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Original Article

Structural validity of Balance Evaluation Systems Test assessed using factor and Rasch analyses in patients with stroke

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Abstract. [Purpose] The Balance Evaluation Systems Test (BESTest) is a comprehensive assessment tool, although it is not confined for use in stroke patients. This study aimed to determine the structural validity of the BESTest in self-ambulatory patients with stroke using both factor and Rasch analyses. [Participants and Methods] This retrospective study included 140 self-ambulatory patients with stroke. The structural validity of the BESTest was analyzed according to principal component, exploratory factor, Rasch, confirmatory factor, and correlation analyses. [Results] The analytical results supported a four-factor model comprising 25 items. The four factors included dynamic postural control with gait, static postural control, stepping reaction, and stability limits in sitting. Evidence of high structural validity and reliable internal consistency suggested that the 25-item BESTest is valid and reliable. Each factor was significantly correlated with lower extremity motor function and walking ability. [Conclusion] Eleven items in the BESTest were poorly correlated, and the remaining 25 items were grouped into four factors that demonstrated good structural validity for patients with stroke. Further studies should validate the applicability of the 25-item BESTest four-factor model in a larger sample of patients with stroke in a clinical setting.

Key words: BESTest, Balance of stroke patients, Structural validity

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INTRODUCTION

Stroke is a major cause of disability and a global burden on disease load[1]. Dysfunction in balance control is one of the most common physical impairments caused by stroke[2]. The loss of balance ability has been associated with reduced ambulatory function[3], poorer performance in activities of daily living[4], and an increased risk of falls[5]. Accordingly, interventions for balance disorders are important[6].

Balance is a composite ability that involves rapid, automatic, anticipatory, reactive integration, and sensory strategies based on information derived from several systems[7]. The characteristics of balance after stroke comprise postural and weight-bearing asymmetry[2], reduced external force reaction[8], anticipatory postural adjustments[9], and dual-tasks in standing and walking[10]. These characteristics also persist in self-ambulatory persons after stroke. A standardized assessment

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of balance function is essential to clarify balance dysfunction after stroke and to better assess the effects of intervention programs[11, 12]. Several tools can assess balance, but none specifically target people with stroke[13]. Moreover, few tools consider the complexity of the multiple physiological systems that are implicated in balance control.

The Balance Evaluation Systems Test (BESTest) was designed as a comprehensive balance assessment tool to assess specific underlying balance impairment[14]. It comprises 36 items representing six underlying postural control systems: biomechanical constraints, stability limits and verticality, anticipatory postural adjustments, postural responses, sensory orientation, and stability in gait. Since its introduction in 2009, the BESTest has been increasingly used for evaluating balance function in various populations. The BESTest has excellent reliability and validity[14–16], and it has been used to evaluate balance deficits in various pathological conditions, including stroke[15], Parkinson disease (PD)[16] and knee osteoarthritis[17]. Moreover, the BESTest has high responsiveness with no floor and ceiling effects in patients with subacute stroke[18]. Over the past few years, a balance theory of the BESTest has emerged after the separate publications of several analyses of scores for each postural control system[15, 17, 19–21]. Additionally, the BESTest was identified as the only standardized balance tool that can consistently measure all components of balance with established conceptual models of the "Systems Framework of Postural Control"[22]. However, administering the BESTest is laborious. To address these potential limitations, a short version of the BESTest, namely the Mini-BESTest[23] has been developed. The Mini-BESTest is a unidimensional scale that focuses on assessing "dynamic balance". The structural validity of the Mini-BESTest has been investigated in patients with PD using factor and Rasch analyses[24]. That study validated the Mini-BESTest as a multidimensional measure of balance control that targets highly relevant aspects of balance. The Mini-BESTest had been regarded as a unidimensional scale that can also reveal different structure of the balance component among persons with various diseases. Evaluation and intervention are facilitated by a clear definition of the structure of the balance component associated with various diseases. Therefore, examinations using the BESTest that contains all components of balance facilitate understanding of the structure of the balance component in stroke.

