The Development of Simple Screening Tool for Predict Risk of Falls in Thai Community-Dwelling Elderly

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Objective: *To develop and examine the psychometric properties of the Three Times Sit-to-Stand Test (TTSST) to evaluate its functional capacity and to predict the risk of fall in community-dwelling elderly.*
Material and Method: *Thirty-six subjects aged older than 60 years, who experienced fall or non-fall, were tested for their functional ability using the TTSST and the Five Times Sit-to-Stand Test (FTSST).*
Results: *The data demonstrated excellent reliability (ICCs = 0.943-0.991) and could clearly distinguish the ability of falling and non-falling subjects. In addition, the TTSST showed significant correlation with the FTSST (r = 0.942, p<0.001), and was an excellent fall indicator (sensitivity 88.89%, specificity 100%, AUC = 0.92, 95% CI = 0.81-1.00).*
Conclusion: *The TTSST is a valid and reliable method for assessing fall risk factors of community-dwelling elderly. We recommend a TTSST greater than 4.54 seconds as the optimal cut-off score for reliable fall risk prediction for the elderly.*

Keywords: *Elderly, Fall, Functional tool, Sit-to-stand, Physical therapy*

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Falls are the primary cause for the loss of independent living and development of fear, which may result in severe limitations of physical activity, loss of social contact and/or death[1]. More than 30% of older adults fall each year, indicating an urgent need to uncover reliable and valid clinical assessment tools to predict falls of the elderly[2]. Recognition of older adults at risk for falls is an important task for physical therapists, as there is increasing evidence that frequency and consequences of falls can be decreased through interventions[3].

Numerous studies have been conducted on risk factors for falls, and many factors related to future falls have been identified. The best predictors appear to be a history of falls and abnormalities of gait or balance[4]. This seems to be result of decreased muscle strength and muscle power impeding older people's ability to maintain postural stability in conditions such as stair climbing or lifting objects, which may also lead to falls[5,6]. Sit-to-stand (STS) movements are essential for daily activities and failure to perform STS movements efficiently and smoothly may lead to fall. Several studies evaluated fall risk in older people by using 5 or 10 times sit-to-stand test cycles[7-11].

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However, in the community, as for many conditions and diseases, a common strategy is to employ a single quick assessment tool with high specificity that could be applied by front-line health care workers without specialized equipment to rule out those with low risk, followed by a more detailed assessment of the remainder, and an intervention plan for risk reduction by more highly trained professionals[12]. Therefore, we developed a simple functional tool, the Three Times Sit-to-Stand Test (TTSST), for evaluating the physical performance and risk of fall in community-dwelling elderly. Hence, the present study was the first to create and employ TTSST to indicate the future likelihood of falls in community-dwelling elderly, with the aim to examine the psychometric properties of TTSST to evaluate functional ability and predict falls in community-dwelling older adults.

Material and Method

Study design and subjects

The present study was a case-control study involving 36 subjects aged 60 years or older recruited from a community in Thailand. The subjects were divided into two groups based on fall history (one or more times). Individuals were included if they were able to walk at least six meters, standing up from a chair or bed independently without using hands or assistive devices, and were alert and oriented.

Exclusion criteria were based on neurological diseases that may affect balance, diabetes with peripheral neuropathy, vestibular impairments, significant pain in the lower extremities that might affect participation, active infection or diagnosis of cancer, current injury, uncorrected visual deficits, and amputation of an extremity. The present study was approved by the Clinical Research Ethics Committee of the University of Phayao, Phayao, Thailand, which required informed consent to be obtained.

Procedures

The subjects were interviewed and assessed for their baseline demographic data and fall history in the previous six months. Subjects were then tested for their functional ability using the FTSST and the TTSST with the following details.

