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Original Article

Sensitivity to change and responsiveness of the Balance Evaluation Systems Test (BESTest), Mini-BESTest, and Brief-BESTest in patients with subacute cerebral infarction

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Abstract. [Purpose] To compare the sensitivity to change and responsiveness of the Balance Evaluation Systems Test, Mini-Balance Evaluation Systems Test, and Brief-Balance Evaluation Systems Test in patients with subacute cerebral infarction. [Participants and Methods] Thirty patients with subacute cerebral infarction participated in this study. The Balance Evaluation Systems Test, Mini-Balance Evaluation Systems Test, Brief-Balance Evaluation Systems Test, Berg Balance Scale, and ambulatory ability were assessed on admission and discharge. Sensitivity to change was calculated using the effect size, standardized response mean, and relative efficiency. Responsiveness was analyzed by comparing the ability of the difference between the scores of the balance assessments at admission and discharge in classifying the participants' ambulatory independence. [Results] All assessments showed significant improvement from admission to discharge. The effect size of the three versions of the Balance Evaluation Systems Test ranged from 0.41 to 0.69. The standardized response mean ranged from 0.75 to 1.28. The cutoff score was 16.7% for the Balance Evaluation Systems Test, 5.5 points for the Mini-Balance Evaluation Systems Test, 1.5 points for the Brief-Balance Evaluation Systems Test, and 3.5 points for the Berg Balance Scale. [Conclusion] The sensitivity to change of the three versions of the Balance Evaluation Systems Test was high or moderate. However, the Mini-Balance Evaluation Systems Test had the highest responsiveness, as determined with the extent of ambulatory independence.

Key words: BESTest, Stroke, Responsiveness

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INTRODUCTION

Patients with stroke present with various impairments or disabilities[1)]. In particular, balance impairment correlates strongly with gait ability[1–4)] or activities of daily living (ADL)[1, 2)] and outcome[5)], so that it is important to evaluate balance ability of patients with stroke. The Berg Balance Scale (BBS) is considered the gold standard for assessing balance in patients with stroke[6)]. However the BBS does not distinguish various aspects of balance ability. The Balance Evaluation Systems Test (BESTest) is a balance assessment that distinguishes 6 aspects of balance ability[7)]: Biomechanical constraints, Limits of stability, Anticipatory adjustments, Postural responses, Sensory orientation, and Stability in gait. The BESTest is produced in two short forms, the Mini-BESTest[8)] and the Brief-BESTest[9)]. The Mini-BESTest was developed to specifically assess

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dynamic balance. The Brief-BESTest consists of 6 items from each part of the original BESTest. It has been demonstrated that the BESTest, Mini-BESTest and Brief-BESTest have excellent reliability and validity for patients with Parkinson's disease (PD), stroke or other neurological diseases in previous studies[7–17].

Sensitivity to change and responsiveness are also important measurement properties in addition to reliability and validity[18–20]. Sensitivity to change is defined as the ability of an instrument to measure a change in state, regardless of whether the change is relevant or meaningful to the decision-maker[19, 21]. Responsiveness is defined as the ability of an instrument to measure a meaningful or important change in a clinical state[19, 21]. Sensitivity to change is a necessary but insufficient condition for responsiveness[19]. Responsiveness is the detection of change over time in the construct to be measured, and score changes over time as derived from the assessment instruments should be compared and correlated to those of a gold-standard or an external criterion[22]. Recent studies examined the responsiveness of the 3 versions of the BESTest[12, 23–25]. They recruited participants with balance disorders including PD or stroke[12], subacute stroke[23, 24], and musculoskeletal disease[25]. They then used the Global Rating of Change (GRC)[12, 23], BBS[23, 24], and Functional Gait Assessment (FGA)[25] as external criteria. However, they did not investigate responsiveness of the 3 versions of the BESTest in ambulatory independent patients with subacute stroke. Outcome measure scores including the Functional Independence Measure (FIM) score are strong predictors of discharge destination in patients with stroke[26]. Ambulatory independence, one of the items of the FIM, is one of the important factors in patients with stroke whose aim is to be discharged home.