The present study aimed to determine the structural validity of the BESTest using both factor and Rasch analyses of self-ambulatory patients with stroke.

PARTICIPANTS AND METHODS

The Gunma University Ethical Review Board for Medical Research Involving Human Subjects (No.15-73) and the Ethics Committees at Hidaka Hospital (No.112), Hidaka Rehabilitation Hospital (No.151101) and Public Nanokaichi Hospital (20160208) approved this study.

The study included 140 patients with stroke who participated in a rehabilitation program at a hospital convalescent rehabilitation ward between 2010 and 2015. The study inclusion criteria were: diagnosis of cerebral infarction, cerebral hemorrhage, or subarachnoid hemorrhage; unilateral hemiplegia; and able to walk without physical assistance from another person (functional ambulation category [FAC] ≥3). Exclusion criteria were: other neuromuscular disorders; missing records in analytical data.

This retrospective study analyzed data from electronic medical records and the database of convalescent rehabilitation centers at the participating institutions. All the data were measured within one week. The BESTest contains 27 items, with some containing two or four subitems (such as separate items for left and right sides), for a total of 36 items. Each item is rated using a 4-level rating scale ranging from 0 to 3, representing severe and no balance impairment, respectively. Maximum scores are calculated as ratios (%) of the maximum possible score of 108, and higher scores indicate better balance performance[14]. The reliability of the BESTest has been confirmed in patients with stroke[15]. Lower extremity motor function was assessed according to the six motor stages defined by Brunnstrom, where lower stages indicate a greater motor deficit. The Brunnstrom recovery stage is reliable for stroke[25]. Walking ability was assessed using the 10-m maximum walking speed (10MWS)[26] test in which participants walked for 16 m at maximum speed. The time taken to walk the central 10 m was measured using a digital stopwatch and used to calculate gait speed. The 10MWS has excellent test-retest reliability (intraclass correlation coefficient, >0.9) for patients with stroke[27].

Five psychometric methods were used to evaluate the structural validity, construct validity, and item response of the BESTest. The measurement properties of the BESTest in patients with stroke were statistically assessed as follows. The unidimensionality of the BESTest was evaluated using principal component analysis (PCA). If >1 dimension was present, the dimensionality of the instrument was assessed using exploratory factor analysis (EFA) that organizes items into factors according to their interrelationships. Unidimensionality, each factor and item responses were assessed using Rasch analysis (RA). As an additional descriptive step, the fit indices of the model based EFA[24, 28] were subsequently estimated from raw data in the same sample and from two other models based original BESTest using confirmatory factor analysis (CFA). Construct validity was determined for each factor of the model based on EFA, lower extremity motor function and walking ability using correlation analyses. Data were statistically analyzed using R 3.4.2 statistical software (R Core Team, Vienna, Austria, 2017). The Item Analysis Package with Standard Errors (rela; http://cran.r-project.org/package=rela; 2009) was used for EFA. The Psychological, Psychometric, and Personality Research Package (psych, http://personality-project.crg/r/psych; 2017) was used for EFA and CFA. The Extended Rasch Modeling Package (eRm; http://r-forge.r-project.org/projects/erm/; 2016) was used for RA. The Latent Variable Analysis Package (lavaan; http://lavaaan.org; 2017) was used for CFA.

We confirmed the unidimensionality of 36 items of the BESTest with PCA based on an Eigenvalue of the first component of ≤2[24]) or the number of factors retained with Eigenvalues >1.

The BESTest item factor structure and reduction were determined using EFA. The suitability of the data was confirmed using the Kaiser-Meyer-Olkin (KMO) measures and the Measure of Sampling Adequacy (MSA). The KMO proposed by Kaiser is as follows ≥0.9,=marvelous; ≥0.8, meritorious; ≥0.7, middling; ≥0.6, mediocre; <0.5, miserable[29]). Variables with MSA<0.5 indicate that item does not belong to a group and may be removed from the EFA[30]). Parallel analysis was applied to determine the number of factors. We used maximum likelihood estimation and orthogonal rotation (Varimax). The number of items were reduced by eliminating factors with a loading of <0.4 from the scale. The analysis was then applied to the reduced item set. The ratio (%) of variance accounted for by a factor was estimated from Eigenvalues.

