Comparing the measurement properties and relationship to gait speed recovery of the Mini-Balance Evaluation Systems Test and the Berg Balance Scale in ambulatory individuals with subacute stroke

Kazuhiro MIYATA, PT, Ph.D, Satoshi HASEGAWA, PT, MSc, Hiroki IWAMOTO, PT, MSc, Tomohiro OTANI, PT, MSc, Yoichi KAIZU, PT, MSc, Tomoyuki SHINOHARA, PT, Ph.D and Shigeru USUDA, PT, Ph.D

1) Department of Physical Therapy, Ibaraki Prefectural University of Health Science
2) Department of Rehabilitation, Public Nanokaichi Hospital
3) Department of Rehabilitation Sciences, Gunma University Graduate School of Health Sciences
4) Department of Rehabilitation Centre, Hidaka Rehabilitation Hospital
5) Department of Rehabilitation Centre, Hidaka Hospital
6) Department of Physical Therapy, Faculty of Health Care, Takasaki University of Health and Welfare

ABSTRACT. Objectives: Although the Mini-Balance Evaluation Systems Test (Mini-BESTest) is known to be a reliable and valid measure of balance in individuals with stroke, the utility of this tool in relation to subacute stroke walking speed and the recovery of gait ability has not been explored. Here, we compared the measurement properties and their relationship to gait speed on the Mini-BESTest and the Berg Balance Scale (BBS) in middle and older ambulatory individuals with subacute stroke, and we investigated which balance assessment tool is more likely to capture the status of the recovery of gait speed.

Methods: We retrospectively analyzed the cases of 88 individuals 50 years or older with stroke who had been evaluated using the Mini-BESTest by using the BBS and by assessing their comfortable walking speed (CWS). The proportion of subjects who showed improvement was calculated for 34 stroke survivors from data obtained at admission to and discharge from the hospital.

Results: Compared with the BBS, the Mini-BESTest showed a better distribution of total scores without a ceiling effect. The two scales showed correlations with gait speed (Mini-BESTest: r=0.702; BBS: r=0.592) and discrimination between fast and slow walkers. The responsiveness of the Mini-BESTest was excellent, with an area under the curve of 0.894, thus discriminating between gait speed improvement versus non-improvement.

Conclusions: These results indicate that the Mini-BESTest is more useful than the BBS in terms of its measurement properties and ability to measure gait recovery in middle and older ambulatory individuals with subacute stroke.

Key words: middle and older adults, postural balance, gait, Mini-BESTest, BBS

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Stroke is the third leading cause of mortality and the common cause of disability in Japan. There are 1.15 million stroke patients in Japan, many over the age of 50\textsuperscript{5}. Recovering the ability to walk is an important goal for people who suffer strokes\textsuperscript{3}. Gait speed is a valid and reliable measure of walking ability across the continuum of recovery after a stroke\textsuperscript{6}. Accordingly, researchers and clinicians commonly use gait speed to assess walking ability post-stroke. Perry et al\textsuperscript{7} found that there was a significant difference in gait speed between participants categorized as having unlimited community ambulation and those in other categories. Based on the results of several studies, average gait speed values for three categories of survivors have been established and widely adopted: home ambulators (<0.4 m/s), limited community ambulators (0.40-0.80 m/s), and full community ambulators (0.8 m/s)\textsuperscript{8,9}. One of the key determinants of gait speed is balance. In people recovering from stroke, loss of balance influences gait speed at the time of discharge from a hospital\textsuperscript{10}. The Berg Balance Scale (BBS) is the most commonly used balance assessment tool across the continuum of stroke rehabilitation. The measurement properties of the BBS have been well assessed, and it has been shown to be a valid and reliable balance assessment tool\textsuperscript{11}. However, some important limitations of the BBS have been observed, such as a ceiling effect\textsuperscript{12}, the need to reduce item redundancy\textsuperscript{13}, and its inability to predict falls\textsuperscript{14}. On the other hand, The Mini-Balance Evaluation Systems Test (Mini-BESTest) is another commonly used balance assessment tool, and it focuses on “dynamic balance”\textsuperscript{15}. Since its introduction in 2010, the Mini-BESTest has been increasingly used for evaluating balance in various neurological populations, such as people with stroke\textsuperscript{16,17}, Parkinson disease\textsuperscript{18}, and spinal cord injuries\textsuperscript{19}. The Mini-BESTest has excellent reliability and validity in people with stroke\textsuperscript{13,16,17}. Moreover, an expert panel recommended that either the Mini-BESTest or BBS should be used when measuring balance in adult populations\textsuperscript{13}. Recent studies have compared the measurement properties of the Mini-BESTest and the BBS in people with neurological diseases\textsuperscript{13,19,20}. All of those studies demonstrated more favorable results (i.e., responsiveness, validity, reliability, skewness, sensitivity, and specificity) for the Mini-BESTest than the BBS. However, no comparison of the measurement properties of the Mini-BESTest and the BBS in ambulatory people with subacute stroke has been reported.

