The Mini-Balance Evaluation Systems Test (Mini-BESTest) Demonstrates Higher Accuracy in Identifying Older Adult Participants With History of Falls Than Do the BESTest, Berg Balance Scale, or Timed Up and Go Test

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ABSTRACT

Background and Purpose: Balance deficit is a significant predictor of falls in older adults. The Balance Evaluation Systems Test (BESTest) and the Mini-Balance Evaluation Systems Test (Mini-BESTest) are tools that may predict the likelihood of a fall, but their capabilities and accuracies have not been adequately addressed. Therefore, this study aimed at examining the capabilities of the BESTest and Mini-BESTest for identifying older adult with history of falls and comparing the participants with history of falls identification accuracies of the BESTest and Mini-BESTest to those of the Berg Balance Scale (BBS) and the Timed Up and Go Test (TUG).
Methods: Two hundred healthy older adults with a mean age of 70 years were classified into participants with and without history of fall groups on the basis of their 12-month fall history. Their balance abilities were assessed using the BESTest, Mini-BESTest, BBS, and TUG. An analysis of the resulting receiver operating characteristic curves was performed to calculate the area under the curve (AUC), sensitivity, specificity, cutoff score, and posttest accuracy of each.
Results: The Mini-BESTest showed the highest AUC (0.84) compared with the BESTest (0.74), BBS (0.69), and TUG (0.35), suggesting that the Mini-BESTest had the highest accuracy in identifying older adult with history of falls. At the cutoff score of 16 (out of 28), the Mini-BESTest demonstrated a posttest accuracy of 85% with a sensitivity of 85% and specificity of 75%. The Mini-BESTest had the highest posttest accuracy, with the others having results of 76% (BESTest), 60% (BBS), and 65% (TUG).
Conclusion: The Mini-BESTest is the most accurate tool for identifying older adult with history of falls compared with the BESTest, BBS, and TUG.
Key Words: dynamic balance, fall prediction, geriatrics, tests and measurements

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INTRODUCTION

Falls are a major health problem among older adults in both developed and developing countries and have been recognized as the fifth leading cause of injury and death in the older population.[1-3] Up to 33% of older adults aged 65 years and older experience 1 or more falls per year. The number of older adults who fall increases to 50% at the age of 80 years and tends to increase further with increasing age.[4] The consequences of falls include illness, physical disability, loss of the ability to perform daily living activities, and burdens on caregivers and society as a whole.[5] Approximately 87% of falls in older adults lead to movement limitations as a result of psychological impairments, such as fear of falling, depression, and a loss of confidence in walking.[6] Some falls result in mortality, which increases dramatically with age.[7] The adverse impacts of falls emphasize the need to identify older adults who are at risk of falls to select an appropriate prevention strategy.

A balance deficit is a significant predictor of falls in older adults.[8] Older people who slip or trip usually demonstrate poor balance and a lack of the balance mechanisms needed for fall prevention.[4,9] Several clinical balance assessments have been used to assess balance ability in older adults, and only a few have been suggested as a screening tool for identifying older adults who have a higher fall risk.[10] Some of the most commonly used clinical balance tools for fall prediction in older adults are the Berg Balance Scale (BBS) and the Timed Up and Go test (TUG).[1,11] Both the BBS and TUG, however, have some limitations in assessing balance ability. For example, the BBS has been known for having ceiling effects in older adults who have a high level of function, as the tested activities do not sufficiently challenge their dynamic balance ability.[12] In addition, most of the items on the BBS assess balance ability during standing with little attention given to balance during gait.[13,14] A recent Rasch analysis of the BBS revealed that some items, such as alternating foot on step, standing on 1 leg, and turning to look behind, were unable to distinguish between individuals with different levels of balance function.[15] In contrast, the TUG does not have a ceiling effect, but it only assesses 1 sequential task of walking and turning and does not assess other factors involved in falls.[16,17] The latest systematic review suggested that the TUG was not useful for discriminating healthy older adult with history of falls because its predictive ability and diagnostic accuracy are moderate.[18]