Responses to items of factors in the model determined by EFA were assessed using RA with a partial credit model (PCM), which assumes that the distance between response options is not identical for all items. The internal construct validity was assessed by determining how well the raw data fit the Rasch model. Fit statistics were calculated as infit, which is the most sensitive for rating items located close to the ability of a person and outfit, which is more influenced by the rating of off-target items. Fit statistics are routinely reported as means of squared residuals (MnSq). According to Wright and Linacre, a MnSq of 0.5 to 1.7 could be considered a reasonable range for infit and outfit measures in clinical observations[31]). The Rasch model provides estimates of the level of difficulty achieved for each item (item difficulty measure), and this parameter is expressed on a common interval scale in logit units. The distribution of latent dimensions and the sequencing of category difficulty thresholds were evaluated using person-item maps. The match of raw data with the Rasch model was determined using fit statistics tests to assess whether each factor was unidimensional by running PCA on the residuals (first residual factor ≤2).

The structural validity of each model was confirmed using CFA with maximum likelihood estimation methods. Data fit was assessed for the following models: 36-item BESTest 1-factor (original), 36-item BESTest 6-factor (original) and guided by the EFA model. Model-data fit was assessed using range of fit statistics[32, 33]). The ratio of χ^2 to degrees of freedom was <3, the root mean square error of approximation (RMSEA) was <0.8, and comparative fit index (CFI) and Tucker-Lewis index (TLI) indices were >0.9. Both Akaike information criteria (AIC) and Bayesian information criteria (BIC) were calculated, with lower values suggesting better model fit.

The psychometric properties of each factor in the model based EFA were clarified using correlation analyses. Relationships between total scores for each factor, BRS and 10MWS were assessed using Spearman rank correlation coefficients. The criteria for correlation coefficients comprised >0.8 (excellent), >0.5 (moderate), and <0.5 (poor)[34]). The level of statistical significance was set at $p<0.05$.

RESULTS

Complete datasets were obtained from all 140 participants and Table 1 shows their assessment outcomes. Table 2 shows the descriptive analysis for the 36-item BESTest.

The 36 items of the BESTest were assessed by PCA. The first component had an Eigenvalue >2 (3.64) and five factors had Eigenvalues >1, indicating that the scale might not be unidimensional.

The suitability for EFA was confirmed by a KMO of 0.88 and items 1, 6c, and 6d had values <0.5 (0.29, 0.49 and 0.49, respectively). Three items were deleted, and 33 items were analyzed for EFA. According to parallel analysis results, the optimal number of factors to analyze was four. The factorial structure with optimal interpretability was that of orthogonal rotation (Table 3). The four factors and 25 items were created from the EFA and included dynamic postural control with gait (factor 1), static postural control (factor 2), stepping reaction (factor 3), and stability limits in sitting (factor 4). Items 3, 4, 7, 8a, 8b, 13, 14, and 27 were reduced because factor loadings was <0.4.

Table 1. Characteristics of participants

Characteristics	Mean (SD)
Age (yrs)	70.0 (11.3)
Gender (female/male)	47/93
Stroke type (ischemic/hemorrhagic/SAH)	94/40/6
Time since stroke (days)	77.9 (56.7)
Hemiplegia (left/right)	69/71
BRS of lower extremity (III/IV/V/VI)	3/22/66/49
FAC (3/4/5)	38/85/17
10MWS (m/s)	1.0 (0.5)
BESTest score (%)	69.3 (18.2)

BESTest: balance evaluation systems test; BRS: Brunnstrom recovery stage; FAC: functional ambulation categories; MWS: maximum walking speed; SAH: subarachnoid hemorrhage; SD: standard deviation.

