การพัฒนาแบบประเมินทางคลินิกฉบับย่อสำหรับทดสอบสาเหตุความบกพร่องในการทรงตัวสำหรับผู้ป่วยโรคหลอดเลือดสมองระยะหลังเฉียบพลัน

THE DEVELOPMENT OF SHORT FORM CLINICAL TEST FOR ASSESSING CAUSES OF BALANCE DEFICITS IN PATIENTS WITH SUBACUTE STROKE

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GRADUATE SCHOOL Srinakharinwirot University

2018

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A

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THE DEVELOPMENT OF SHORT FORM CLINICAL TEST FOR ASSESSING CAUSES OF BALANCE DEFICITS IN PATIENTS WITH SUBACUTE STROKE

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The Balance Evaluation Systems Test (BESTest) is a valid and reliable tool to evaluate balance impairments, but the administration time is long and some items may not be pertinent to people with stroke. This study aims to develop the short form BESTest for people with stroke (S-BESTest) and test psychometric properties of the S-BESTest in people with stroke such as the reliability, validity, and responsiveness. Methods: The S-BESTest was created from the BESTest scores from one hundred and ninety-five participants with stroke during subacute or chronic stage using Rasch analysis and expert agreement. Twelve persons with subacute stroke and twenty persons with chronic stroke participated in the intrarater and interrater reliability study. Seventy persons with subacute stroke participated in the concurrent validity using the Berg Balance Scale (BBS) as the reference standard. The predictive validity was studied to predict motor outcome at discharge using the Stroke Rehabilitation Assessment of Movement (STREAM). The S-BESTest determined the floor and ceiling effect. Internal and external responsiveness measure at 2 and 4 weeks were calculated using the standardized response mean (SRM) and the minimal clinically important difference (MCID), respectively. The Receiver Operating Characteristics (ROC) curve approach was used to demonstrate external responsiveness that used to quantify the sensitivity, specificity and posttest accuracy for classifying persons with no balance change and with balance change based on the BBS score change < 7 and higher/ the global rating of change (GRC) score change ≤ 5 and higher. Results: Thirteen items were included in the S-BESTest. The intrarater and interrater reliability of the S-BESTest were excellent with ICC of 0.98 and 0.95. The S-BESTest presented excellent concurrent validity that was highly correlated with the BBS (Spearman Rank *r*=.95). The S-BESTest was able to predict motor function outcome at discharge. In addition, the S-BESTest showed no floor and ceiling effects. Internal responsiveness measure at 2 and 4 weeks of the S-BESTest were high (SRM 1.28 and 1.29). The MCID for persons with subacute stroke who have balance change after getting intervention on the S-BESTest measure at 2 and to 4 weeks was 7 and 6 points, respectively. The S-BESTest is the shorter version of the BESTest that contains the items essential for assessing balance impairments in people with stroke. The S-BESTest reduced the administration time in clinical practice and is reliable, valid and sensitive to change in persons with subacute stroke.

Keyword : psychometric - physical therapy - postural control - cerebrovascular disease.

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INTRODUCTION

Background

Balance problems are commonly found following stroke. Deficits in different systems; including musculoskeletal, perceptual, sensory, and cognitive systems, can lead to decreased balance ability in patients with stroke. It is evidenced that balance impairment in these patients could be resulted partly from ankle and hip weaknesses, poor motor control of the affected side, muscle imbalance,[(1-4)] and decreased hip and ankle range of motion.[(5)] Delayed postural responses to external perturbation, such as inability to execute ankle strategies are correlated with decreased ankle proprioception and ankle muscle weakness or decreased base of support.[(4, 6)]

Perceptual system, including sense of verticality through visual, postural and haptic inputs, functions to orient the body parts with respect to gravity, support surface, visual surround and internal references. Patients with stroke who are diagnosed with pusher syndrome or visuospatial neglect demonstrate inaccurate internal representation of verticality. For example, patients with pusher syndrome mistakes the estimation of the body tilt (postural verticality) with respect to gravitational direction whereas those with visuospatial neglect shows inaccurate perception of visual vertical with respect to gravitational line.[(1)-(2)] Abnormal interaction between the three sensory systems: visual, somatosensory, and vestibular systems is also evident in persons with stroke.[(7) -(8)] Excessive reliance on visual input more than another inputs when standing on the firm surface may be the compensatory response of sensory reweighting.[(9)] Limited attention during static and dynamic balance maintenance can lead to loss of balance in the population with stroke as the control of balance and cognitive processing share the central resources when performing them together.[(1)-(2)] All of the above mentioned impairments could result in high incidence of fall in this group of population.

