1	6	20.00			
≥2	11	36.70			
Thai stair style house					
Yes	2	6.70			
No	28	93.30			

SD: Standard deviation; CI: Confidence interval; Thai-FRAT: Thai falls risk assessment test.

TABLE 2
Test-retest reliability and minimal detectable change results (n=30)

	Day 1	Day 7	Difference					
Functional test	Mean±SD	Mean±SD	Mean±SD	p^a	$ICC_{2,k}$	95% CI^b	SEM	MDC_{95}
10MWT (m/s)								
Preferred speed	0.88±0.21	0.92±0.20	0.03±0.11	0.125	0.92	0.83 to 0.96	0.06	0.16
Fast speed	1.10±0.28	1.12±0.27	0.03±0.09	0.086	0.97	0.94 to 0.99	0.04	0.12
TUG (s)	13.51±4.88	12.91±4.77	0.61±2.08	0.118	0.95	0.90 to 0.98	1.10	2.96
FTSST (s)	14.47±3.95	13.97±4.33	0.50±2.27	0.237	0.92	0.83 to 0.96	1.30	3.51
6MWT (m)	266.80±84.53	281.38±81.20	14.59±40.01	0.055	0.94	0.87 to 0.97	20.60	57.20

SD: Standard deviation; ICC: Intraclass correlation coefficient; CI: Confidence interval; SEM: Standard error of measurement; MDC_{95}: Minimal detectable change with a 95% confidence interval; 10MWT: 10-m walk test; TUG: Timed up and go test; FTSST: Five times sit to stand test; 6MWT: 6-min walk test; a: P for significance of difference between Day 1 and Day 7 using dependent samples t-test; b: Indicates statistically significant difference (p<0.001).

MDC_{95} values were 0.16 m/sec, 0.12 m/sec, 3.00 sec, 3.50 sec, and 57.20 m, respectively (Table 2).

DISCUSSION

The aim of this study was to quantify test-retest reliability and MDC_{95} of the functional tests (10MWT, TUG, FTSST, and 6MWT) in community-dwelling older adults with high risk of falls. The test-retest reliability and SEM of 10MWT (CGS and FGS) in our study (ICC2,3=0.92 and 0.97; SEM=0.04 and 0.06 m/sec) were similar to the study of Perera et al.,[19] which showed that SEM of 10MWT in older adults with mild to moderate mobility limitations was 0.04 m/sec and 0.06 m/sec, respectively. Our results showed less error and variability of 10MWT compared to the study of Mangione et al.,[18] which reported an ICC2,2 of 0.90 and 0.93 and SEM of 0.08 and 0.09 m/sec in older African American adults. Since the SEM value represents the variability or change in functional ability when the same tests are repeated with no changes in any of the test conditions, the slightly higher SEM value may be explained by the variability in walking ability in their participants. More than half (56%) of the participants in their study walked with an assistive device, whereas none of our participants used assistive devices. Our participants had better gait ability and evidence supports that the evaluation of gait speed in older adults with better performance and health status showed less variation during test performance.[27]

The TUG task in our study (ICC2,3=0.95, SEM=1.10 sec) showed less error compared to the study of Mangione et al.[18] The discord in the findings may be due to differences in the TUG test method. Mangione et al.[18] recorded the time to complete the TUG task at the preferred gait speed along a 3.28-m walkway. The TUG test at a lower speed is associated with increased variability;[28] therefore, the likelihood of an error regarding the time to complete the task was less in our study. The faster speed provides information on an individual's functional reserve capabilities in the community.[29] In addition, previous research in older adults with Alzheimer's disease reported an MDC90 value of 4.09 sec in the TUG test,[30] which is higher than MDC_{95} in the present study (3.00 sec). The higher MDC may be explained by the limitation of older adults with Alzheimer's disease in sustaining attention to complete the tests, in addition to their limited balance ability with aging.

Goldberg et al.[17] studied the test-retest reliability of FTSST and reported lower SEM (0.90 sec) and better ICC (0.95) values compared to our study (SEM=1.30 sec, ICC2,3=0.92). Additionally, the MDC_{95} value of 2.50 sec in the FTSST in their study was lower than our study (MDC_{95}=3.50 sec). Furthermore, Bieler et al.[31] reported these values in participants with hip osteoarthritis, where they showed lower SEM (0.91 sec), ICC (0.88), and MDC90 (2.11 sec) values. This might occur due to the differences in participants' characteristics since previous studies recruited older adults aged at least 60 years and with symptomatic hip osteoarthritis without reporting a risk of fall.[17,31]

Regarding the 6MWT, the SEM found in this study (20.60 m) was similar to the study of Perera et al.,[19] which was done in older adults with mild to moderate mobility limitations (SEM=21 m). Mangione et al.[18] reported an MDC90 value of 65 m for 6MWT in their study of 52 older African American adults. The higher MDC values in their study compared to ours (57.2 m) may reflect the higher variability in their participants' ability to walk, as they included participants who used gait aids.

This study has some limitations. All the participants were older adults with a risk of fall and could walk independently without a walking device. Most participants were female. Additionally, we screened the participants' risk of fall using the Thai-FRAT. Although this questionnaire has acceptable reliability and validity and is commonly used in community-dwelling older Thai adults, its applicability in other cultures or regions may be limited. All of these may limit the generalizability of the results.

In conclusion, all functional tests (10MWT, TUG, FTSST, and 6MWT) had excellent test-retest reliability with reliable SEM and MDC values. Thus, the present study confirmed the application of these tests, which can help clinicians interpret the effectiveness of interventions and determine changes in functional ability over time in older adults at high risk of falls.

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Ethics Committee Approval: The study protocols and consent procedures were approved by the Khon Kaen University Ethics Committee for Human Research (date: 17.09.2018, no: HE602302). All participants provided written informed consent before being enrolled in the study protocol. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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