Four factors based on EFA were estimated using RA. Table 4 shows item difficulty measures and fit information. Overall, three items of the 25-item BESTest 4-factor model misfit the underlying construct (infit and outfit MnSq between 0.5 and 1.7). More precisely, items 6b (infit MnSq, 0.474), 9 (outfit MnSq, 0.489), and 19a (infit MnSq, 0.405 and outfit MnSq, 0.428) overfit the model. Figure 1 presents a person-item map, which is the simultaneous location of patient balance ability and item difficulty estimates along the 25-item BESTest four-factor model. Item difficulty was evenly spread from the easiest (items 22, 19a, 16, and 6b for factors 1, 2, 3 and 4, respectively) to the most difficult (items 25, 11a, 18a, and 6a for factors 1, 2, 3 and 4, respectively. Ability estimates for each person spanned from −2.969 to 4.034, −3.680 to 4.202, −1.833 to 2.194, −1.209 to 2.278 logits for factors 1, 2, 3 and 4, respectively. To estimate whether the four factors were unidimensional, residuals from the four separate RA were included in separate PCA. None of the values had a first component with an Eigenvalue >2 (1.267, 1.393, 1.337, and 1.412 for factors 1, 2, 3 and 4, respectively), indicating a high degree of unidimensionality.

Table 5 shows the CFA results of the three BESTest models. The fit of the single factor model containing all 36 BESTest items, was very poor (e.g. CFI, 0.726), with all fit indices except χ^2/dt falling well below acceptable standards. These results did not support the unidimensional structure of the original BESTest. The fit indices of the six-factor model was slightly

Table 2. Results of all BESTest items

Section	Item		Mean	SD
I	1	Base of support	2.84	0.47
	2	CoM alignment	2.36	0.83
	3	Ankle strength and ROM	2.04	1.02
	4	Hip/Trunk lateral strength	1.36	1.08
	5	Sit to floor and stand up	1.93	1.20
II	6a	Sitting verticality, a/s	2.65	0.61
	6b	Sitting verticality, s/s	2.74	0.56
	6c	Sitting lateral lean, a/s	2.84	0.42
	6d	Sitting lateral lean, s/s	2.89	0.33
	7	Functional reach forward	2.11	0.56
	8a	Functional reach lateral, a/s	1.85	1.02
	8b	Functional reach lateral, s/s	2.33	0.59
III	9	Sit to stand	2.82	0.43
	10	Rise to toes	1.84	1.08
	11a	Stand on one leg, a/s	1.12	1.01
	11b	Stand on one leg, s/s	1.37	1.08
	12	Alternate stair touching	1.54	1.15
	13	Standing arm raise	2.68	0.78
IV	14	In-place response, forward	2.45	0.71
	15	In-place response, backward	2.14	0.91
	16	Compensatory stepping correction, forward	2.16	1.14
	17	Compensatory stepping correction, backward	1.68	1.13
	18a	Compensatory stepping correction, lateral, a/s	1.44	1.21
	18b	Compensatory stepping correction, lateral, s/s	1.61	1.30
V	19a	Stance on firm surface, EO	2.92	0.36
	19b	Stance on firm surface, EC	2.56	0.75
	19c	Stance on foam surface, EO	2.29	0.91
	19d	Stance on foam surface, EC	1.55	1.01
	20	Incline, EC	2.18	1.05
VI	21	Gait, level surface	1.97	0.96
	22	Change in gait speed	2.43	0.93
	23	Walk with head turns, horizontal	1.89	1.09
	24	Walk with pivot turns	1.66	0.94
	25	Step over obstacles	1.56	1.12
	26	Timed "Get Up & Go" test	1.96	1.07
	27	Timed "Get Up & Go" test with dual task	0.99	0.94

a/s: affected side; BESTest: balance evaluation systems test; CoM: center of mass; EC: eyes closed; EO: eyes open; ROM: range of motion; SD: standard deviation; s/s: sound side.

better (CFI, 0.833). In comparison with these, the 25-item BESTest 4-factor model based on EFA, CFI and TLI values was closer to 0.9, the RMSEA was acceptable, and the information criteria were lower than in other two models. Figure 2 presents the results of CFA in 25-item BESTest 4-factor model.