Madhavan et al\textsuperscript{20} compared the usefulness of the Mini-BESTest with that of the BBS in relation to gait speed in people with chronic stroke. The authors found that the Mini-BESTest has a stronger relationship with gait speed than the BBS, and the Mini-BESTest has greater discriminative ability than the BBS to categorize individuals with chronic stroke into slow and fast walkers. There is a need for a balance assessment tool that is related to gait speed and to detect changes in gait speed for people with subacute stroke in the recovery stage. To our knowledge no previous study has compared the usefulness of the Mini-BESTest with that of the BBS in relationship to change of gait speed in people with subacute stroke. Understanding the relationship between balance (as measured by the Mini-BESTest) and gait speed in the subacute recovery stage may provide better guidance for more directed clinical decision-making. Also, no study selects participants based on age, which affects recovery after a stroke. Therefore, this study targeted middle and older people with stroke, who account for the majority of stroke patients in Japan.

The purposes of this study were: (1) to compare the measurement properties and relationship to gait speed of the Mini-BESTest and the BBS in middle and older ambulatory people with subacute stroke; and (2) to investigate which balance assessment tool is more likely to capture the status of the recovery of gait speed.

Methods

This study was a retrospective observational study; data were collected from three hospitals with convalescent rehabilitation ward. All subjects were evaluated using the Mini-BESTest, the BBS, and comfortable walking speed (CWS) assessments by trained physical therapists. The research protocol was approved by the Gunma University Ethical Review Board for Medical Research Involving Human Subjects (No. 15-73) and the Ethics Committees of Hidaka Hospital (No. 112), Hidaka Rehabilitation Hospital (No. 151101), and Public Nanokaichi Hospital (20160208). The reporting of this study conforms to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement\textsuperscript{21}.

Subjects

The study included 88 people with stroke who participated in a rehabilitation program in a convalescent rehabilitation ward from July 2010 to August 2015. The subjects were required to meet all of the following inclusion criteria: (1) aged ≥50 years; (2) subacute stroke (ranging from 7 days to 4 months after stroke onset)\textsuperscript{22}; (3) diagnosis of cerebral infarction, cerebral hemorrhage, or subarachnoid hemorrhage; (4) hemiplegia; (5) ability to walk without physical assistance from another person; and (6) all data measured at the same time point for each individual. Subjects meeting any of the following criteria were excluded from the study: (1) musculoskeletal or neurological conditions other than stroke that could interfere with gait; (2) cognitive impairments (Hasegawa Dementia Scale-Revised; HDS-R <21/30)\textsuperscript{23}; and (3) missing records. All subjects received a con-
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Conventional stroke rehabilitation program, prescribed by a doctor, with physical therapists, occupational therapists, and speech therapists, as required. The therapies were customized and included muscle strength, balance, gait, arm activities, activity of daily living, cognitive and speech training. Therapy was carried out 7 days a week, for 2-3 h per day on weekdays and 1-2 h on Saturdays, Sundays, and national holidays.

Clinical assessments

Mini-BESTest

The Mini-BESTest contains 14 items from sections of the original BESTest related to anticipatory postural adjustments, postural responses, sensory orientation, and stability in gait. Each item is scored on a 3-level ordinal scale from 0 (severely impaired balance) to 2 (i.e., no balance impairment), and the maximum possible score is 28 points. The reliability of the Mini-BESTest has been confirmed in people with stroke.

BBS

The BBS consists of 14 items including standing and sitting unsupported, reaching forward, and placing the alternate foot on a stool, and each task is rated from 0 to 4 for a maximum score of 56 points. This assessment shows a high degree of inter-rater reliability in individuals with stroke.

CWS

Each subject’s gait speed was measured in accord with item 21 on the original BESTest. For the CWS test, the subjects were instructed to walk at his or her self-selected comfortable speed for a set distance of 6 m (i.e., “Walk at your normal speed from here past the next mark and stop”). The time taken to walk the 6 m was measured with a digital stopwatch and used to calculate the gait speed. A speed of 0.8 m/s is indicative of community ambulation. As in the previous study by Madhavan et al., a person with a gait speed ≥ 0.8 m/s was considered to be a “fast walker” and an individual with a speed lower than 0.8 was considered to be a “slow walker”.