The purpose of this study was to examine sensitivity to change and responsiveness of the BESTest, Mini-BESTest, and Brief-BESTest assessing ambulatory independence and to compare the 3 versions of the BESTest for sensitivity to change and responsiveness in patients with subacute cerebral infarction.

PARTICIPANTS AND METHODS

The participants were patients with cerebral infarction referred to the physical therapy service at a convalescent rehabilitation ward of Public Nanokaichi Hospital in Japan. Individuals were included in this study if they met the following criteria as screened by physical therapists: diagnosis of cerebral infarction with stable medical condition, onset within 2 months, and ability to follow instructions to complete the assessment. The exclusion criteria were as follows: neurological conditions other than stroke or musculoskeletal conditions that affect balance, and any other serious illnesses or pain that precluded participation. Prior to taking part in the study, all participants signed an informed consent form that had been approved by the Ethics Committee of the Public Nanokaichi Hospital.

The BESTest consists of 36 items graded on a 0 to 3 scale, with higher numbers signifying better balance and a maximum of 108 points[7]. The total score was converted into a percentage score. The Mini-BESTest consists of 14 items focusing on dynamic balance; it contains some items from section 3 to section 6 of the original BESTest[8]. The score for each item ranges from 0 (severe impairment) to 2 (no impairment). The total possible score on the Mini-BESTest is 28 points. The Brief-BESTest is a 6-item balance assessment containing 1 item from each of the 6 subsections of the original BESTest[9]. Items were chosen based on correlational analysis. The 1 item from each specific section of the original BESTest with the strongest correlation to that total section score was included in the Brief-BESTest. Each item was scored the same as in the original test; performance was rated 0 to 3, with 0 representing severe balance impairment or inability to perform a task without falling and 3 representing no balance impairment. Because 2 of the items in the Brief-BESTest have left and right components, the maximum possible score for the Brief-BESTest is 24 points. The BBS consists of 14 functional balance items. Each item is scored on a 5-point ordinal scale ranging from 0 (unable to perform) to 4 (normal performance), so that the aggregate score ranges from 0 to 56[6].

Three physical therapists were included as the raters. Prior to the study, the 3 raters had enough discussion to ensure that scoring was sufficiently reliable. All participants were evaluated with the balance assessments twice, within a month at admission to and at discharge from the convalescence rehabilitation ward. Each participant's demographic and clinical information (Brunnstrom Recovery Stage [BRS][27], BBS, FIM[28], and ambulatory ability) was assessed by the responsible physical therapists or nurses. In this study, ambulatory independence was defined as the ability to walk stably at the full range of convalescence ward with a T-cane or without an assistive device. The only assistive device permitted was a T-cane; walkers or any other devices were not permitted.

All statistical analyses were performed using IBM SPSS software version 25.0. The significance level was set a priori at $\leq$0.05. Descriptive statistics were calculated for demographic and clinical information. Paired t-tests were used to compare balance scores at admission and discharge. The effect size (ES) was calculated by dividing the observed mean change scores by the standard deviation of the first score for the same participant[29–31]. The standardized response mean (SRM) was calculated by dividing the observed mean change score by the standard deviation of the change score for the same participant[24, 25, 29–31]. For the ES and SRM, greater than 0.8 was considered a large change, 0.5 to 0.8 a moderate change, and 0.2 to 0.5 a small change[25, 29–31]. The relative efficiency (RE) was calculated from paired-samples t-tests as pairwise squared t-values (t^2 scale 1 / t^2 scale 2)[32]. In this study, the RE calculated substituting the BBS for scale 2 and any one of the 3 versions of the BESTest for scale 1 to compare with the BBS as the gold standard for assessing balance for sensitivity to change. An RE of greater than 1 indicates that the sensitivity to change of any one of the 3 versions of the BESTest is greater than that of the BBS, and an RE of less than 1 indicates that the sensitivity to change of any one of the 3 versions of the BESTest is inferior to that of the BBS.