The incidence of fall among persons with stroke is ranged from 14-73%[10-14] and forty seven percent of those fell more than once.[15]-[10] Falls in persons with stroke occur during both hospitalization[4] and discharged home.[16] Most fall accidents are caused by a failure to recover from a postural perturbation.[17] Falls can lead to injuries such as fractures or soft tissue damage leading to readmission to hospital, fear of falling,[18] reduction of activity daily living (ADL) and social activity, diminutive quality of life, career stress, and increasing cost of financial.[17, 19] For the aforementioned reasons, the impact of fall in patients with stroke is enormous. Therefore, balance evaluation is important in order to assess balance deficits to deliver effective treatment of balance deficits and fall prevention.

Three main approaches of clinical balance assessment include quantitative, functional, and a systems/physiological assessment.[20] Quantitative assessment such as the use of posturography can precisely detect change of postural sway but the equipment is not easily affordable and portable to clinical settings. Functional balance evaluation includes the use of an ordinal scale such as Berg Balance Scale (BBS), the Postural Assessment Scale for Stroke Patients (PASS), the Community Balance and Mobility Scale (CB&M), and Dynamic Gait Index (DGI)[21] to identify balance problem through the assessment of functional task that requires balance. The functional scale is easy to use but many of these scales have limited ability to specify balance problem. Systems assessment is developed to determine the cause of balance deficits. This includes Physiological Balance Profile (PPA) that assesses vision, cutaneous sensation on the feet, leg muscle force, reaction time, and postural sway in stance.[22] The PPA focuses on physiological impairment related to fall risk but this scale cannot identify the underlying extensive cause of balance.[20, 22-24]

The Balance System Evaluation Test (BESTest) is one of the systems assessment designed to specify the underlying cause of balance impairments for guiding balance training specific to the systems that are impaired.[20] Construct of the BESTest covers six interaction systems of postural control including biomechanical constraints, stability limits/verticality, anticipatory postural adjustments, postural response, sensory orientation, and stability in gait. This scale consists of 36 items of which scored on 4 levels, ordinal scale from 0 to 3 where 0 indicates poor performance and 3 indicates high performance. Total score for the test, as well as for each section, are provided as a percentage of total points.[25] Similar to the validation of this scale in patients with several neurological conditions, the psychometric properties of the BESTest in patients with subacute stroke demonstrated excellent intrarater reliability and interrater reliability (intraclass correlation coefficient (ICC)= .99). Excellent convergent validity with the Berg Balance Scale (BBS) (Spearman *r*= .96), Postural Assessment Scale for Stroke (PASS) (*r*= .96), Community Balance and Mobility Scale (CB&M) (*r*= .91), and the Mini-BESTest (*r*= .96) has been reported.[26] Moreover, unlike the BBS, the BESTest showed no floor and ceiling effects. This scale was able to classify the patients with stroke who had high or low motor functional ability at the cutoff score of 49% (sensitivity of 0.71, specificity of 0.91, accuracy of 81%). Thus, the BESTest is reliable and valid for evaluating balance ability in persons with subacute stroke.[26] However, the only drawback of the BESTest is that it requires 35 minutes to complete the evaluation, thus, this scale may not be practical to implement in routine clinical practice. Therefore, there is a need for the shortened version of the BESTest. In addition, the previous study found that some items in the BESTest such as verticality and base of support were not commonly impaired in the patients with subacute stroke, thus, those items may be omitted to reduce the assessment time.[26]

The Mini-BESTest, a shortened version of the BESTest, has been developed to assess only dynamic balance.[27] It consists of 14 items from the 3^{rd}-6^{th} system of the BESTest, omitting 2 systems (Biomechanical Constraints and Stability Limits/Verticality). Each item scored on 3 levels, from 0 to 2, where 0 indicates severe dynamic balance and 2 indicates normal dynamic balance. The Mini-BESTest demonstrated moderate concurrent validity with the Activities- Specific Balance Confidence Scale (ABC) (*r*= 0.63).[27] Tsang and colleagues examined the psychometric properties of the Mini-