Statistical analysis

All statistical analyses were conducted using SPSS Statistics 24.0 (IBM Corp., Armonk, NY) and Microsoft Excel. The level of statistical significance was set at 5%. The following analysis was performed on the 88 subjects with stroke for whom we were able to collect data at one point during their hospitalization. Descriptive statistical analysis was conducted for the Mini-BESTest and BBS; the floor and ceiling effects were confirmed by calculating the skewness and the proportion of subjects who obtained the minimum and maximum scores. A skewness greater than +1 indicates a substantial floor effect while a value smaller than -1 indicates a substantial ceiling effect. If the minimum and maximum scores made up a proportion of greater than 20% of the scores, this proportion was considered to be significant. Demographic characteristics were compared between fast walkers and slow walkers using independent t-tests and Fisher’s exact tests. Partial correlation analyses were used to assess the relationship between the Mini-BESTest and BBS with CWS. The age was entered into the partial correlation analysis as a covariate variable, because gait speed might be affected by aging. Correlation coefficients were categorized as follows: 0.00-0.25 = little to no relationship, 0.25-0.49 = fair correlation, 0.50-0.69 = moderate correlation, 0.70-0.89 = strong correlation, and 0.75-1.00 = very strong correlation. Receiver operating characteristic (ROC) curve analysis was used to determine the relative performance of the Mini-BESTest and BBS for classifying subjects into two groups based on their walking speeds. The accuracy of each test was assessed using the area under the curve (AUC) and its 95% confidence interval (CI), which can be interpreted as the probability of correctly classifying subjects into the designated groups (i.e., fast vs. slow walkers). An AUC value >0.9 was interpreted as showing high accuracy, 0.7-0.9 = moderate accuracy, 0.5-0.7 = low accuracy, and <0.5 = due to chance. In addition, the cut-off, sensitivity, and specificity values were then calculated from Youden’s index.

We analyzed the data of a final total of 34 stroke survivors for whom data obtained at admission to and discharge from the hospital were available. We dichotomized the 34 subjects into two groups based on their having achieved (improved) or not achieved (unchanged) important improvement in gait speed from admission to discharge. The anchor was defined as the minimal clinically important difference (MCID) of the CWS in people with subacute stroke, an improvement of 0.16 m/s (improved) and <0.5 = due to chance. For each balance assessment tool (the Mini-BESTest and BBS), we calculated the differences between assessments (discharge – admission). Differences in the Mini-BESTest and BBS change scores between the improved and unchanged groups were assessed with paired t-tests. The change score of the Mini-BESTest and that of the BBS were explored in ROC curve analyses using a dichotomized scale of the improved and unchanged subjects as the dependent variable. The AUC was used as the measure of responsiveness; an AUC value >0.7 is considered adequate.

Results

The demographic characteristics of the study subjects are summarized in Table 1. The score distributions of the Mini-BESTest and BBS are shown in Fig. 1, and the skewness values of the BBS was smaller than -1.0 (i.e., a ceiling effect). The proportions of the subjects who obtained the minimum and maximum possible scores on the Mini-
Table 1. Characteristics of study subjects

| Characteristics                        | All participants (n=88) | Gait speed group |
|----------------------------------------|-------------------------|------------------|
|                                        |                         | Fast (n=61)      | Slow (n=27)     |
| Age (years)                            | 71.1 (9.2)              | 69.4 (8.8) *     | 75.0 (8.9) *    |
| Sex (female/male), n                   | 32/56                   | 18/43            | 14/13           |
| Stroke type (ischemic/hemorrhagic/SAH), n | 61/24/3                | 40/18/3          | 21/6/0          |
| Time since stroke (days)               | 60.3 (28.5)             | 57.5 (26.1)      | 66.7 (11.3)     |
| Hemiplegic side (left/right), n        | 45/43                   | 35/26            | 10/17           |
| BRS of lower extremity (III/IV/V/VI)   | 2/5/45/36               | 0/2/29/30        | 2/3/16/6        |
| Mini-BESTest (/28)                     | 18.5 (6.4)              | 21.1 (4.0) †     | 12.4 (6.6) †    |
| BBS (/56)                              | 48.9 (12.9)             | 52.9 (7.5) †     | 39.6 (17.5) †   |
| CWS (m/s)                              | 0.98 (0.37)             | 1.17 (0.23) †    | 0.53 (0.21) †   |

Note: All values are given as means (SD); the others are categorical values. * p<0.01, † p<0.001: Significant difference between fast and slow gait speed groups. Walking gait speed was classified as fast (≥0.8 m/s) or slow (<0.8 m/s). SAH, subarachnoid hemorrhage; BRS, Brunstrom recovery stage; Mini-BESTest, Mini-Balance Evaluation Systems Test; BBS, Berg Balance Scale; CWS, comfortable walking speed.