A relatively new balance tool, the Balance Evaluation Systems Test (BESTest), was developed as a system-specific assessment to identify the postural control systems that underlie balance impairments to direct specific treatments for balance problems.[19] The BESTest contains 36 tasks for evaluating 6 different balance control systems, including biomechanical constraints, stability limits with verticality, anticipatory postural adjustments, automatic postural responses, sensory organization, and stability in gait. Each item on the BESTest is scored on a 4-point ordinal scale ranging from worst performance (0) to best performance (3), giving a total possible score of 108, which is expressed as 100%.[19] A recent study demonstrated that the BESTest can differentiate between patients with Parkinson disease (PD) who fall and those who do not with a cutoff score of 69%.[20] Furthermore, the BESTest showed a sensitivity of 62% and specificity of 74% for predicting falls in patients with PD in a 1-year prospective study.[21]

The only disadvantage of the BESTest is the time required to complete the assessment (35 minutes).[20] As a result, the short form of the BESTest, the Mini-BESTest, was developed to reduce the assessment time.[21] On the basis of a Rasch analysis, redundant items and 2 sections of the BESTest (biomechanical constraints and stability limits with verticality) were removed to yield the assessment of dynamic balance in the Mini-BESTest.[20,21] With only 14 tasks leading to a total possible score of 28 points, the Mini-BESTest requires only 10 to 15 minutes to conduct.[22] The cutoff score of 19 (out of 28) was selected to predict future falls in persons with PD with an accuracy of 86.4%, and it has been demonstrated that the Mini-BESTest, unlike the BBS, does not have a ceiling effect.[23,24]

The BESTest and Mini-BESTest have demonstrated their potential for use as a fall prediction tool. The use of both balance tools will also provide more information on the postural control systems underlying balance impairments and help guide specific treatments for balance deficits. However, the capabilities and accuracies of the BESTest and Mini-BESTest in predicting falls in older adults have not been adequately addressed. Therefore, this study aimed at determining whether the BESTest and Mini-BESTest can be used to identify older adults who have fallen and comparing the accuracies of participants with history of falls identification of the BESTest and Mini-BESTest to those of the BBS and TUG.

METHODS

Participants

Healthy male and female older adults were recruited from a suburban community in Thailand with the following inclusion criteria: (1) 60 years of age or older; (2) ability to walk without using walking aids; (3) independence in basic daily activities; (4) no history of neurological diseases such as PD or stroke; and (5) no severe knee pains that affected walking on the day of the assessment. Participants were excluded if they (1) were on medications that affect balance; (2) had signs or symptoms of vestibular disorders such as vertigo or nystagmus on the day of the assessment; (3) had blindness or severe vision impairments affecting their ability to walk independently; (4) were unable to follow instructions; (5) had cognitive impairments determined by a score less than 24 out of 30 on the Mini-Mental State Examination—Thai version 2002 (MMSE-Thai)[25,26]; and (6) had uncontrolled comorbid conditions such as heart disease, hypertension, or diabetes mellitus. A total of 200 older adults participated in this study, and signed informed consent forms were obtained from all participants. The protocol was approved by the Human Research Protection Committee, Faculty of Health Science, Srinakharinwirot University, Thailand.

Procedure

Four balance evaluation scales, the BESTest, Mini-BESTest, BBS, and TUG, were used in this study to assess the balance ability of the participants. The BBS is considered the reference standard for assessing balance in older adults.[12] It consists of 14 items designed to measure mobility tasks related to daily activities. Each item receives a score of 0 to 4, where a score of 0 represents an inability to complete all of the items and a score of 4 represents the ability to complete the task independently, yielding a total possible score of 56.[27-29] A score of less than 45 out of 56 is generally accepted as an indicator for balance deficits.[29,30] The TUG, on the contrary, assesses the ability to perform sequential motor tasks related to walking and turning. This tool measures the time in seconds that a person takes to stand up from a standard armchair, walk at a comfortable pace for 3 m, turn, walk back to the chair, and sit down again.[16]

Prior to balance assessments, basic subject information and fall histories for the previous 12 months were gathered from the District Health Station database by rater 1, who also performed the following assessments: sensation including light touch, a pinprick and proprioception at both ankles using the Nottingham sensory testing protocol,[31] vestibular disorders using the subject's history and the Dix-Hallpike test,[32] lower extremity strength using manual muscle testing, and cognitive function using the MMSE-Thai.[25] The fall histories were used to categorize the participants into 2 groups—participants with and without history of falls. Those who had 1 fall or more were classified as participants with history of falls and those who did not report falling in the past 12 months were identified as participants without history of falls.