The ES, SRM, and RE for the 3 versions of the BESTest were used to indicate sensitivity to change. To examine responsiveness, ambulatory independence was used as the external criterion. The 27 participants without ambulatory independence at admission were classified into 2 groups at discharge based on whether they had achieved ambulatory independence. Receiver operating characteristic (ROC) curves were used to assess the ability of the difference between admission and discharge of the 4 balance assessments to correctly classify participants into 2 groups, and the area under the curve (AUC) was determined for each. The optimal cutoff value of balance assessments for ambulatory independence was determined using the Youden index in the present study[34].The cutoff scores to assess the ability of the difference between admission and discharge of the 4 balance assessments to correctly classify participants into 2 groups (participants with or without ambulatory independence at discharge) were determined to indicate responsiveness.

RESULTS

Thirty patients with cerebral infarction participated in this study. Fourteen out of 27 patients without ambulatory independence at admission became ambulatory independence at discharge. The demographic and clinical characteristics of the participants are shown in Table 1. Table 2 shows the score of the balance assessments at admission and discharge in the convalescence rehabilitation ward and the indices of sensitivity to change (ES, SRM, and RE) for all participants. All assessments showed significant improvement from admission to discharge. For the results of the ES, the BESTest sectionIII (0.51), IV (0.51), V (0.51), VI (0.71), BESTest total (0.56), Mini-BESTest (0.69), and BBS (0.74) showed moderate changes. For the results of the SRM, the BESTest sectionI (1.16), III (1.06), IV (0.87), V (0.97), VI (1.03), BESTest total (1.28), Mini-BESTest (1.17), and BBS (1.28) showed large changes, and BESTest sectionII (0.67), and Brief-BESTest (0.75) showed moderate changes. The REs of all balance assessments were less than 1, and the RE of the BESTest total (0.99) was the highest of all balance assessments. Table 3 shows the cutoff score and associated sensitivity, specificity, and AUC of each balance assessment for classifying participants by ambulatory independence at discharge. The cutoff score for the difference between

Table 1. Participants' characteristics (n=30)

Characteristics	Mean ± SD Median [first–third quartile]
Age (years)	76.4 ± 10.4
Gender: male/female (n)	17/13
Duration since stroke onset (days)	23.9 ± 10.5
Time between 2 assessments (days)	78.7 ± 54.2
Paretic side: right/left (n)	19/11
BRS: Upper extremity (n)	5.0 [5.0–6.0]
BRS: Hand (n)	5.0 [4.0–6.0]
BRS: Lower extremity (n)	5.0 [4.0–6.0]
FIM (points)	78.2 ± 27.1

BRS: Brunnstrom recoery stage; FIM: functional independence measure.

Table 2. Score distributions and indices of sensitivity to change of the balance assessments

Measure	Mean ± SD			ES	SRM	RE
	at admission	at discharge	change score			
BESTest SectionI (%)*	56.4 ± 29.6	70.7 ± 27.9	14.2 ± 12.3	0.48	1.16	0.81
BESTest SectionII (%)*	77.3 ± 25.6	85.7 ± 21.0	8.4 ± 12.5	0.33	0.67	0.28
BESTest SectionIII (%)*	49.3 ± 30.4	64.6 ± 27.9	15.4 ± 14.5	0.51	1.06	0.69
BESTest SectionIV (%)*	47.6 ± 36.6	66.3 ± 34.6	18.7 ± 21.6	0.51	0.87	0.46
BESTest SectionV (%)*	54.9 ± 35.1	72.7 ± 28.1	17.8 ± 18.4	0.51	0.97	0.57
BESTest SectionVI (%)*	34.1 ± 34.1	58.3 ± 33.8	24.1 ± 23.5	0.71	1.03	0.65
BESTest Total (%)*	53.3 ± 29.4	69.7 ± 26.8	16.5 ± 12.9	0.56	1.28	0.99
Mini-BESTest (points)*	10.3 ± 8.0	15.8 ± 7.7	5.5 ± 4.7	0.69	1.17	0.83
Brief-BESTest (points)*	8.7 ± 7.3	11.7 ± 7.0	3.0 ± 4.0	0.41	0.75	0.35
BBS (points)*	32.8 ± 19.1	46.9 ± 13.6	14.1 ± 11.0	0.74	1.28	-