Table 6 shows correlation results. The BRS and 10MWS significantly correlated with each factor. Correlations between BRS and factor 1, and between 10MWS and factors 1, 2, and 3 were moderate.

DISCUSSION

Although the BESTest has gradually become more popular for assessing balance ability in persons with stroke[15, 18, 35)], the structure of balance component of the tool has not been investigated in this population. Therefore, the present study examined the dimensionality of the construct of structure of balance component in stroke, as well as the properties of each item and their interrelationships in the BESTest. To the best of our knowledge, this is the first analysis of the BESTest using factor and Rasch analyses for self-ambulatory stroke patients. Our results showed that patients with stroke had a four-factor structure, and that the 25-item BESTest was the most appropriate.

The BESTest is a comprehensive balance assessment tool comprising six postural control systems with 36 items[14)]. A previous study found that the BESTest with 24 items showed unidimensionality and that dynamic balance in people with neurological disorders could be evaluated by dimensional analysis[23)]. On the other hand, the Mini-BESTest appeared to be unidimensional, but one study indicated that it might be multidimensional in PD[24)]. Therefore, we established a hypothesis in which the BESTest is another way of interpreting dimensions in patients with stroke who are self-ambulatory. The present study generated evidence supporting the 4-factor structure, structure validity, and internal construct validity of the 25-item BESTest (Tables 3 and 4, Fig. 2). The structural validity assessed by EFA and CFA was better fit than models in the original BESTest (Table 5). We also confirmed construct validity by comparisons among the 25-item BESTest, lower extremity motor function and walking ability (Table 6). Therefore, a 4-factor structure should be considered when assessing balance in patients with stroke.

Table 3. Exploratory factor analysis of 25-item BESTest 4-factor model

Item	Factor 1	Factor 2	Factor 3	Factor 4
21	**0.79**	0.33	0.25	0.15
25	**0.66**	0.38	0.38	0.18
26	**0.65**	0.42	0.36	0.09
22	**0.65**	0.18	0.27	0.07
23	**0.63**	0.22	0.06	0.16
24	**0.56**	0.36	0.34	0.22
12	**0.54**	0.38	0.27	0.24
15	**0.45**	0.30	0.21	0.04
20	0.25	**0.65**	0.18	0.14
19b	0.15	**0.64**	0.15	0.09
19c	0.36	**0.62**	0.20	0.17
19d	0.32	**0.59**	0.19	0.08
10	0.35	**0.52**	0.36	0.11
19a	0.13	**0.51**	0.07	0.03
9	0.28	**0.51**	0.27	0.09
11a	0.38	**0.47**	0.40	0.04
5	0.36	**0.46**	0.36	0.25
11b	0.32	**0.46**	0.32	0.09
2	0.17	**0.40**	0.32	0.35
18b	0.22	0.23	**0.79**	0.15
18a	0.23	0.20	**0.79**	0.17
17	0.23	0.29	**0.65**	0.09
16	0.33	0.18	**0.51**	0.12
6a	0.08	0.11	0.10	**0.98**
6b	0.26	0.06	0.19	**0.73**

Major loading are shown in bold.

Table 4. Summary of Rasch analyses of 25-item BESTest 4-factor model containing item difficulty measure and fit information

Factor	Item	Measure	Infit MnSq	Outfit MnSq
1	22	−0.749	1.080	0.974
	15	−0.151	1.450	1.525
	21	0.080	0.530	0.506
	26	0.343	0.714	0.656
	23	0.417	1.326	1.278
	24	0.967	0.853	0.861
	12	1.097	0.846	0.808
	25	1.228	0.613	0.635
2	19a	−2.371	0.405	0.428
	9	−1.664	0.757	0.489
	19b	−0.836	1.024	0.739
	2	−0.406	1.198	1.382
	19c	0.003	0.802	0.642
	20	0.336	0.985	0.934
	5	0.801	1.021	1.313
	10	0.917	0.880	0.851
	19d	1.372	0.868	0.878
	11b	1.664	0.967	1.000
	11a	2.121	0.672	0.646
3	16	−0.698	1.076	1.135
	17	0.162	0.815	0.833
	18b	0.372	0.690	0.636
	18a	0.643	0.583	0.632
4	6b	−1.134	0.474	0.510
	6a	−0.821	0.531	0.526

MnSq: mean of squared residuals.