For the FTSST, subjects were required to sit on a standard armless chair with back upright and hip flexion of 90 degrees, with their feet placed flat on the floor at 10 cm behind the knees, and with their arms on their sides. Then the subjects were instructed to stand up with the hips and knees in full extension, and sit down five times at the fastest safe speed without using the arms. The time required to complete the test was recorded. For the TTSST, subjects were required to perform the same set of motions as in the FTSST, but only three times. For both kinds of tests, the subjects performed three trials per test, with a period of rest as needed between the trials. Then the average findings of the three trials were used for data analyses. During the tests, subjects did not wear shoes, in order to prevent shoe type variation affecting the outcome. In addition, the subjects had to wear a lightweight safety belt around their waist, with a physiotherapist walking or being alongside the subjects throughout the tests in order to ensure the subjects' safety and improve the accuracy of the outcome.

The present study also investigated the inter-tester reliability of the tools in the first 20 subjects by three physiotherapists who had different clinical experience (ranging from 2 to 5 years). Prior to the participation, the assessors were trained to use the same standard methods. Then they concurrently investigated the ability of the subjects using the TTSST. Each subject performed three trials per test, with a period of sufficient rest between the trials. Then the average findings for the three trials of each assessor were used to analyze the inter-tester reliability of the tool.

Statistical analysis of the study

The data analysis was performed using SPSS for Windows (SPSS Statistics 17.0, IBM Corporation, 1 New Orchard Road Armonk, NY, USA, serial number: 506805). Descriptive statistics were applied to explain baseline demographics and findings of the study. The point Pearson's correlation coefficient (r) was applied to determine the levels of correlation between findings of TTSST and the standard test (FTSST). The independent sample t-test was used to primarily determine the discriminative ability of the tools for the faller and non-faller group. The inter-tester reliability was determined using the intraclass correlation coefficients (ICCs 3.3). Receiver-operating characteristic (ROC) curves were further utilized to explore an optimal cut-off score, sensitivity, specificity, and AUC for the tests to indicate fall risk. The ROC curve is a graphical technique that is generated by plotting sensitivity values on the y-axis and 1-specificity values on the x-axis of all possible cut-off scores for the tests, using data of all subjects[13,14]. Sensitivity is a true positive rate, or the probability of a positive result in subjects with the condition (fallers). On the contrary, specificity is a true negative rate, or the probability of a negative result in subjects without the condition (non-fallers). A test that perfectly discriminates between subjects who fall and non-fall would yield a curve that coincides with the left and top side of the plot. In addition, a perfect test would have an area under the ROC curve (AUC) of 1.0, while a completely useless test would have an AUC of 0.5. In other words, the closer the AUC is to 1, the better the overall diagnostic performance of the test, and the closer it is to 0.5, the poorer the diagnostic performance of the test[14,15]. The level of significance was set at $p<0.05$.

Results

The baseline demographics and the mean time to complete the TTSST and FTSST of subjects were shown in Table 1. The data demonstrate that most of the subjects were female. The average age showed no significant difference, and number of falls was in the range of one to four times.

Fig. 1 demonstrated that the TTSST showed a high correlation with the FTSST ($r = 0.942$; $p<0.001$). Data distribution of non-faller and faller subjects, indicating the discriminative ability of the TTSST and FTSST, were shown in Fig. 2. The data demonstrate that subjects in the faller group required significantly more time to complete the tests than those in non-faller group ($p = 0.001$ and 0.007, respectively).

Table 1. The baseline demographics and functional ability of subjects

Variables	Reliability test (n = 20)	Faller (n = 18)	Non-faller (n = 18)
Age (years), maen ± SD	68.00±5.38	66.67±5.36	67.78±6.95
Sex, n (%)			
Male	8 (40.00)	6 (33.33)	9 (50.00)
Female	10 (60.00)	12 (66.67)	9 (50.00)
BMI (Kg/m^2), mean ± SD	22.45±3.10	23.50±4.10	22.71±2.62
History of fall, n (%)			
Non-falls	18 (90.00)	0 (0)	18 (100)
1 time	2 (10.00)	10 (55.56)	0 (0)
2 or more times	0 (0)	8 (44.44)	0 (0)
Disease, n (%)			
None	3 (15.00)	7 (38.89)	7 (38.89)
HT	12 (12.00)	6 (33.33)	9 (50.00)
DM	0 (0)	2 (11.11)	0 (0)
DM and HT	5 (25.00)	3 (16.67)	2 (11.11)
TTSST* (seconds), mean ± SD	-	6.44±2.33	4.07±0.22
FTSST* (seconds), mean ± SD	-	11.17±4.01	7.57±1.03