ES: effect size; SRM: standardized response mean; RE: relative efficiency; BESTest: Balance Evaluation Systems Test; BBS: Berg Balance Scale.
*$p<0.001$ for comparison after admission with before discharge.

Table 3. Cutoff scores and associated values for sensitivity, specificity, and AUC of the four balance assessments for classifying participants with ambulatory independence at discharge

Classification	BBS	BESTest	Mini-BESTest	Brief-BESTest
Cutoff score	3.5 points	16.7%	5.5 points	1.5 points
AUC	0.62	0.77	0.82	0.77
Sensitivity (%)	93.3	73.3	73.3	80.0
Specificity (%)	33.3	75.0	91.7	66.7

BBS: Berg Balance Scale; BESTest: Balance Evaluation Systems Test; AUC: area under the curve.

admission and discharge of the 4 balance assessments to classify participants into 2 groups (with or without ambulatory independence at discharge) were 16.7% (sensitivity 73.3%, specificity 75.0%) for the BESTest, 5.5points (sensitivity 73.3%, specificity 91.7%) for the Mini-BESTest, 1.5 points (sensitivity 80.0%, specificity 66.7%) for the Brief-BESTest, and 3.5 points (sensitivity 93.3%, specificity 33.3%) for the BBS. The AUCs were high for the Mini-BESTest (0.82), BESTest total (0.77), and Brief-BESTest (0.77), in the order of the BBS (0.62).

DISCUSSION

Sensitivity to change and responsiveness of the BESTest, Mini-BESTest, and Brief-BESTest in patients with subacute cerebral infarction at a convalescence rehabilitation ward were examined. In terms of sensitivity to change assessed by the ES and SRM, the BESTest and Mini-BESTest showed high or moderate change, and the Brief-BESTest showed moderate or low change. The BESTest had the highest sensitivity to change as assessed by the RE on the basis of change in the BBS as the gold standard for assessing balance. The Mini-BESTest had the highest responsiveness determined by the extent of ambulatory independence.

Sensitivity to change is defined as the ability of an instrument to measure a change in state, regardless of whether the change is relevant or meaningful to the decision-maker[19, 21)]. Responsiveness is defined as the ability of an instrument to measure a meaningful or important change in a clinical state[19, 21)]. The ES and SRM are used as parameters of responsiveness[23, 24)], as well as sensitivity to change[20, 35–37)]. However using parameters such as the ES or SRM to assess responsiveness in common states is inappropriate[22)]. In this study, the ES, SRM and RE were used as parameters of sensitivity to change. Responsiveness evaluated by score changes over time as derived from the assessment instruments should be compared and correlated to those of a gold-standard or an external criterion[22)]. In this study, ambulatory independence was used as an external criterion of responsiveness.

The ES and SRM showed moderate and high sensitivity to change, respectively[20, 21)]. An RE of greater than 1 would indicate that the responsiveness of the 3 versions of the BESTest was greater than that of the BBS, and an RE of less than 1 would indicate that the responsiveness of the 3 versions of the BESTest was inferior to that of the BBS[32)]. Consequently, the 3 versions of the BESTest showed high sensitivity to change. A recent study considered the SRM of the 3 versions of the BESTest and BBS in patients with acute or subacute stroke, and they demonstrated that the 4 balance assessments had good results (SRM: 0.9–1.6)[23, 24)]. The results of the present study agree well with these previous studies. The BESTest and Mini-BESTest are highly useful, and the Brief-BESTest is moderately useful for measuring change of balance ability in patients with subacute stroke.

