Reliability of the Stroke-Balance Evaluation Systems Test (S-BESTest) in People with Chronic Stroke

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Abstract

The Stroke-Balance Evaluation Systems Test (S-BESTest) is an assessment tool for assessing 6 domains of postural control impairments. However, consistency of its score over time and across multiple raters that used the S-BESTest in people with chronic stroke were necessary to be tested. Therefore, this study aimed to examine the reliability of the S-BESTest in chronic stroke patients. Three physical therapists examined the patients' performance from the same set of ten video clips on 2 separate occasions performed 10 days after the first occasion. The performance' scores were based on scoring criteria of the S-BESTest (English version). Scores from the first and second occasions of each rater were used to determine intra-rater reliability using intraclass correlation coefficient (ICC) model 3,1. The scores from the first occasions were used to determine inter-rater reliability using ICC model 2,1. The intra-rater reliability of the S-BESTest total score and domain scores were excellent with ICC (95% CI) of 0.96-0.99 (0.85-0.99) and 0.93-1.00 (0.71-1.00), respectively. The inter-rater reliability of the S-BESTest total score and domain scores were excellent with ICC (95% CI) of 0.97 (0.93-0.99) and 0.91-0.98 (0.76-0.99), respectively. Clear instructions of how to score and how the rater practice and discuss the session with an experienced physical therapist are necessary for such degree of reliability of the S-BESTest. Further study should examine validity properties of the S-BESTest to ensure measurement properties before using it in assessing postural control impairments in people with chronic stroke.

Keywords*: *Stroke, Postural control, Balance assessment, Psychometric properties

1. Introduction

Loss of balance and unsteadiness are significant problems in patients with hemiplegic stroke (Hatem et al., 2016; Lawrence et al., 2001). A study reported that about 83% of stroke survivors suffered from balance impairment (Tyson, Hanley, Chillala, Selley, & Tallis, 2006), which was an important fall risk factor in stroke patients (Harris, Eng, Marigold, Tokuno, & Louis, 2005). It is known that functional balance problems can be affected by multiple systems such as sensory deficit, cognitive impairment, biomechanical constraints, and impaired movement strategies (Horak, Henry, & Shumway-Cook, 1997). Therefore, identification of balance problems and their underlying impaired systems may help guide specific training for the stroke survivors (Shumway-Cook & Woollacott, 2016).

In a clinical setting, the Berg Balance Scale (BBS) is a reference tool for assessing functional balance problems in patients with stroke (Blum & Korner-Bitensky, 2008). It is a reliable measure to detect static and dynamic sitting and standing balance (Mao, Hsueh, Tang, Sheu, & Hsieh, 2002). However, the BBS is not appropriate for evaluation in people with chronic stage after stroke since it has a ceiling effect (47.7%) (Knorr, Brouwer, & Garland, 2010). Regarding the systems approach for balance evaluation, the impairments of physiological systems (i.e. sensory-musculoskeletal systems, neuromuscular-sensory strategies, and internal representations) and mechanisms (adaptive and anticipatory mechanisms) underlying postural control problems are mainly emphasized (Horak, 2006) to determine the underlying causes of the balance deficit for specific and effective treatment (Horak et al., 1997). However, the BBS does not cover various systems of postural control as they assess only the stability in gait and anticipatory postural adjustment. Therefore, it cannot provide a specific impairment of the systems underlying functional balance problems.

The Balance Evaluation System Test (BESTest) is one of the clinical balance tests that use a systems approach to characterize the underlying causes for impaired balance control. The BESTest is a 36-items tool comprising 6 domains of postural control assessment, including biomechanical constraints, stability

limits/verticality, anticipatory postural adjustments, postural responses, sensory orientation, gait stability, and the cognitive involvement in gait (Horak, Wrisley, & Frank, 2009). The BESTest is a good measurement to evaluate balance in people with stroke in subacute and chronic phases (Chinsongkram, Chaikeeree, Saengsirisuwan, Horak, & Boonsinsukh, 2016; Rodrigues, Marques, Barros, & Michaelsen, 2014). However, multiple items of the BESTest required a long administration time (estimated 30-45 minutes to complete) that can limit its practicality in the clinic (Horak et al., 2009). Therefore, the S-BESTest, a short version of the BESTest, has been developed to be used in patients with stroke (Winairuk, Pang, Saengsirisuwan, Horak, & Boonsinsukh, 2019).

