The Mini Balance Evaluation System Test (Mini-BESTest) for Predicting Recurrent Fall in Active Older Adults from 1-Year Prospective Study

นิพนธ์ต้นฉบับ

Original Article

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วารสารไทยเภสัชศาสตร์และวิทยาการสุขภาพ 2561;13(4):164-170.

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บทคัดย่อ

วัตถุประสงค์: เพื่อตรวจสอบความถูกต้องของแบบประเมิน Mini Balance Evaluation System Test (Mini-BESTest) ในการทำนายการหกล้มซ้ำในผู้สูงอายุที่มีพฤฒพลังโดยการติดตามผล 12 เดือน เปรียบเทียบกับแบบประเมิน Berg Balance Scale (BBS) และแบบประเมิน Timed Up and Go Test (TUG) **วิธีการศึกษา:** ผู้สูงอายุที่มีพฤฒพลังจำนวน 200 คน แบ่งกลุ่มโดยอ้างอิงจากประวัติการหกล้มใน 12 เดือนที่ผ่านมาออกเป็น 2 เป็นกลุ่ม ได้แก่ กลุ่มที่มีประวัติการหกล้มและกลุ่มที่ไม่มีประวัติการหกล้ม ผู้เข้าร่วมงานวิจัยได้รับการประเมินการทรงตัวโดยใช้แบบประเมิน Mini-BESTest, BBS และ TUG ติดตามอุบัติการณ์การหกล้มทุกเดือนเป็นเวลา 12 เดือน วิเคราะห์ข้อมูลโดยใช้ receiver operating characteristic (ROC) curves เพื่อคำนวณหา area under the curve (AUC), sensitivity, specificity, cut-off score, likelihood ratio (LR) และ posttest accuracy ในแต่ละแบบประเมิน และเปรียบเทียบกับข้อมูลจากการติดตามผล 12 เดือนก่อนหน้า และติดตามผลต่อ 6 เดือนและ 12 เดือน **ผลการศึกษา:** จากการติดตาม 12 เดือน แบบประเมิน Mini-BESTest แสดงค่า AUC (0.71) สูงกว่า BBS (0.59) และ TUG (0.41) ในการทำนายการหกล้ม และ Mini-BESTest มีค่า posttest accuracy สูง(94.5%) ในขณะที่ BBS (74.2%) และ TUG (27%) แสดงค่าความถูกต้องต่ำ ค่าคะแนนจุดตัด (cut-off score) ของแบบประเมิน Mini-BESTest เป็น 18 จากคะแนนเต็ม 28 มีค่าsensitivity 0.91, specificity 0.71, LR+ 2.4 และ LR- 0.09 ซึ่งค่าที่ได้มีความถูกต้องมากกว่าการคำควณจากข้อมูล 12 เดือนย้อนหลังและความสัมพันธ์ทางคลินิกดีกว่าค่าที่คำนวณจากข้อมูลที่ติดตาม 6 เดือน **สรุป:** แบบประเมิน Mini-BESTest มีความแม่นยำในการทำนายการหกล้มซ้ำในผู้สูงอายุที่มีพฤฒพลังมากกว่าแบบประเมิน BBS และ TUG และการศึกษานี้เสนอแนะค่าคะแนนจุดตัดจากการติดตามผล 12 เดือนที่ 18 จากคะแนนเต็ม 28

คำสำคัญ: หกล้มซ้ำ, ผู้สูงอายุที่มีพฤฒพลัง, Mini-BESTest

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Abstract

Objective: To determine the accuracy of the Mini Balance Evaluation System Test (Mini-BESTest) for predicting recurrent fall in the active elderly using the data from 12-month follow up, as compared to the Berg Balance Scale (BBS) and Timed Up and Go Test (TUG). **Method:** Two hundred healthy older adults participated and were classified into 2 groups based on of their previous 12-month fall history; with and without history of fall groups. Participants received balance assessments using the Mini-BESTest, BBS, and TUG at the initial visit. Fall incidence was monitored every month for 12 months. An analysis of the receiver operating characteristic curves was performed to calculate the area under the curve (AUC), sensitivity, specificity, cut-off score, likelihood ratio (LR) and posttest accuracy of each scale. In addition, those parameters were calculated and compared based on data from previous 12 months, 6-month and 12-month follow up. **Results:** Using the prospective 12-month data, The Mini-BESTest demonstrated the highest AUC (0.71) for fall prediction, as compared to that of the BBS (0.59) and TUG (0.41). This is supported by the highest posttest accuracy of the Mini-BESTest (94.5%), whereas the BBS (74.2%) and TUG (27%) showed lower accuracy. The cut-off score of the Mini-BESTest was 18 out of 28, with the sensitivity of 0.91 and specificity of 0.71, and LR+ of 2.4 and LR- of 0.09. These values yielded better accuracy than the values calculated from retrospective 12-months and better clinical relevance than the values calculated from prospective 6-month data. **Conclusion:** The Mini-BESTest is more accurate to predicting recurrent falls in active elderly persons than the BBS and TUG. The suggested cut-off score based on 12-month follow up is 18 out of 28.