BMI = body mass index; HT = hypertension; DM = diabetes mellitus; TTSST = three times sit-to-stand test; FTSST = five times sit-to-stand test

* p-value from independent sample t-test, $p<0.01$

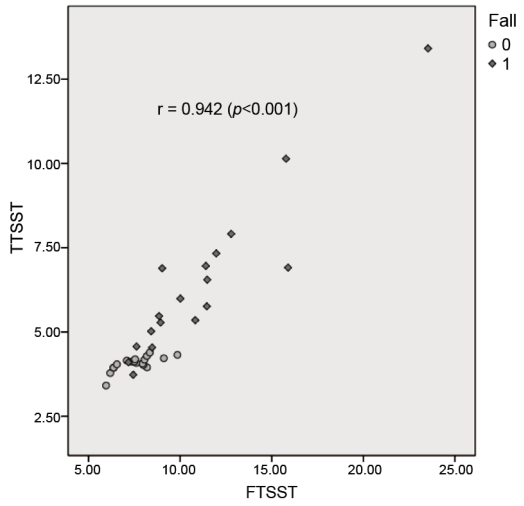

Fig. 1 Correlation between the TTSST and FTSST.

Table 2 demonstrated that the inter-tester reliability of the TTSST was excellent when analyzed using the ICCs (3.3) (0.973, 95% CI = 0.944-0.989). Fig. 3 and Table 2 demonstrated ROC curves, cut-off scores, sensitivity, specificity, and AUC. The data from ROC analysis indicated that the TTSST had predictive qualities, such as sensitivity, specificity, and AUC, better than the FTSST. The optimal cut-off scores of TTSST and FTSST were 4.54 and 8.85 seconds, respectively. The time required to complete the TTSST greater than 4.54 seconds (Table 3) had good-to-excellent capability to indicate fall in the future.

Discussion

The study explored the capability of the TTSST to determine the risk of falls in community-dwelling elderly. The data indicate that a TTSST

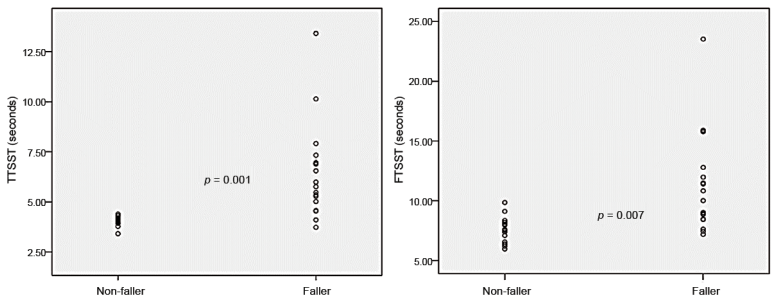

Fig. 2 Demonstrates data distribution of subjects with non-faller and faller.

completion time of more than 4.54 seconds can be used as a quantitative criterion for functional gain and intervention for fall prevention, in order for community-dwelling elderly to decrease risk of falls. However, for field application of the tests, area and equipment availability needs to be considered, along with the limited physical abilities of the elderly.

Lower limb muscle strength can be assessed directly using standard equipment, such as force transducers and isokinetic dynamometer. However, these devices are too cost- and time-intensive to be considered realistically in clinical or community settings[16]. Functional tests, such as the STS test, do not require expensive equipment and are usually quick to administer. The ability to rise from a chair or bed independently is a fundamental movement in daily activities[17]. The task is mechanically demanding and requires adequate torques to be developed at each joint during spatial and temporal motion of the body segments[18]. Thus, STS results are highly correlated to not only muscle strength, but also sensation, balance, speed, and the psychological status of the individual[19]. Hughes et al[20] reported that older adults used a greater proportion of quadriceps muscle strength capability than young adults (78% and 34% for older and young adults, respectively) to perform the same STS task. The STS performed with double leg support is an appropriate and safe protocol for elderly and people with balance-related problems[21].