The S-BESTest contains 13 items of the 6 domains of the BESTest (Winairuk et al., 2019). Measurement properties of the S-BESTest were evaluated in a patient with subacute stroke. The S-BESTEst has excellent reliability (Inter-rater reliability ICC = 0.88-0.95 and intra-rater reliability ICC = 0.96-0.98) and excellent validity when tested against the BBS (r = 0.95) (Winairuk et al., 2019). Compared with the BBS, the S-BESTest can evaluate all systems of the postural control that is related to balance while standing and walking in a real situation such as Timed Up and Go test (TUG) with dual-task, change in gait speed, and walk with head turn (Winairuk et al., 2019). Previous studies showed stability in gait problems in hemiplegia patients who had had a stroke attack for over six months (chronic stroke), that is, a significant decrease in gait velocity while performing a second task simultaneously with walking (Shin et al., 2017), difficult to change in gait speed (Olney & Richards, 1996), and alter body orientation or head position when turning a corner or turning the head (Balasubramanian, Clark, & Fox, 2014).

Rehabilitation for regaining motor and balance performance is important for all stages of recovery after stroke (Ballester et al., 2019). Even in the chronic stage (time since stroke over than 6 months) physical therapy training could help the patient re-learn to control movement and balance (Lee, Park, & Park, 2019; Tetik Aydoğdu, Aydoğdu, & Inal, 2018). Therefore, the assessment of movement and balance in people with chronic stroke is necessary to plan effective treatment. From the above review, the S-BESTest would be the potential clinical tool for a comprehensive balance assessment in people with chronic stroke. However, the S-BESTest has not been validated in people with chronic stroke. Before the validity testing, reliability testing is equally important to determine the consistency of the measurement (Coaley, 2010). The reliability includes consistency of the test results when being measured by different examiners (inter-rater) and within the same examiner across time (intra-rater) (Zangaro, 2019).

2. Objectives

To examine the intra-rater and inter-rater reliability of the S-BESTest in people with chronic stroke.

3. Materials and Methods

3.1 Material

The S-BESTest instruction and scoring criteria and video clips of performance on the S-BESTest were materials used in this study. The S-BESTest is a performance-based assessment tool that consists of 13 tasks within the six components of the postural control system. Hip/trunk strength, functional reach-lateral non-paretic side, and compensatory stepping correction-lateral paretic side are for determining the impairment of biomechanical constraint, stability limits, and reactive postural response, respectively. Three tasks including a rise to toes, single-leg stance, and standing arm raise aim to assess the impairment of the anticipatory postural adjustment. Standing on foam with eyes opened and on firm and inclined with eyes closed are used for examining impairment of sensory orientation for balance. Three tasks including change in gait speed, walk with head turns, and TUG with dual-task are for determining the stability in gait. Information in the instruction document of the S-BESTest (English version) consists of assessment method, equipment, command and starting position, and scoring criteria. Each task has its criteria to determine patients' performance, which ranges from "0 cannot perform" to "3 perform fully." The total score of the S-BESTest is 39 points (Winairuk et al., 2019), and it requires 7-10 minutes for administration.

3.2 Participants

Ten people with chronic stroke were recruited in the previous study (Winairuk et al., 2019). The inclusion criteria were: diagnosis of the first unilateral hemispheric stroke, aged 18 years old and older, onset more than 6 months, able to perform walk independently with or without gait aid at least 6 meters, and able to perform serial-3 subtraction from 90 at least 5 steps or able to perform verbal fluency of fruits category at least 5 fruits. The participants were excluded if they had a motor and/or sensory aphasia, recurrent stroke, any neurological disorder other than stroke, other diseases or conditions that affect participant's safety during a session of data collection, namely, unstable vital signs, chest pain with unstable angina, untreated trauma injury, and any others red flag signs such as fever, history of trauma or cancer, unexplained weight loss (Leerar, Boissonnault, Domholdt, & Roddey, 2007), or pain that affect the ability to stand and walk on the day of the testing session. All participants gave consent to participate in the study and to be video recorded.

3.3 Procedure

This study is composed of two main steps including 1) rater training and 2) reliability testing. The study protocol was approved by the institutional review board of the Faculty of Physical therapy, Srinakharinwirot University (number PTPT2021-002).