Figure 1. Frequency distribution of scores for the Mini-BESTest and BBS.
Skewness: Mini-BESTest = -0.99; BBS = -2.56.

BESTest were 1.1% and 1.1%, and the proportions on the BBS were 0% and 34.1%, respectively. A significant ceiling effect was found in the BBS. Independent t-tests and Fisher’s exact tests comparing the characteristics, balance assessment tool scores, and gait speeds for the fast and slow walkers showed significant group differences for age, Mini-BESTest, BBS, and CWS (Table 1). The CWS showed strong correlation with the Mini-BESTest and moderate correlations with the BBS (r=0.702, p<0.001 and r=0.592, p<0.001, respectively). ROC analyses were used to further evaluate the discriminative ability of the Mini-BESTest and BBS to classify subjects into fast and slow walkers. The AUC for the Mini-BESTest was 0.874 (95% CI: 0.793-0.956; p<0.001), and the AUC for the BBS was 0.856 (95% CI: 0.773-0.940; p<0.001) (Fig. 2). The optimal cut-off point of the Mini-BESTest was determined to be 17.5, resulting in a sensitivity of 80.3 % and a specificity of 81.5%. The optimal cut-off point of the BBS was determined to be 53.5, resulting in a sensitivity of 75.4% and a specificity of 85.2%.

A total of 34 people with stroke were subjects in the change score analysis. The average duration of hospitalization for these subjects was 44.2 (22.0) days, and the proportion of the improved group was 52.9% (n=18). A significant difference was observed between the improved group and the unchanged group in the change on the Mini-BESTest (p<0.001), but not in the change on the BBS (p=0.866) (Table 2). The Mini-BESTest demonstrated excellent ability to discriminate between improved and unchanged subjects according to the ROC analysis; the AUC was 0.894 (95%CI: 0.775-1.000; p<0.001, Fig. 3).
Discussion

Balance assessment using Mini-BESTest is increasingly being applied to individuals with stroke. However, there have been no reported comparisons of the measurement properties and relationship with change in gait speed of the Mini-BESTest and the BBS in self-ambulatory individuals with subacute stroke. Therefore, in this study, we compared the measurement properties and the correlations with gait speed of the two balance assessment tools in a cohort of middle and older individuals with subacute stroke. Further, we investigated which balance assessment tool was best able to measure recovery related to recovery. Our results suggested that the Mini-BESTest is more useful than the BBS in terms of its measurement properties and its ability to measure recovery, but not in terms of its relationship with gait speed. To the best of our knowledge, this is the first study to compare the newly developed Mini-BESTest with the BBS in middle and older ambulatory people with subacute stroke.

Our results revealed that the Mini-BESTest is the only balance assessment tool related to the relationship between balance and gait speed recovery. It is important to capture the changes in physical functions and abilities at the recovery stage of stroke, and our present findings indicate that such changes may be better captured by the Mini-BESTest than the BBS, which has been widely used. After a stroke, the survivor can recover gait speed and balance through balance training. Age has been reported to affect a patient’s recovery after stroke. We therefore analyzed middle and older ages stroke survivors. Balance is a composite ability that involves rapid, anticipatory, reactive integration plus sensory strategies based on information derived from several systems. The characteristics of balance after stroke include postural and weight-bearing asymmetry, reduced external force reaction, anticipatory postural adjustments, and dual tasks in standing and walking. Unlike the Mini-BESTest, the BBS does not include tests of postural reactions or dynamic gait, and it may thus miss some deficits. The Mini-BESTest includes four categories of balance: anticipatory, reactive postural control, sensory orientation, and dynamic gait. The BBS was not designed with such systems in mind, but if a system categorization is assigned to each item, the BBS items evaluate primarily the

![Figure 2](image1.png)  
**Figure 2.** Receiver operating characteristic curve of the Mini-BESTest and the BBS for categorizing subjects into fast and slow walkers (n=88).