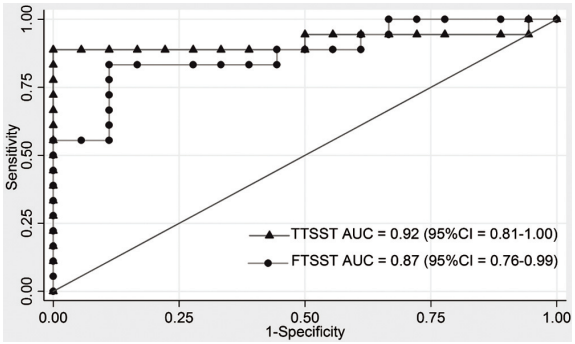

Fig. 3 ROC curves, AUC, and 95% CI of TTSST and FTSST.

Table 2. Demonstrates the inter-tester reliability of the TTSST

Testers	ICCs	95% CI	
		Lower	Upper
Tester A and B	0.946	0.864	0.979
Tester A and C	0.991	0.976	0.996
Tester B and C	0.943	0.856	0.977
Average of 3 testers	0.973	0.944	0.989

ICCs = intraclass correlation coefficients

Previously, STS has been used widely in elderly and patients with other conditions. Buatois et al[7] found that time required to complete the FTSST longer than 15 seconds indicates a high risk of recurrent fall in elderly (sensitivity 55%, specificity 65%). Mong et al[22] also reported that a cut-off score of 12 seconds could discriminate healthy elderly and subjects with stroke (sensitivity 83% and specificity 75%). The present study performed three-times STS by adapting methodology and instruction from the traditional test and the standard test (FTSST) for evaluating lower extremity muscle strength (LEMS). The results showed that the TTSST significantly correlated with FTSST (r = 0.942, p<0.001). The explored data may indicate that the TTSST can be a functional test for LEMS in the elderly, on par with the FTSST. In a previous study, Tapanya et al[16] suggested that the three-repetitions sit-to-stand has good correlation with LEMS, as measured by a Contrex MJ isokinetic dynamometer (r = 0.753, p<0.01).

From the authors' knowledge, there has been no existing evidence for the use of TTSST in community-dwelling elderly. Therefore, we examined the inter-tester reliability of the test. Our findings indicated that this method had an excellent inter-tester reliability (ICCs = 0.973, 95% CI = 0.944-0.989), with the ICCs between tester A and C being the highest. Tester A was the main tester (physical therapy student) in the present study, and tester C was the lecturer and expert in functional tools and older adults. Thus, the findings of the present study supported the use of this tool by people with various levels of clinical experience, including physical therapists, clinical practitioners, and

Table 3. The predictive parameters and cut-off scores of the functional tests

Functional tests	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Correctly classified (%)	Cut-off score (seconds)
TTSST	88.89	100	100	90.00	94.44	4.54
FTSST	72.22	88.89	86.67	76.19	80.56	8.85

PPV = positive predictive values; NPV = negative predictive values

physical therapy students. However, the assessors should be trained prior to participation to use the same standardized methods. The reliability of FTSST was evaluated in elderly. Tiedemann et al[23] examined test-retest reliability in older community-dwelling people. The study found that the FTSST had high test-retest reliability (ICC = 0.890). Consistently, the study of Bohannon[24] found excellent test-retest reliability (ICC = 0.957) in community-dwelling elderly.

For the predictive validity of the TTSST, the findings suggested that a completion time of 4.54 seconds or higher is an excellent indicator of future fall likelihood (sensitivity 88.89%, specificity 100%, AUC = 0.92, 95% CI = 0.81-1.00). The results of the study may have a significant impact on primary care clinical practice in the field of fall risk evaluation. Physical therapists and other health care professionals could easily classify elderly community-dwelling subjects in the fall-risk group, facilitating a more effective fall prevention program management. Results of FTSST suggested that a completion time of 8.85 seconds is an excellent indicator of future fall likelihood in community-dwelling elderly. However, the findings showed moderate to high ability to predict falls (sensitivity 72.22%, specificity 88.89, AUC = 0.87, 95% CI = 0.75-0.99). Essentially, the study showed that the TTSST is a more efficient fall risk predictor than the FTSST. In a community setting, we recommend a simple test such as the TTSST to screen the risk of fall in community-dwelling elderly. The test's accurate time-based assessments ensure that the results are sensitive and clearly quantify functional alteration in community-dwelling older people.