For responsiveness in the present study, ambulatory independence was used as an external criterion. The reason for using ambulatory independence as an external criterion is that it is so important for patients with stroke at a convalescent rehabilitation ward, and it is related closely to balance ability[3, 4)]. The relationship between balance assessments and ambulatory independence is clear. An AUC of greater than or equal to 0.8 is considered to show excellent discrimination[12, 23)]. Only the Mini-BESTest showed excellent responsiveness (AUC: 0.82), and the other 3 balance assessments showed moderate responsiveness (AUC of the 3 balance assessments: 0.62–0.77). Duncan et al.[33)] considered the accuracy of the 3 versions of the BESTest for identifying recurrent fallers among patients with PD, and they noted that the accuracies of the BESTest (AUC: 0.84), Mini-BESTest (AUC: 0.86), and Brief-BESTest (AUC: 0.82) for identifying recurrent fallers based on retrospective fall reports were all excellent. Godi et al.[12)] considered the accuracy of the Mini-BESTest and BBS in classifying individual patients who showed significant improvement in balance function, and they found that the accuracies of the Mini-BESTest (AUC: 0.92) and BBS (AUC: 0.91) in patients with balance disorders (including PD or stroke) were excellent. Madhavan et al.[3)] compared the discriminative ability of the Mini-BESTest and BBS to categorize walking speeds in patients with chronic stroke, and they found that the Mini-BESTest had higher accuracy to discriminate slow and fast walkers (AUC Mini-BESTest: 0.81; AUC BBS: 0.67). Chinsongkram et al.[14)] considered the responsiveness of the BESTest and Mini-BESTest on the basis of BBS score changes, and they found that the AUCs of the BESTest and Mini-BESTest were excellent (0.92 and 0.89, respectively). Winairuk et al.[23)] compared the responsiveness of the BESTest, Mini-BESTest, and Brief-BESTest using the BBS and the GRC in patients with subacute stroke, and they found that the BESTest had higher accuracy (AUC: 0.89), and the Mini-BESTest and Brief-BESTest had moderate accuracy (AUC: 0.68–0.79 and 0.77–0.79, respectively) using the BBS, and the 3 versions of the BESTest had moderate accuracy (AUC: 0.50–0.73) using the GRC. The present study showed that the Mini-BESTest had excellent responsiveness, and the BESTest and Brief-BESTest had moderate responsiveness assessed using ambulatory independence as an external criterion in patients with subacute stroke. The Mini-BESTest was developed to specifically assess dynamic balance[8]. This test suggests that it is important to assess dynamic balance abilities to determine ambulatory independence for patients with subacute stoke. The cutoff scores to assess the ability of the difference between admission and discharge of the 4 balance assessments to correctly classify participants into 2 groups (participants with or without ambulatory independence at discharge) were determined. The cutoff score indicates amount of change of the balance assessments that is needed for patients with subacute stroke to become ambulatory independence, and help therapists to interpret the result of the balance assessments. The results suggest that acquiring the ability to walk stably at the full range of convalescence with a T-cane or without an assistive device in patients with subacute stroke is predicted by change of the balance ability equal to greater than the cutoff score of the 3versions of the BESTest and BBS.

Balance assessments were performed twice in the present study. However, the time between the two assessments was not clearly specified, so that it ranged from several weeks to several months and was different depending on the participants. This is a limitation of present study. If the time between the two assessments were to be specified, sensitivity to change and responsiveness for each recovery process would be more distinct.

In conclusion, the BESTest and Mini-BESTest showed high or moderate sensitivity to change and the BESTest showed sensitivity to change equivalent to that of the BBS. The Mini-BESTest had the highest responsiveness determined by the extent of ambulatory independence. The cutoff score for ambulatory independence was: 3.5 points for the BBS; 16.7% for the BESTest; 5.5 points for the Mini-BESTest; and 1.5 points for the Brief-BESTest.

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