Rater 2 evaluated balance abilities using the BESTest, Mini-BESTest, and BBS; rater 1 administered the TUG. Each rater carried out the evaluation in a separate room, and rater 2 was blinded to subject characteristics and grouping. Prior to the study, both raters received training on administration of the BESTest, Mini-BESTest, BBS, and TUG until their scorings were accurate. After training, the intrarater reliabilities of rater 2 for scoring of the BESTest and Mini-BESTest were calculated in 12 older participants using an intraclass correlation coefficient (ICC). An ICC value of 0.80 and greater indicates excellent agreement, 0.80 to 0.60 indicates adequate agreement, and 0.60 to 0.40 indicates poor agreement.[33] Results of the reliability test indicated excellent intrarater reliability of rater 2 for the BESTest (ICC = 0.85) and Mini-BESTest (ICC = 0.90). Similarly, the intrarater reliability of rater 1 for the scoring of 12 older participants on the TUG was also excellent (ICC = 0.92).

When administering the tests, the items in all of the balance tests (ie, BESTest, Mini-BESTest, and BBS) were grouped into the following 4 sequences: A, B, C, and D. The order of each sequence was (1) BBS items 1 to 7, BBS items 8 to 14, BESTest/Mini-BESTest Sections 1 to 3, BESTest/Mini-BESTest Sections 4 to 6; (2) BBS items 8 to 14, BBS items 1 to 7, BESTest/Mini-BESTest Sections 4 to 6, BESTest/Mini-BESTest Sections 1 to 3; (3) BESTest/Mini-BESTest Sections 1 to 3, BESTest/Mini-BESTest Sections 4 to 6, BBS items 1 to 7, BBS items 8 to 14; and (4) BESTest/Mini-BESTest Sections 4 to 6, BESTest/Mini-BESTest Sections 1 to 3, BBS items 8 to 14, BBS items 1 to 7. The sequence of the balance tests was randomly selected by simple randomization (handpicking a ticket) for each participant such that an equal number of participants were placed in each of the 4 groups. Each balance test was scored once, with the exception of the TUG, which was carried out 3 times at a comfortable pace, and the average of the 3 trials was recorded. The evaluation was performed in the same laboratory setting, and all participants received the same verbal instructions. Vital signs and blood pressures were monitored before and after testing. Participants were allowed to rest for 10 minutes during each test to avoid fatigue. The total assessment time was approximately 35 minutes, and the entire testing session was videotaped to verify the accuracy of the scoring.

Data Analysis

The statistical analysis was performed using SPSS version 11.5 (SPSS Inc., Chicago, IL, USA). A descriptive statistical analysis of the demographic and baseline clinical characteristics of the participants was conducted. The Mann-Whitney *U* test was used to compare balance scores between the participants with and without history of falls, and a *P* value of less than .05 was considered as statistically significant. The receiver operating characteristic (ROC) curves were used to determine the relative performances of the BESTest, Mini-BESTest, BBS, and TUG scores for classifying participants with and without history of fall groups. The accuracy of each balance test for discriminating participants with and without history of falls was assessed using the area under the curve (AUC). An AUC value of 0.9 and greater indicates high accuracy, 0.7 to 0.9 indicates moderate accuracy, 0.5 to 0.7 indicates low accuracy, and 0.5 and less indicates a result due to chance.[34] The cutoff score was chosen by selecting the score that provided the best balance between high sensitivity and high specificity.[35] A positive likelihood ratio (LR+) and a negative likelihood ratio (LR−) were also calculated for each test. An LR+ more than 5 and an LR− less than 0.2 indicate that the test is useful due to its high probability of correctly identifying participants with and without history of falls, but LR values close to 1.0 indicate that the test is useless, as the probability of correctly and incorrectly identifying participants with history of falls is the same.[35]

To determine whether the selected cutoff score could correctly identify the older adult with history of falls, the percentage accuracy of the older adults who actually fell was calculated using the cutoff score. The floor and ceiling effects were calculated as the percentage of samples scoring the minimum or maximum possible scores, respectively. Ceiling and floor effects of 20% or greater are considered significant.[36] In this study, we also presented a "responsive ceiling effect" that was determined using the scores within the top 10%, which allows for a sufficient amount of scores to measure changes over time.[37]

RESULTS

Two hundred older adults, split equally between the participants with and without history of fall groups, participated in the study (Table 1). Up to 95% of the older adults in the participants with history of fall group had a single fall in the past 12 months; 5% had experienced more than 1 fall. Of note, most falls occurred outdoors as a result of a trip, slip, or postural transition, such as moving from sitting to standing or standing to sitting. Participants with and without history of falls did not significantly differ in age, body mass index, lower limb muscle strength, and Mini Mental State Examination (MMSE) scores.