BESTest in 106 people with chronic stroke. They showed that the Mini-BESTest had excellent intrarater reliability (ICC= 0.97), interrater reliability (ICC= 0.96), and internal consistency (Cronbach alpha = 0.89–0.94).(28) It was also strongly correlated with other balance measures, such as BBS and one-leg standing (OLS). The minimal detectable change of the Mini-BESTest at 95% confidence interval was 3.0 points.(28) In contrast, Chinsongkram and colleagues showed that the Mini-BESTest had a floor effect in the low functional group of patients with subacute stroke, suggesting the limited ability of the Mini-BESTest to evaluate balance in patients with subacute stroke who had low motor functional ability.(26)

The Brief-BESTest, another shorted version of the BESTest, was recently developed.(29) The Brief-BESTest composed of 6 items derived from each section of the BESTest, including hip abductor strength, functional reach, one-leg stance, lateral push-and-release, standing on foam with eyes closed, and the Timed “Up & Go” Test. Although the Brief-BESTest was validated in people with neurological disorders (1 person with stroke included), it cannot be fully used in people with stroke without further validation. The Brief-BESTest demonstrated excellent interrater reliability with ICC of greater than 0.98. The accuracy of identifying people with or without a neurological diagnosis was 72%. The sensitivity to fallers was 100% and specificity ranged from 95% to 100% to identify nonfallers. It requires less equipment and less time than the Mini-BESTest and BESTest.(29) Nevertheless, this scale may be insufficient to cover all of balance problems because only one item is used to represent each section of postural control system.

This study, therefore, aimed to develop a short form of the BESTest that could be used in the patients with subacute stroke. The development of the short form BESTest (S-BESTest) was performed by Rasch Analysis of the BESTest data previously collected in patients with stroke. The S-BESTest along with the Brief-BESTest was tested for its psychometric properties including reliability, concurrent validity, predictive validity and responsiveness in the form of minimal clinically important difference (MCID). MCID was necessary in real clinical practice as it detected real change of balance ability which patients could perceived.[30] MCID was provided useful information regarding the true effectiveness of balance intervention.

Research question

Can the short form Balance Evaluation System Test (S-BESTest) and the Brief-BESTest be used to assess balance in patients with subacute stroke?

Objectives of the study

1. To develop the short form BESTest (S-BESTest) from the BESTest data previously collected in the patients with stroke.

2. To examine the intrarater reliability and interrater reliability of the S-BESTest and Brief-BESTest in persons with subacute and chronic stroke.

3. To assess the extent of association between the S-BESTest and Brief-BESTest with Berg Balance Scale (BBS) (concurrent validity).

4. To investigate whether or not the score of the S-BESTest and Brief-BESTest could be used to predict motor outcome at discharge (predictive validity).

5. To determine the floor and ceiling effect of the S-BESTest and Brief-BESTest, as compared to the BESTest in people with subacute stroke.

6. To determine the minimal clinically important difference (MCID) of the S-BESTest and Brief-BESTest, as compared to the BESTest in people with subacute stroke.

Hypotheses of the study

The S-BESTest will demonstrate better psychometric properties including reliability, concurrent validity, predictive validity and responsiveness, than the Brief-BESTest in capturing balance impairments in patients with subacute stroke.

Significance of the study

This study will provide a reliable, valid and responsive clinical scale that requires less time to administer for assessing the underlying cause of balance impairments in persons with subacute stroke in order to guide the appropriate balance program. The minimal clinically important difference will enable clinicians to analyze treatment outcome for decision making of continuing balance treatment program or changing to another program.

Keywords

Scale development, Short version, Postural control, Psychometric property, Cerebrovascular disease.

Conceptual Framework

The conceptual framework of this study is presented in figure 1.