Keywords: recurrent fall, active older adults, Mini-BESTest

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Introduction

Falls are one of the common problems found in the geriatric population.[1] One third of community-dwelling elderly person fell each year.[2] Recurrent fall seems to be more evident as the age increases. Thirty-three percent of older persons aged 65 years and over experience one or more falls per year.[3] Having the history of fall increased the risk of recurrent fall.[4] Other risk of recurrent fall in the older person had been related to the ability to perform physical activity and balance.[5] It has been reported that balance performance is the significant fall predictor in the older persons.[6]

Balance is a complex ability involved multi-systems in the body that are referred to as the postural control system.[7] The postural control system includes the musculoskeletal system, sensory system, sensorimotor strategy, internal body representation, adaptive mechanism and anticipatory mechanism.[8] Two main goals have been implicated for the postural control system; the maintenance of body alignments in relation to each other and to the environment, and the control of center of body mass within the base of support. Impairment of any component in the postural control system can contribute to increased risk of fall in the elderly; therefore, it is necessary to evaluate each system of postural control for preventing falls or reducing recurrent falls.

Two clinical balance assessments; the Berg Balance Scale (BBS) and the Timed Up and Go test (TUG), have been commonly used as balance screening tools for identifying the elderly who has higher fall risks.[9-11] Both BBS and TUG, however, have some limitations in assessing balance ability. The BBS was developed for frail older persons; the items in the BBS were not balance-challenging as most of the items assessed balance ability during standing.[12-13] As a result, the BBS demonstrates ceiling effect in the active elderly who has a high performance level.[7] The TUG can assess balance quickly due to only one sequential task of walking and turning is assessed. Although there is no report of the ceiling effect in the TUG as seen in the BBS when assessing the active elderly, the TUG does not cover multifactor of postural control system, resulting in moderate predictive and diagnostic accuracy.[14-16]

The Balance Evaluation System Test (BESTest) was developed from a theoretical understanding of postural control system. The BESTest covers all domains in the postural system, resulting in the lengthy assessment time.[17] It's shorten version, the Mini-BESTest, decreases the assessment time from 30 minutes to 10-15 minutes. The Mini-BESTest focuses on dynamic balance only, through its 14 items in 4 main domains, including anticipatory postural adjustments (the control of body center of mass prior to voluntary movement), reactive postural control (maintenance of balance during external perturbation), sensory orientation (sensory reweighing for balance control) and dynamic gait (the control of balance during walking).[17] These domains are known to challenge balance during activities of daily living in different types of patients.[18] The Mini-BESTest has excellent interrater (ICC = 0.91), and test-retest (ICC = 0.88) reliability.[17] This test also showed excellent ability to identify risk of fall in persons with balance disorders (sensitivity 94% and specificity 81%)[18], persons with chronic stroke (sensitivity 64% and specificity 64%)[19] and in persons with Parkinson's disease (sensitivity 75 - 88% and specificity 78 - 79%).[20,21] The Mini-BESTest would be more appropriate than the BBS and the TUG to assess the postural control impairment underlying risk of fall in the active elderly. Using retrospective method of collecting fall history in the past 12 months, the Mini-BESTest was able to identify the active older adult who had a history of fall more accurately than the BBS and TUG using the cut-off score of 16 out of 28 (sensitivity 85 %, specificity 0.75%).[22] However, the retrospective methods of collecting fall history may be susceptible to recalled bias.[22] The prospective study was suggested as an alternative to the retrospective method of collecting fall data, as it showed higher sensitivity than the retrospective methods.[23] This study, therefore, aimed to determine the accuracy of the Mini-BESTest to predict recurrent fall in the active elderly using the data from 12-month follow up, as compared to those of the BBS and TUG. In addition, the accuracy of the Mini-BEST test based on retrospective and prospective data were compared in this study.