Results of balance evaluations using the BBS, BESTest, Mini-BESTest, and TUG for both participants with and

Table 1. Subject Characteristics[a]

Characteristics	Participants Without History of Falls, Mean (Standard Deviation)	Participants With History of Falls, Mean (Standard Deviation)
Age (y)	70.2 (6.8)	70.3 (7.3)
Range (min-max)	60-95	60-96
Sex (M/F)	43/57	31/69
Fall history within 12 mo (N)		
0	100	0
1	0	95
More than 1	0	5
Fall locations (N)		
Indoor	…	38
Outdoor	…	67
Types of falls (N)		
Slip	…	49
Trip	…	33
Postural transition	…	23
Lower extremity muscle strength (/5)	4.00	4.00
Body mass index (kg/cm^2)	21.8 (4.5)	22.8 (4.7)
Mini Mental State Examination (/30)	24.9 (1.2)	24.7 (1.1)

[a]All values are shown as mean (SD) from 100 participants in each group, except the lower extremity muscle strength, which is presented as median. Significant difference between participants with and without history of falls at $P < .05$.

Table 2. Balance Scores Between Participants With and Without History of Fall Groups[a]

Assessment Scale	Participants Without History of Fall, Mean (Standard Deviation)	Participants With History of Falls, Mean (Standard Deviation)
Berg Balance Scale (/56)	52.3 (2.1)	50.8 (2.3)[b]
Mini-Balance Evaluation Systems Test (/28)	17.7 (2.2)	14.1 (3.0)[b]
Balance Evaluation Systems Test (100%)	70.2 (7.2)	62.01 (10.5)[b]
Timed Up and Go Test (s)	7.7 (2.7)	9.7 (2.8)[b]

[a]All values are shown as mean (SD) from 100 participants in each group.
[b]Significant difference between participants with and without history of falls at $P <.05$.

without history of falls are presented in Table 2. Participants with and without history of falls exhibited significantly different scores for all of the balance tools. Scores for the BBS ($P < .05$), BESTest ($P < .05$), and Mini-BESTest ($P < .05$) were significantly lower for the participants with history of falls than for the participants without history of falls, suggesting that the participants with history of falls have a lower ability to balance than the participants without history of falls. Similar results were observed in the TUG scores, in which the participants with history of falls took more time than the participants without history of falls ($P < .05$) to complete the test. The calculation of ceiling and floor effects revealed that only the BBS had ceiling or floor effects. The BBS demonstrated a ceiling effect, with 7 participants (5 participants without history of falls and 2 participants with history of falls) receiving the maximum score (56 points). However, when the responsive ceiling effect was considered, 142 participants (82 participants without history of falls and 60 participants with history of falls), or 71% of all participants, had BBS scores within 10% of the maximum score, whereas none of the other tools used demonstrated a responsive ceiling effect.

Results from the ROC analyses are shown in Figure 1 and Table 3. As shown in Table 3, the Mini-BESTest and BESTest were moderately accurate at classifying participants with and without history of falls (AUC between 0.7 and 0.9), whereas the accuracies of the BBS and TUG were low (AUC <0.7) and very low (AUC <0.5), respectively. The cutoff scores for each scale and their sensitivities and specificities are also presented in Table 3. The Mini-BESTest demonstrated the highest sensitivity (0.85) and specificity (0.75) of the scales, as well as the highest post-test accuracy (85%) using the selected cutoff score (16/28). In addition, the LR+ and LR− analyses indicated that the Mini-BESTest was the most appropriate scale for classifying participants with and without history of falls compared with the other tools. Although the BESTest and BBS had similar sensitivities and specificities, the BESTest was much more accurate than the BBS. It should also be noted that the cutoff score of the BBS was close to the maximum score (51 out of 56).