The rater's training process was to ensure that Thai raters understood the S-BESTest (English version) with the same context. During the rater training, a researcher (KS), a post-graduate physical therapy student, and two physical therapists (PS and PE) with stroke rehabilitation experience of at least 2 years were involved in the data collection of this study (raters). All raters participated in training workshops before the data collection of this study. They were asked to study a document of assessment method and scoring criteria of the S-BESTest. Then, they were asked to practice scoring two patients' performance recorded on video clips. Scores from the raters were compared, and a discrepancy was discussed with two physical therapy lecturers (TW and NC) who have experience of using these assessment tools.

For the reliability testing, a sample size of ten was estimated from a power of 0.80 and an alpha level of 0.05. A null intraclass correlation coefficient (ICC) of 0.60 and expected correlation coefficients of 0.94 were determined by a previous study (Winairuk et al., 2019). In this study, the authors used video clips conducted in 2018 by one of our researchers (TW) who conducted a study with Hong Kong Polytechnic University. Ten video clips of 10 different patients' performance on the S-BESTest were shared with all raters on Google Drive. The raters were asked to watch and score the performance on the video clip within the same limited time. Each set of video clips contains multiple video clips of a participant that was filmed during his or her performance when being tested with the S-BESTest. Each video clip showed 1-2 items of the S-BESTest. The raters were asked to score immediately after the end of each S-BESTest item. A few minutes of braking periods were provided to the raters after finished watching and scoring each video clip. However, stopping or pausing a video clip during a performance test of any item was not allowed. Besides, the raters were allowed to repeat the video clips to prevent bias for scoring the patients' performances. Discussion of scores or patients' performances were not allowed either. All raters scored each patient's performance from the same set of video clips on 2 separate occasions. The second occasion was performed 10 days after the first occasion to prevent recall bias. The scores of S-BESTest items were recorded in Google Form generated for each rater. The raters were asked to submit the scores within 5 minutes after completely scoring the performance of each patient.

3.4 Data analysis

Demographic and clinical characteristics of the patients with chronic stroke in the video clips were analyzed using descriptive statistics. Age and time since stroke onset were presented in mean with standard deviation (SD). Gender, type of stroke, and affected sides were presented in frequency with percentage.

The intra-rater reliability of total score and domain scores were determined by comparing the score of the first and the second occasions for each rater. The inter-rater reliability of total and domain scores were determined by comparing scores of the first occasion between all raters. The intra- and inter-rater reliability were calculated using the intraclass correlation coefficient (ICC) model (3, 1) and model (2, 1), respectively.

ICC value of 0.80 and above indicates excellent correlation (good reliability), while 0.80 to 0.60 indicates adequate correlation (moderate reliability) and 0.60 to 0.40 indicates poor correlation (weak reliability) (Portney & Watkins, 2009). Statistical significance will be set at a p-value < 0.05. The statistical analysis was conducted using the SPSS statistical software (SPSS version 25, ICN:793700).

4. Results and Discussion

4.1 Results

4.1.1 Characteristics of patients in the video clips

Video clips of the S-BESTest assessment used in this study were recorded from a total of 10 people with chronic stroke. They were both male and female (7 and 3 persons, respectively) aged between 53 to 72 years old and had a wide range of time post-stroke (35 to 155 months). Average age and time since stroke onset and other clinical characteristics are shown in Table 1.

Table 1 Demographic and clinical characteristics of people with chronic stroke (n=10) in the video clips

Characteristics	
Age (years), mean ± SD	63.9 ± 6.6
Gender, (male), n (%)	7 (70%)
Time since stroke onset (months), mean ± SD	103.9 ± 38.3
Type of stroke (ischemic), n (%)	7 (70%)
Affected side (right), n (%)	4 (40%)

4.1.2 Reliability of the S-BESTest total score

The intra-rater reliability of the S-BESTest total score of all raters was excellent with ICC $_{(3, 1)}$ ranging from 0.96 to 0.99 (95% CI = 0.85 to 0.99) (Figure 1 A, B, C). The inter-rater reliability of the S-BESTest total score was excellent with ICC (2, 1) of 0.97 (95% CI = 0.93 to 0.99) (Figure 1 D).

4.1.3 Reliability of the S-BESTest domain scores

The intra-rater reliability of the domain scores was excellent with ICC (3, 1) 0.93 to 1.00 (95% CI = 0.71 to 1.00) (Table 2). Likewise, the inter-rater reliability of the domain scores of the S-BESTest was excellent with ICC $_{(2, 1)}$ 0.91 to 0.98 (95% CI = 0.76 to 0.99) (Table 3).