Methods

This prospective cohort study was the continuation of the study by Yingyongyudha et al. (2016)[22], where it initially assessed the balance performance of the elderly participants and prospectively monitored the fall incident in this group of participants for 12 months.

Participants

Two hundred active older adults were recruited from communities in Krasang and Ban Kruat districts (Buriram province) as well as Mueang Surin, Prasat and Khwao Sinrin districts (Surin province), Thailand. The inclusion criteria were: 1) age of 60 years or more; 2) being able to walk without walking aids; 3) independence in activity of daily living; 4) no history of neurological disease; and 5) no severe knee pain that affected walking on the day of assessment. The 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 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 (MMSE-Thai); and 6) had uncontrolled comorbid conditions such as heart disease, hypertension or diabetes mellitus. The signed informed consents were obtained from all participants. The protocol was approved by the Human Research Protection Committee, Faculty of Health Science, Srinakharinwirot University, Thailand (Approval No.: HS2013-011, Approval date 25/03/2013)

Procedures

The main outcome variables in the study were balance scores obtained from three balance evaluation scales, the Mini-BESTest, BBS, and TUG. These scores were then calculated to determine the accuracy of predicting the elderly with recurrent falls through the area under the curve (AUC), sensitivity, specificity, likelihood ratio and posttest accuracy. Prior to the study, both raters received training on administration of the BESTest, Mini-BESTest, BBS, and TUG until their scorings were accurate. Mini-BESTest test consists of 14 tasks. With a possible score of 0 to 2 for each task, the possible maximum score is 28 points. A score of zero indicates the lowest level of function and 2 indicates the highest level.[17] The BBS consists of 14 items designed to measure mobility tasks related to daily activities. Each item is scored from 0 to 4, where 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.[24] A score of less than 45 out of 56 is generally accepted as an indicator for balance deficits.[25] The TUG measures the time in seconds that a person takes to stand up from a standard armchair, walk at a comfortable pace for 3 meters, turn, walk back to the chair, and sit down.[14]

Prior to balance assessments, basic 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, vestibular disorders using the subject's history and the Dix-Hallpike test, lower extremity strength using manual muscle testing, and cognitive function using the Mini Mental State Examination (MMSE). The fall histories were used to categorize the participants into 2 groups - participants with and without history of falls. Those who had one 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 Mini-BESTest, and BBS; rater 1 administered the TUG. Vital signs and blood pressures were monitored before and after testing. Each rater carried out the evaluation in a separate room, and rater 2 was blinded to subject characteristics and grouping. 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. 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. After the testing, all participants received a log book to record their falls each month until 12 months. The village's health volunteers (VHV) followed the participants monthly and reported the monthly fall incidence to the researchers.

Data analysis

The statistical analysis was performed using SPSS version 11.5. 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 as the scores were non-normal distributed, and a *P*-value of less than 0.05 was considered as statistically significant. The receiver operating characteristic (ROC) curves were used to determine the relative performances of the Mini-BESTest, BBS, and TUG scores for classifying participants on fall history to identify those with and without history of fall and those who fell in the 6 and 12-month follow up. Area under the curve (AUC) was obtained to summarize the accuracy of the diagnostic test. The cut-off score was chosen by selecting the score that provided the best balance between high sensitivity (ability to correctly identify fallers) and high specificity (ability to correctly identify non-fallers).

A positive likelihood ratio (LR+) and a negative likelihood ratio (LR-) were also calculated for each test to determine the clinical relevance of the selected cut-off score. A positive likelihood ratio is the probability of a positive outcome given a positive screening, while a negative likelihood ratio is the probability of a negative outcome given a negative screening. The LR+ of more than 2 and LR- of less than 0.2 were acceptable as having clinical relevance.[26] To determine whether the selected cut-off score could correctly identify the older adult with recurrent falls, the posttest accuracy (percentage accuracy of the older adults who actually fell) was calculated using the cut-off 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.[27]

Results

A total of 200 individuals; equal number of participants with history of fall and without history of fall, participated in the study. There was no significant difference in age and proportion of gender between the participants with history of fall and those without history of falls. However, those participants with history of falls demonstrated significant poorer balance performance as measured by Mini-BESTest, BBS and TUG (Table 1). One hundred and ninety-nine active elderly completed the study at 12 months. A reason for one dropout in the "participants without history of falls" group at 12 months was due to death. The participants with history of fall also had significant higher recurrent falls than those without history of fall.