The AUC of the section scores from the BESTest and Mini-BESTest are displayed in Table 4. One section of the BESTest (Stability in Gait) and 2 sections of the Mini-BESTest (Sensory Orientation and Stability in Gait)

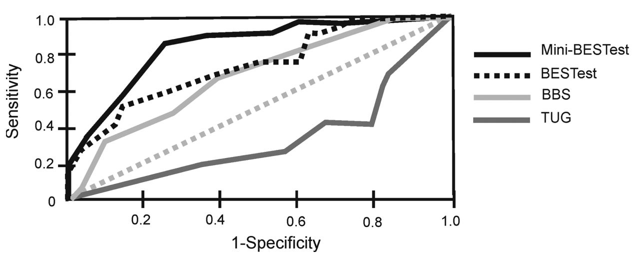

Figure 1. Receiver operating curve for identifying participants with history of falls using the scores from the Berg Balance Scale (BBS), the Balance Evaluation System Test (BESTest), the Mini-Balance Evaluation System Test (Mini-BESTest), and the Timed Up and Go Test (TUG).

Table 3. Area Under the Curve, Cutoff Score, Sensitivity, Specificity, Likelihood Ratio, and Percentage of Posttest Accuracy at the Selected Cutoff Score[a]

Variables	Mini-BESTest (/28)	BESTest (/100%)	BBS (/56)	TUG
Area Under the curve	0.84	0.74	0.69	0.32
Cutoff Score	16	66	51	8
Sensitivity (95% CI)	0.85 (0.77-0.90)	0.76 (0.67-0.83)	0.77 (0.57-0.85)	0.40 (0.31-0.49)
Specificity (95% CI)	0.75 (0.66-0.83)	0.50 (0.40-0.60)	0.42 (0.38-0.57)	0.34 (0.26-0.44)
Positive Likelihood Ratio	3.40	1.52	1.76	0.61
Negative Likelihood Ratio	0.20	0.48	0.53	1.77
Posttest Accuracy (%)	85	76	60	65

Abbreviations: BBS, Berg Balance Scale; BESTest, Balance Evaluation Systems test; CI, confidence interval; Mini-BESTest, Mini-Balance Evaluation Systems test; TUG, Timed Up and Go test.
[a]Posttest accuracy was calculated using the selected cutoff score.

produced larger AUCs (>0.7) than the other sections, suggesting that the Stability in Gait and Sensory Orientation sections were more accurate at identifying participants with and without history of falls than the other sections.

DISCUSSION

This study is the first to explore the ability of the BESTest and the Mini-BESTest to identify older adult with history of falls compared with the previously used balance tools, the BBS, and TUG. Our results demonstrated that the Mini-BESTest was the most accurate tool for identifying older adult with history of falls based on it having the highest posttest accuracy (85%) using the suggested cutoff score. In this study, the Mini-BESTest showed the highest AUC (0.84), sensitivity (0.85), and specificity (0.75). These findings were in line with previous studies that compared the Mini-BESTest with other clinical tools, such as the BBS, 5-Time-Sit-to-Stand Test, and Unified Parkinson's Disease Rating Scale.[20,23,38,39] For example, prospective and retrospective studies in people with PD reported a higher fall prediction sensitivity and specificity for the Mini-BESTest than for the BBS.[20,38] It was also evident that the Mini-BESTest had fewer floor and ceiling effects than the BBS.[24] In our study, we searched for a responsive ceiling effect, defined as the number of scores within 10% of the maximum, which indicates the capability of the scale to detect change over time. The responsive ceiling effect was 71% for the BBS, suggesting a limited ability of the BBS to detect changes in balance ability over time. In contrast, we did not find a ceiling effect or responsive ceiling effect for the Mini-BESTest. In addition, this study suggested a score of 16 (out of 28) as the cutoff score for the Mini-BESTest for identifying older adult with history of falls. This cutoff score is in the same range as the prospective study, which reported the cutoff score of the Mini-BESTest as 17.5 for predicting fall risk in patients with stroke (64% sensitivity and 64.2% specificity).[40]

Table 4. The Area Under the Curve of Each Section of the Balance Evaluation Systems Test (BESTest) and the Mini-Balance Evaluation Systems Test (Mini-BESTest)

Section No.	Section Name	BESTest	Mini-BESTest
I	Biomechanical Constraints	0.56	…
II	Stability Limits/Verticality	0.61	…
III	Anticipatory Postural Adjustments	0.66	0.63
IV	Postural Responses	0.69	0.62
V	Sensory Orientation	0.65	0.74
VI	Stability in Gait	0.77	0.81

Abbreviations: BESTest, Balance Evaluation Systems test; Mini-BESTest, Mini-Balance Evaluation Systems test.