Table 2 Intra-rater reliability of domain scores of the S-BESTest in people with chronic stroke (n=10)

Domains of the S-BESTest	**Rater 1**		**Rater 2**		**Rater 3**	
	ICC (3,1)	**95% CI**	**ICC (3,1)**	**95% CI**	**ICC (3,1)**	**95% CI**
I Biomechanical constraints	0.98	0.90-0.99	0.93	0.71-0.98	0.96	0.84-0.99
II Stability limits	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-1.00
III Anticipatory adjustment	0.99	0.97-0.99	0.99	0.94-0.99	0.93	0.73-0.98
IV Reactive postural response	1.00	1.00-1.00	0.98	0.93-0.99	1.00	1.00-1.00
V Sensory orientation	1.00	1.00-1.00	1.00	1.00-1.00	1.00	1.00-1.00
VI Stability in gait	0.95	0.79-0.99	0.93	0.72-0.98	0.93	0.72-0.98

All intraclass correlation coefficients (ICCs) were significant, with a p-value of <0.001. CI: confidence interval

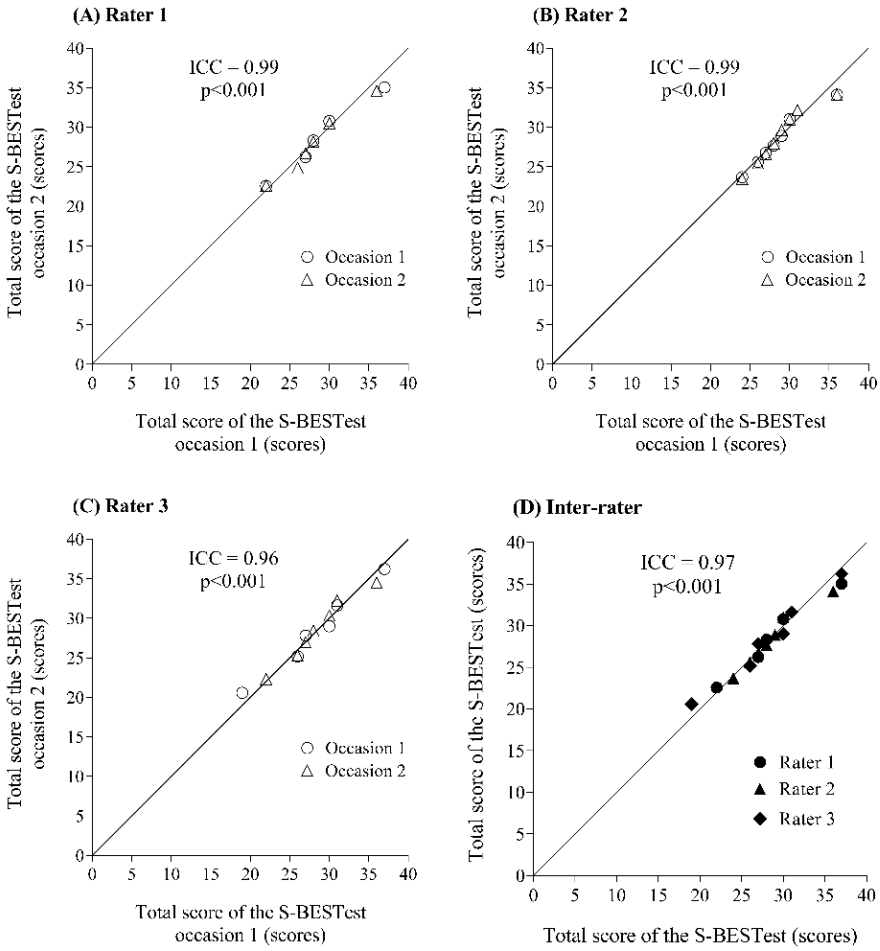

Figure 1 Intra-rater and inter-rater reliability of total score of the S-BESTest in people with chronic stroke (n=10): (A) intra-rater reliability assessed by rater 1, (B) intra-rater reliability assessed by rater 2, (C) intra-rater reliability assessed by rater 3, and (D) intra-rater reliability between three raters, S-BESTest: Stroke-Balance Evaluation System Test, ICC: intraclass correlation coefficient

Table 3 Inter-rater reliability of domain scores of the S-BESTest in people with chronic stroke (n=10)

Domains of the S-BESTest	Inter-rater reliability	
	ICC (2,1)	95% CI
I Biomechanical constraints	0.98	0.95-0.99
II Stability limits	0.91	0.76-0.98
III Anticipatory adjustment	0.97	0.90-0.99
IV Reactive postural response	0.94	0.82-0.98
V Sensory orientation	0.91	0.76-0.98
VI Stability in gait	0.97	0.92-0.99

All intraclass correlation coefficients (ICCs) were significant, with a p-value of <0.001. CI: confidence interval

4.2 Discussions

This study examined the reliability of the S-BESTest in people with chronic stroke. The findings of excellent intra-rater and inter-rater reliability of the S-BESTest are as expected. The intra-rater reliability of the S-BESTest reflected that the raters' judgment between the first and second occasions was consistent.