Conclusion

The TTSST had successfully undergone validation and was proven reliable to apply in community-dwelling older adults. The authors recommend a TTSST greater than 4.54 seconds as the optimal cut-off score to predict fall risk. The screening tool provided in the present study can easily be administered, and using this tool for monitoring would provide valuable quantitative data to indicate functional alteration and risk of fall in community-dwelling older adults.

What is already known on this topic?

Previously, the functional tests such as the STS, the Timed Up and Go test (TUGT) have been used widely in elderly and patients with other conditions. In Thailand, the health professional commonly use TUGT for predict risk of fall in older, and some studies use STS for predict risk of fall in community-dwelling eldery.

What this study adds?

This study performed TTSST by adapting methodology and instruction from the traditional test and the standard test for evaluating lower extremity muscle strength and predict falls. The result supports that the TTSST has successfully undergone validation and proven reliable to apply in community-dwelling older adults. The authors recommend a TTSST greater than 4.54 seconds as the optimal cut-off score to predict fall risk. The screening tool provided in this study can easily be administered, and using this tool for monitoring would provide valuable quantitative data to indicate functional alteration and risk of fall in community-dwelling older adults.

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Potential conflicts of interest

None.

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การพัฒนาเครื่องมือคัดกรองอย่างง่ายเพื่อใช้ทำนายการล้มในผู้สูงอายุไทยในชุมชน

พุทธิพงษ์ พลคำฮัก, ใหม่ทิพย์ สิทธิตัน, อรุณรัตน์ ศรีทะวงษ์

วัตุประสงค์: *เพื่อพัฒนาและประเมินคุณสมบัติของการทดสอบการลุกจากท่านั่งขึ้นยืนสามครั้ง (ITSST) ในการประเมินความสามารถในการทำงานและทำนายความเสี่ยงต่อการล้มในผู้สูงอายุในชุมชน*

วัสดุและวิธีการ: *อาสาสมัครจำนวน 36 ราย อายุตั้งแต่ 60 ปีขึ้นไป ที่เคยล้มและไม่ล้ม และถูกประเมินความสามารถในการทำงานด้วยการทดสอบ การลุกจากท่านั่งขึ้นยืน 3 ครั้ง และการทดสอบการลุกจากท่านั่งขึ้นยืน 5 ครั้ง*

ผลการศึกษา: *ข้อมูลแสดงถึงความน่าเชื่อถือในระดับดีเยี่ยม (ICCs = 0.943-0.991) และการทดสอบการลุกจากท่านั่งขึ้นยืน 3 ครั้ง มีความสามารถในการแบ่งระดับความสามารถของกลุ่มที่เคยล้มและไม่ล้มออกจากกันได้ นอกเหนือจากนั้น การลุกจากท่านั่งขึ้นยืน 3 ครั้ง ยังแสดงให้เห็นถึงความสัมพันธ์ที่สูงกับการทดสอบการลุกจากท่านั่งขึ้นยืน 5 ครั้ง ($r = 0.942$, $p<0.001$) และเป็นตัวทำนายถึงความเสี่ยงต่อการล้มได้ในระดับดีเยี่ยม (sensitivity 88.89%, specificity 100%, AUC = 0.92, 95% CI = 0.81-1.00)*

สรุป: *การทดสอบการลุกจากท่านั่งขึ้นยืน 3 ครั้ง เป็นวิธีการทดสอบที่มีความเที่ยงตรงและความน่าเชื่อถือสำหรับการประเมินความเสี่ยงต่อการล้มในผู้สูงอายุในชุมชน และการศึกษานี้แนะนำค่าตัดแบ่งของการทดสอบ การลุกจากท่านั่งขึ้นยืน 3 ครั้ง ตั้งแต่ 4.54 วินาที เป็นค่าที่เหมาะสมสำหรับนำมาใช้ทำนายความเสี่ยงต่อการล้มสำหรับผู้สูงอายุ*