The four factors were classified as being close to mechanical structures, such as movement towards the center of gravity accompanied by changes in the base of support, postural control that fixed the base of support, and postural strategy, from the structure of the balance component[8]. This solution also seemed to be the most rational, because the factors broadly consisted of items from a subscale of the original BESTest from which the items were originally derived, namely dynamic postural control with gait (factor 1), static postural control (factor 2), stepping reaction (factor 3), and stability limits in sitting (factor 4). Most items are located in of section VI (stability in gait) for factor 1, section IV (postural responses) for factor 3, and section II (stability limits and verticality) for factor 4, which was a composite of sections I (biomechanical constraints), III (anticipatory postural adjustments) and V (sensory orientation) for factor 2 of the original BESTest. The results of correlation

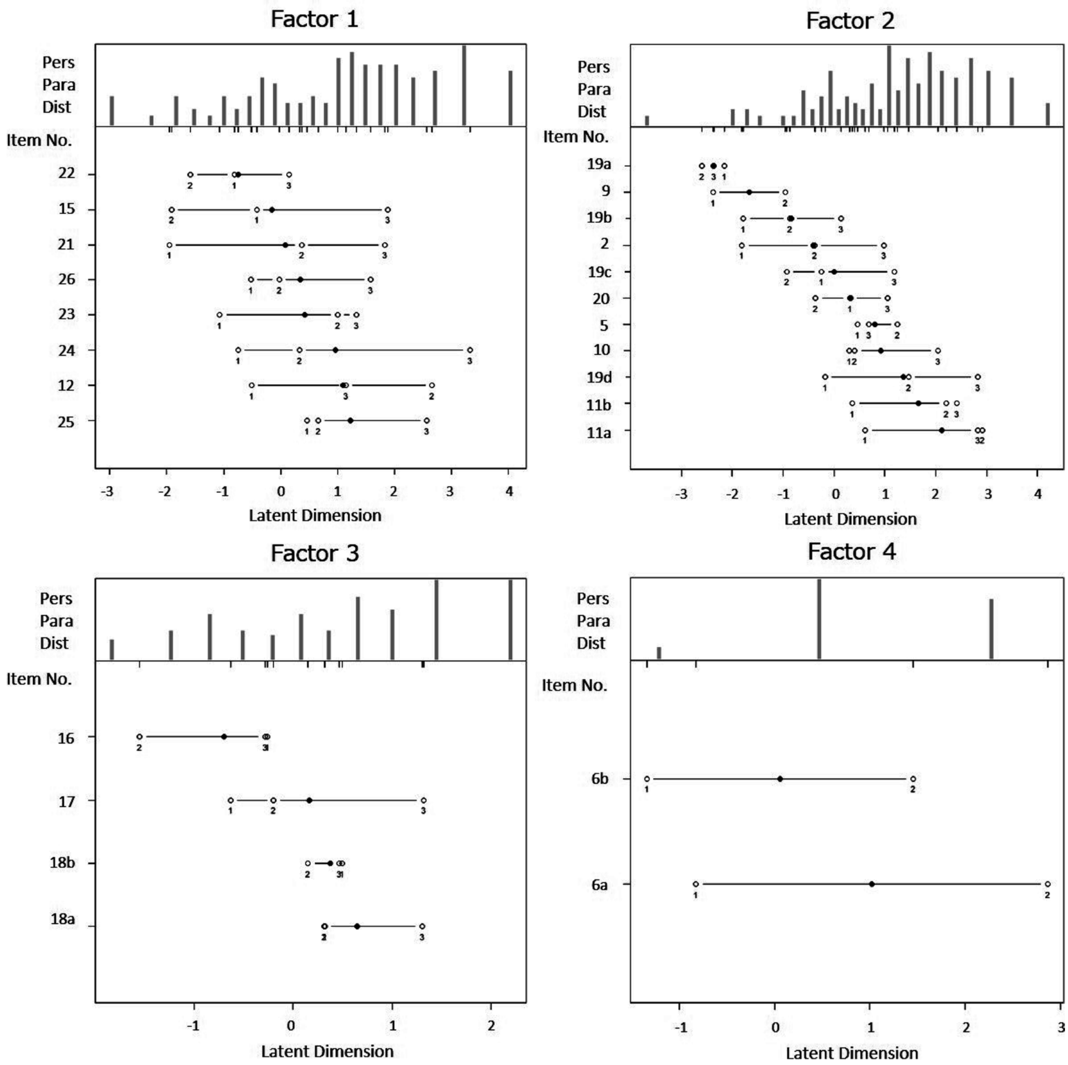

Fig. 1. Person-item map of each factor from Rasch analysis, with items in ascending order of mean difficulty (black circles). White circles indicate thresholds between each category.
Dist: distribution; Para: parameter (item); Per: person.

Table 5. Fit statistics from CFA of BESTest items

Model	χ^2/df	RMSEA	CFI	TLI	AIC	BIC
36-item BESTest 1-factor model (original)	2.2	0.093	0.726	0.710	10,637.986	10,849.785
36-item BESTest 6-factor model (original)	1.8	0.074	0.833	0.820	10,161.137	10,384.702