Results on the excellent inter-rater reliability of the total score of the S-BESTest reflected that there were a few variations of the patients' performance that were scored by three different raters. These results are probably due to clear instructions on how to rate the patients' performance and the raters' training process. Comparing with another study of the S-BESTest, degrees of the reliability of the total score and domain scores of the S-BESTest reported in this study (ICCs = 0.91 to 1.00) were corresponded to a previous study in patients with subacute stroke (ICCs = 0.88 to 0.98) (Winairuk et al., 2019). The raters' training process and scoring the patients' performance from videos could be a reason for similar results between the present and the previous study (Winairuk et al., 2019). These results confirmed that the S-BESTest could provide reliable test results when used to assess postural control problems in any recovery stage of patients with hemiplegic stroke.

In this study, the overall inter-rater reliability of the domain scores of the S-BESTest was excellent with ICCs of 0.91 to 0.97, which were higher than ICCs of 0.88 to 0.96 reported in the previous study (Winairuk et al., 2019). During the raters' training, two discussion sessions about how to score each item of the S-BESTest were done before and after the practice of scoring the patient's performance in a video demonstration. This process could help the raters to understand the scoring criteria of the S-BESTest with the same context better than practice scoring performance of a healthy person as done in a previous study (Winairuk et al., 2019). It could be a reason for the higher intra-rater reliability of the domains' score of the S-BESTest among this study and a previous study in patients with subacute stroke (Winairuk et al., 2019).

Regarding the lower border of 95% CI the intra-rater reliability of domain scores of the S-BESTest, the authors founded that the stability in the gait showed the lowest value of the reliability (95% CI of ICCs = 0.72 to 0.79) when compared with the other domains (95% CI of ICCs = 0.71 to 1.00). This result was in line with the finding of a previous study in patients with subacute stroke that the stability in the gait domain had the lowest intra-rater reliability (Winairuk et al., 2019). Some errors found in the stability in the gait domain indicated that the raters prescribed different scores for the same patients when repeating the measurement. Since the patients' gait performances were rated from the same set of video clips, changes in the performance of the patients were not a reason for such inconsistency. It could be from the limitation of the scoring from the video where the points to start and stop the timing of walking were not as clear as in the field testing. Also, the lower border of 95% CI the inter-rater reliability of sensory orientation domain score of the S-BESTest showed an adequate correlation of the reliability (95% CI of ICCs = 0.76 to 0.98), however, it was lower than the reliability of the scores from other domains (lower border of 95% CI of ICCs = 0.82 to 0.95). The result on the inter-rater reliability of the sensory orientation domain reported in this study was similar to the previous study in the patients with subacute stroke that 95% CI of ICCs of this domain was 0.82 to 0.97 (Winairuk et al., 2019). Determining the patients' performance of sensory orientation included time of standing on various surfaces with or without postural sway in the front view of the patients' performance in the video clips. The camera angle was important to decide postural sway while standing on various surfaces. Thus, the raters should score the patients' performance along with the lateral view of the video clips. Besides, the authors recommended the use of a measuring tape with a highly visible and accurate distance line to reduce an error of the rater's judgment about the distance the patient can reach.

The reliability of the raters is the first requirement before the use of standardized scales in clinical practice. This study established that the rater's training can help improve the rater's reliability. The method of rater training where clinicians can apply to their clinical settings is also suggested in this study. However, this study reported only the reliability of the S-BESTest in chronic stroke patients. The validity of the S-BESTest in people with chronic stroke should be evaluated in a future study with other commonly used clinical scales, namely, the BBS and the Community Balance and Mobility Scale (CB&M).

5. Conclusion

The S-BESTest had excellent intra-rater and inter-rater reliability in people with chronic stroke. Clear instructions on how to score and training sessions with an experienced physical therapist before using the scale are necessary for achieving excellent rater reliability of the S-BESTest.

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