![Figure 3](image2.png)  
**Figure 3.** Receiver operating characteristic curve of the change score of the Mini-BESTest and the BBS for categorizing the subjects into the improved and unchanged groups (n=34).

| Test          | CWS change | Admission score | Discharge score | Change score | p    | AUC (95% CI)    |
|---------------|------------|-----------------|-----------------|--------------|------|----------------|
| **Mini-BESTest** | Improved   | 14.4 (6.9)      | 21.3 (4.8)      | 6.8 (3.8)    | <0.001 | 0.894 (0.775-1.000) |
|               | Unchanged  | 19.5 (4.6)      | 21.6 (4.4)      | 2.1 (1.8)    |       |                |
| **BBS**       | Improved   | 42.8 (15.0)     | 53.8 (4.0)      | 10.9 (11.9)  | 0.866 | 0.543 (0.345-0.742) |
|               | Unchanged  | 44.3 (13.2)     | 54.5 (2.9)      | 10.3 (11.8)  |       |                |

Note: Values are given as means (SD); MCID, minimal clinically important difference; CWS, comfortable walking speed; Mini-BESTest, Mini-Balance Evaluation Systems Test; BBS, Berg Balance Scale; AUC, area under the curve.
Gait speed and balance are well associated. This might be of relevance for physical therapists, as necessary to have fast gait speed and achieve community ambulation ability of 18 to 19 on the Mini-BESTest may be needed. Further prospective studies of the BBS are thus needed.

The Mini-BESTest showed a good distribution of scores without a ceiling effect and showed less skewness than the BBS in this study. The results of other investigations showed that the Mini-BESTest has a wider distribution than the BBS and has no ceiling effect\(^{12,13}\). It was suggested that the Mini-BESTest is useful for evaluating the functional abilities of ambulatory people because the Mini-BESTest, a shorter version of the original BESTest, was developed to assess functional balance, and it focuses on tasks that involve gait and dynamic balance\(^{14}\). The BBS is a commonly used tool for assessing balance post-stroke, but it does not include challenging tasks that test dynamic balance\(^{15}\). The BBS can thus exhibit a ceiling effect in individuals who have achieved moderate recovery.

In the present study, the correlation adjusted by age between the Mini-BESTest and gait speed was similar to the correlation obtained with the BBS. In addition, the Mini-BESTest and BBS scores were different for the cohorts of slow versus fast walkers, and the AUC regarding the discriminative ability to classify subjects into slow and fast walkers was moderate in both the Mini-BESTest and the BBS. The optimal cut-off point for the Mini-BESTest was 17.5, and that for the BBS was 53.5. Cut-off points of gait speed (≥0.8 m/s) have been reported for the Mini-BESTest and the BBS in people with chronic stroke\(^{16}\). A cut-off point <18.5 on the Mini-BESTest and <47.5 on the BBS indicates stroke survivors who walk slowly. This value of the Mini-BESTest was similar to the cut-off points in our present study; at any time for stroke survivors, a balance ability of 18 to 19 on the Mini-BESTest may be necessary to have fast gait speed and achieve community ambulation. This might be of relevance for physical therapists, as gait speed and balance are well associated\(^{17}\), but since the BBS results differ between the subacute and chronic stages, additional research is necessary to clarify this point.

This study has findings that are important for clinical practice, as it recommends the use of the Mini-BESTest to evaluate the balance of middle and older ambulatory people with subacute stroke. A valid and reliable assessment tool is needed to evaluate ambulatory individuals with subacute stroke and to determine how to intervene to provide rehabilitation for such individuals who have the ability to walk without physical assistance. Herein, the Mini-BESTest showed a better distribution of scores compared to the BBS and had no ceiling effect. The Mini-BESTest is also considered a good balance assessment tool that can capture an individual’s recovery based on the relationship with the change in gait speed among middle and older ambulatory individuals with subacute stroke.

There were several limitations to this study. First, there may have been a self-selection bias among the subjects because they participated in different studies at each hospital. In addition, this study included a sample of individuals with subacute stroke who were ambulatory with or without aid. Also, the measurement of gait speed was carried out in accordance with the original BESTest, and no preliminary pathway was provided. Therefore, the generalization of our results may be limited. Further research performed with consideration of all these issues is required.

**CONCLUSIONS**

Our findings demonstrated that the Mini-BESTest and the BBS are valid scales for assessing balance control in middle and older individuals with subacute stroke who are able to walk. The Mini-BESTest seems to be the preferable balance assessment tool for middle and older ambulatory individuals with subacute stroke due to its lack of a ceiling effect, better responsiveness, and ability to capture the status of gait recovery. However, for individuals with poorer walking function, the BBS may be more suitable. Defining the levels of gait speed that best correspond to the use of each of these scales may be helpful in clinical practice.

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