Table 1 Subject characteristics.

Characteristics	Participants without history of falls (n = 100)	Participants with history of falls (n = 100)
Age (years)	70.22 ± 6.76	70.3 ± 7.26
Gender (Male/Female)	43 /57	31/69
Mini-BESTest scale	17.68 ± 2.19	14.10 ± 3.01 *
Berg Balance Scale	52.28 ± 2.07	50.76 ± 2.27 *
Timed Up and Go Test	7.73 ± 2.69	9.67 ± 2.75 *
Recurrent fall in 6 months (N)	0	21
Recurrent fall in 12 months (N)	3	41

Note: All values are shown as mean ± SD.

*Significant difference between participants with and without history of fall at *P*–value < 0.05.

Table 2 demonstrates fall characteristics of both groups of participants. Most recurrent falls were from participants with history of fall with only 3 falls occurred from participants without history of fall (Table 1). The number of falls increased every month, so there was a higher number of falls at 12 months than that at 6 months. Most recurrent fall occurred largely from slips and trips that happened both indoor and outdoor.

Table 2 Fall characteristics.

Fall Characteristics	Recurrent fall in 6 months	Recurrent fall in 12 months
Number of person who fell	21	44
Number of fall (N)		
1 fall	21	43
More than 1 fall		1
Fall location (N)		
Indoor	14	24
Outdoor	7	22
Types of fall(N)		
Slip	12	22
Trip	4	17
Postural transition	5	6

Using the cut-off score from previous study[22] for identifying fallers, the accuracy of prediction in all balance tests continued to decrease when the follow up was extended from 6 to 12 months (Table 3). Table 4 shows the new cut-off scores for predicting elderly fallers that were re-calculated based on the 6- and 12-month follow up data. It can be seen that the cut-off score from all balance scales were higher when comparing to the cut-off score from the retrospective data. Similar trend (increasing) was observed on sensitivity, specificity, AUC and posttest accuracy using the new cut-off scores.

Table 3 Accuracy of cut-off score from the retrospective data of fall history.

Scale	Cut-off score (previous study)	Posttest Accuracy (%)		
		Past 12 months	Prospective 6 months	Prospective 12 months
Mini-BESTest*	16	85	71	70
BBS# (/56)	51	60	29	34
TUG$ (s)	8	65	29	18

* Mini-BESTest = Mini-balance evaluation systems test (total score of 28)

BBS = Berg balance scale (total score of 56)

$ TUG = Timed up and go test

The Mini-BESTest demonstrated higher AUC and post-test accuracy to predict future fall, whereas the BBS and TUG showed lower accuracy. The re-calculated cut-off scores were the same for the data obtained during 6 or 12-month follow up. Compared to posttest accuracy using the cut-off scores from retrospective (85%) (Table 3), the posttest accuracy from the prospective data for the Mini-BESTest was the highest (94.5%). Only the cut-off score from 12-month prospective data showed clinical relevance as can be seen from the value of LR+ (2.4) and LR- (0.09).

Table 4 Accuracy of the new cut-off score based on the prospective data.

Scale	Cut-off	Sensitivity (95% CI)	Specificity (95% CI)	AUC	LR+	LR-	Posttest Accuracy (%)
Mini-BESTest (/28)							
Prospective (6 mo)	18	0.91(0.77-0.99)	0.62 (0.73-0.85)	0.71	1.45	0.25	90.48
Prospective (12 mo)	18	0.91 (0.88-1.00)	0.62 (0.70-0.83)	0.71	2.4	0.09	94.50
BBS (/56)							
Prospective (6 mo)	52	0.76 (0.55-0.89)	0.62 (0.55-0.69)	0.59	1.23	0.63	76.19
Prospective (12 mo)	52	0.75 (0.61-0.85)	0.61 (0.53-0.68)	0.59	1.23	0.64	74.26
TUG (s)							
Prospective (6 mo)	11	0.72 (0.50-0.86)	0.75 (0.68-0.81)	0.47	0.95	1.16	28.57
Prospective (12 mo)	11	0.73 (0.58-0.84)	0.75 (0.67-0.81)	0.41	0.97	1.08	27.00

Note: Mini-BESTest = Mini- balance evaluation systems test; BBS = Berg balance scale; TUG = Timed up and go test.