In this study, we demonstrated that the ability of the TUG to correctly identify participants with and without history of falls was the lowest of the studied tests. This finding was in accordance with a meta-analysis of the TUG that reported a moderate predictive ability and poor diagnostic accuracy in discriminating older adult with history of falls.[18] The Mini-BESTest may be more accurate than the BBS and the TUG in identifying older adult with history of falls because it assesses balance ability in a way that is related to the nature of falls in older adults. Our results showed that most falls in this population occurred as a result of tripping or slipping during walking (Table 1). It has been shown that falls during slips or trips were caused by lack of automatic postural responses, impaired postural control during dual tasks, and impaired cutaneous sensation and vestibular functions.[9,41] The Mini-BESTest is able to capture these abilities because it contains items that assess automatic postural responses and postural control during dual tasks.[21] On the basis of the ROC analysis of the Mini-BESTest, it was determined that the "Stability in Gait" and "Sensory Orientation" domains can correctly identify participants with history of falls better than the test's other domains. In contrast, the BBS was developed for use with frail older adults; thus, it assesses general balance abilities without posing any challenges to individuals.[12] Even though the BESTest contains the "Stability in Gait" and "Sensory Orientation" domains, our ROC results suggest that only the "Stability in Gait" domain demonstrated a moderate ability to identify older adult with history of falls. Both "Stability in Gait" and "Sensory Orientation" domains contain more items in the BESTest (ie, stance with eyes closed on firm surface, stance with eyes open on foam surface, level surface gait, and timed get up and go test) than in the Mini-BESTest. Our results demonstrated that these additional items on the BESTest could reduce its accuracy for identifying participants with history of falls, as they are not relevant to balance ability in this population.

Our findings, however, do not agree with those of a previous study that found that the BESTest and Mini-BESTest had a similar ability to identify patients with PD who fell.[39] Those results for the Mini-BESTest and the BESTest, based on 6 months of retrospective fall data, included AUCs of 0.86 and 0.84, sensitivities of 0.88 and 0.84, and specificities of 0.78 and 0.76, respectively. The disparity of the findings could be due to differences in the population groups studied; for example, the impairments underlying the falls may be different.

In this study, the sensitivity, specificity, and AUC of the BBS for identifying older adult with history of falls were lower than those of previous studies. This discrepancy could arise from differences in age, methods of classifying participants with history of falls, and whether the fall histories were obtained retrospectively or prospectively. Previous studies recruited participants older (mean age of 79 years or older) than those in this study (mean age of 70 years).[4,42] Differences in the ages of the participants suggest that the Mini-BESTest is more suitable for use with younger older adults, as it is more accurate than the BBS in this age group. Although the classifications of participants with history of falls, such as defining them by having had 1 or more falls or 2 or more falls, could contribute to the inconsistent findings, previous studies did not show significant differences in sensitivities or specificities with either fall classification.[20,23,24,38-40] The retrospective and prospective methods of gathering the fall data are another major concern. The prospective studies of older adults reported a range of sensitivities of 25% to 69% and specificities of 92% to 96%.[4,36] In contrast, the retrospective studies demonstrated a higher range of sensitivities (88%-95%) and lower range of specificities (76%-95%).[42,43] Retrospective studies may be susceptible to recall bias. However, a recent study of fall prediction demonstrated that 6-month retrospective fall data gathered from persons with PD led to fall prediction values that were similar to values calculated using 6-month prospective fall data.[39]

This study suggested the scale that can be used to correctly identify older persons who have fallen based on their functional balance skills. Other fall risk factors, such as psychological aspects, medications, and comorbidities were not examined in this study. With regard to the age of participants, the results should be carefully interpreted in light of the healthy and young older adults. In addition, the majority of participants with history of falls in this study had only a single fall, so another group of older adults with histories of several falls should be examined in a future study.

CONCLUSIONS

The Mini-BESTest demonstrated the highest ability to correctly identify older adult with history of falls, as this scale showed the highest AUC (0.84) compared with the BESTest (0.74), the BBS (0.69), and the TUG (0.35). The suggested cutoff score on the Mini-BESTest for identifying older adult with history of falls is 16 out of 28, giving a sensitivity of 85% and a specificity of 75%. Using the suggested cutoff score gives the BESTest the highest posttest accuracy (85%) when compared with the BESTest (76%), the BBS (60%), and the TUG (65%).

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