25-item BESTest 4-factor model (EFA)	1.8	0.075	0.898	0.887	7,457.414	7,616.263

AIC: Akaike information criteria; BIC: Bayesian information criteria; CFA: confirmatory factor analysis; CFI: comparative fit index; EFA: exploratory factor analysis; RMSEA: root mean square error of approximation; TLI: Tucker-Lewis index.

analyses showed that each of the four factors correlated poorly to moderately with lower extremity motor function and walking ability. Lower extremity motor function was poorly related, except for factor 1, suggesting that static postural control and the step reaction are affected by other functions. Factor 4 was poorly related to both function and ability, which is a reasonable finding because it is assumed to be associated with trunk function.

Recent studies have used item response theories such as RA to evaluate the effectiveness of assessment tools for rehabilitation[36, 37)]. The Mini-BESTest and the Berg balance scale are tools to measure balance that have recently become more popular[24, 38–40)]. Goljar et al. showed that all items except item 14 (Cognitive Get Up & Go) in the Mini-BESTest were properly sequenced in a sample of people with subacute stroke, with infit and outfit values falling within the range of 0.7 to 1.3[38)]. They also found that the Eigenvalue for unexplained variance conformed to the definition of unidimensionality. In contrast, another study found that items 1 (Standing up from a seated position) and 7 (Standing with feet together on a