Discussions and Conclusion

In our previous study, we showed that the Mini-BESTest was superior than the Berg Balance Scale (BBS) and Timed Up and Go Test (TUG) in identifying the active elderly who had history of fall. Again, we demonstrated in this current study that the Mini-BESTest was more accurate than the BBS and TUG to predict falls in the active elderly using the data from 12-month follow up. These findings are consistent with the prospective study in people with Parkinson's disease that demonstrated higher sensitivity and specificity of the Mini-BESTest than the BBS for fall prediction.[28] Other previous studies reported that the TUG had poor accuracy for discriminating elderly with fall history.[16,22] We also found that the elderly with history of fall was more prone to have recurrent fall than those without history of fall. This is in accordance with the previous study indicating the risk of recurrent fall increased with the number of previous falls, suggesting the history of fall was a strong predictor for risk of falls.[29]

This study presented the cut-off score of the Mini-BESTest, which was calculated from prospective data as 18 out of 28, to identify fall risk in the active elderly. This cut-off score was in the same range as the Mini-BESTest cut-off scores in different populations; 17.5 in people with stroke[19] and 19 in people with Parkinson's disease.[30] However, the cut-off scores of the BBS and TUG from this study were quite different from those in the previous studies. In the original study by Berg et al.[31], the cut-off point of BBS was 45, whereas our study showed 52. The discrepancy of the findings could arise from age and frailty factors. The previous study recruited elderly persons from the health care center who were much older (mean age of 83 years) than those in this study (mean age of 70 years).

It can be seen that the cut-off scores calculated from prospective data were more accurate than those from retrospective data to predict future falls in the active elderly. We showed 94.50% posttest accuracy from the Mini-BESTest for predicting recurrent fall, as compared to 85% posttest accuracy using the retrospective information. This may be due to recall bias from the retrospective data such that the elderly may forget their falls, or they may report only the more serious falls.[32] As a result, the number of falls may be underestimated with retrospective study. With the prospective data, using the logbook and the assigned health volunteers in this study can help improve the accuracy of the fall incidence data.

With the same area under the curve, sensitivity and specificity between 6- and 12-month follow up, we suggested that the likelihood ratio (LR) needs to be taken into consideration. LR is another index of clinical relevance, where LR+ refers to the increase in the odds of having a recurrent fall when using the cut-off as suggested and LR- refer to the increase in the odds of not fall.[33,34] The acceptable value of LR+ is more than 2 and LR- is less than 0.5. In our study, only the LR value from the Mini-BESTest 12-month follow up was within the clinical relevance criteria (LR+ and LR- were 2.4 and 0.09, respectively). This indicated that elderly with a score below 18 (cut-off score) are 2.4 times more prone to have a fall than those with higher scores, suggesting that the data from 12-month follow up would be more clinically valid than the 6-month follow up. This could be because intrinsic factors of fall such as functional disabilities were associated with increasing age.[35] Therefore, recurrent fall in community-dwelling older adults would be more evident when observed for the duration of 12 months.[36] This finding is in line with other prospective studies of fall in the elderly that usually carried out for a period of at least 12 months.[37] However, since our results from 6-month follow up also yielded high AUC and posttest accuracy, the 6-month follow up could be the suitable alternative to the 12-month follow up, when facing budget constraints.

This study has some limitations. The number of falls from follow up may be underestimated as being included in the study raised the awareness of the participants regarding falls. As a result, they may be more careful to prevent falls during the period of data collection. The results were obtained from the elderly that were active in daily activities in the community; therefore, the cut-off scores were more suitable for predicting fall in this group of population. The results from this study may not be appropriate to be used in frail elderly or those who is dependent in performing activities of daily living and could be explored further in the future study.

Conclusion

The cut-off scores obtained from 12-month prospective fall data were more accurate and clinically relevant than the cut-off score calculated from 12-month retrospective fall data to be used for fall prediction in the active elderly.

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