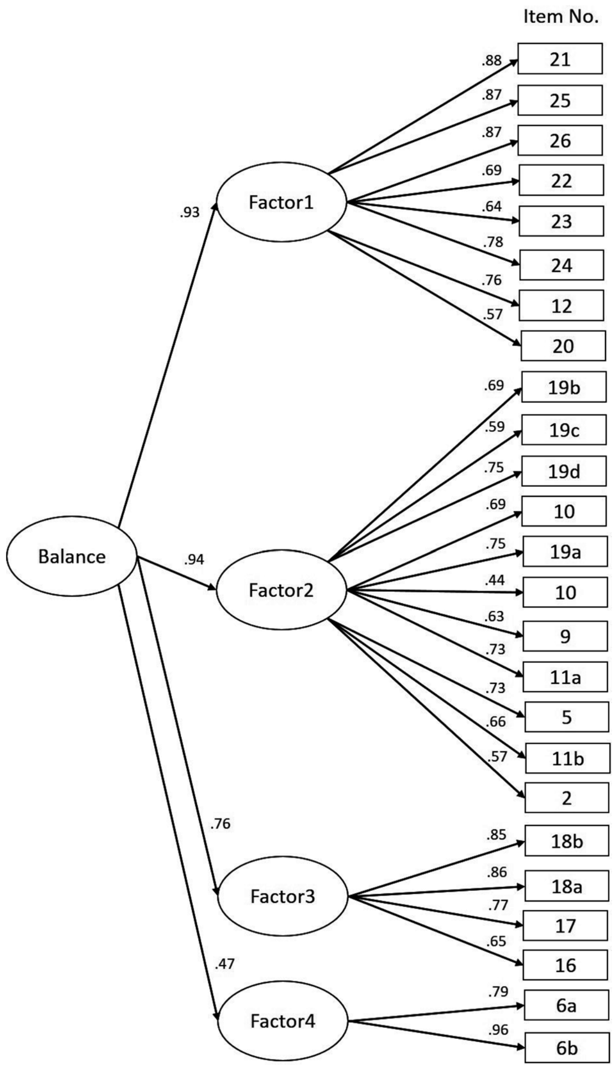

Fig. 2. Confirmatory factor analysis of 25-item BESTest 4-factor model.
At χ^2/df=1.8, root mean square error of approximation was 0.075, comparative fit index was 0.898, Tucker-Lewis index was 0.887, Akaike information criterion was 7,457.414, and Bayesian information criterion was 7,616.263.

Table 6. Correlation coefficients among BRS, 10MWS and total score for each factor

	Factor 1	Factor 2	Factor 3	Factor 4
BRS	0.50*	0.36*	0.24*	0.30*
10MWS	0.79*	0.66*	0.58*	0.42*

BRS: Brunnstrom recovery stage; 10MWS: 10-m maximum walking speed.
*Statistically significant at 5% level.

firm surface with eyes open) were misfits, suggesting that they are not unidimensional in mild to moderate PD[24]. Thus, the response appears to vary according to the disease and term, even on the same balance scale. Here, we analyzed the structure of the balance component and item response in detail among self-ambulatory persons with stroke. The results were different from those of Frachignoni et al., that were published when the Mini-BESTest was created[23]. The present results suggested that they reflect the balance in stroke. In this way, the usefulness of balance evaluation was considered using RA, which is important for detailed assessment and the development of interventions for balance.

Eleven items in our sample were not suitable for evaluation in the original BESTest according to EFA (Table 3) and were reduced. Their properties included factors related to the basic components of postural control (items 1, 3, 4) and the stability limit in standing (item 7 to 8b). Others have reported that the composite structure is more related to falls than to the basic structure of balance ability[41]. The reason for reducing these items was that they involved tasks that might not be sufficiently challenging for this group of patients. Furthermore, item 27 suggested that being able to concurrently execute motor and cognitive tasks (dual tasking) represents a different structure. Others have found that dual tasking has different properties in various neurological diseases[24, 38]. Continued investigations of dual task items are needed.

The 25-item BESTest 4-factor model has several clinical implications. A valid and reliable assessment is needed for evaluation and intervention with rehabilitation for balance disorders associated with stroke. The 25-item BESTest 4-factor model is an evaluation tool intended to collect information specific to balance in stroke. Moreover, this model can serve as a tool to clarify balance problems and facilitate therapy for dynamic postural control with gait, static postural control, stepping reaction, and stability limits in sitting. The 25-item BESTest 4-factor model might assist less-experienced therapists to establish plans to treat the balance dysfunction of stroke. The effects of applying the 25-item BESTest 4-factor model will require verification.

This study has a few limitations. One is that EFA resulted in a factor consisting of two items. We followed this because it had different specificity from the other factors. However, this will require re-analysis in a larger cohort of patients. In addition, our sample comprised only self-ambulatory persons, which restricts generalization of the results to other groups or settings. Moreover, the structure of the balance component of the stroke was shown in four factors to be close to mechanical structure. However, whether this is specific for stroke remains unknown. Additional studies are required to address these limitations and validate the present findings.

In conclusion, the 25-item BESTest 4-factor model is a valid, reliable means of assessing postural control systems in self-ambulatory patients with stroke. Further studies should validate the clinical applicability of the 25-item BESTest 4-factor model in a large sample.

Conflict of interest

None.

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