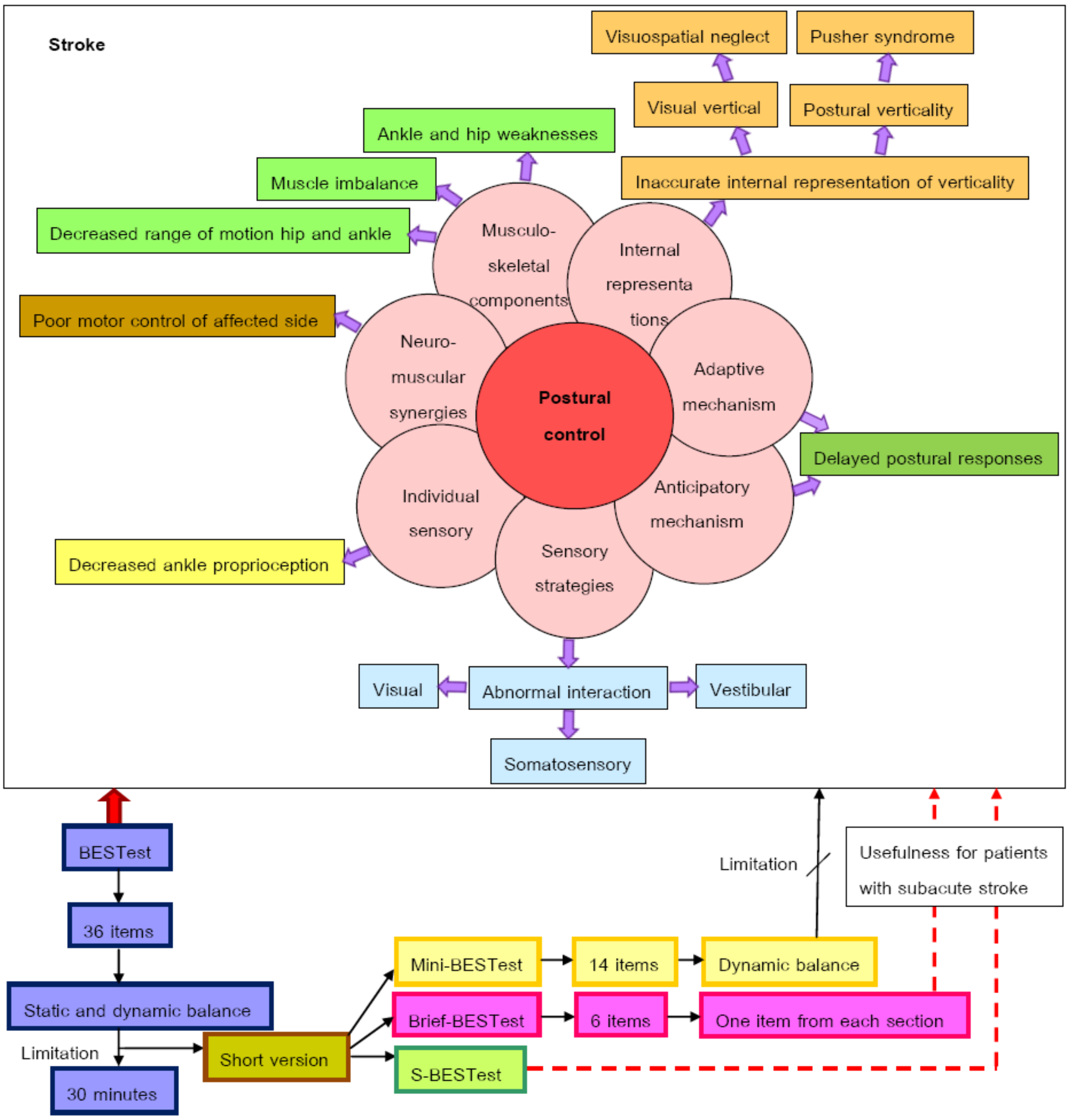


FIGURE 1 CONCEPTUAL FRAMEWORK.

CHAPTER 2
THE LITERATURES REVIEW

The literatures review part is separated into 4 sections as following.

1. Postural control components
2. Postural control deficits in stroke
3. Balance measurement tools
4. Method to shorten scale and its related psychometric properties testing

1. Postural control components

Postural control is important for performing activities of daily living. It can help stabilize the movement and prevent falls. Postural control consists of postural orientation and postural equilibrium.[2] Postural orientation or posture is the ability to maintain an appropriate part of the body segments with relation to themselves and to the environment. This includes the control of head and trunk in the same line with the gravity while standing or sitting on different surface orientation. Postural equilibrium or balance is defined as the ability to control the center of mass (CoM) into the base of support (BoS).[31] The CoM is a center of point of the total body mass, whereas the BoS is area of the body that contacts with surface. The CoM is related to the BoS in such a way that while person standing, CoM must be maintained inside the BoS in order to maintain postural stability.[32]

Postural control is a complex task, as it requires the coordination of various systems in the body.[1]-[2] Seven different systems are implicated in the postural control (Figure 2).[33] Musculoskeletal component includes the properties of muscle, spinal flexibility, biomechanical alignment of the body segments, and ranges of the joint motion. Neural systems consist of sensory system, motor and higher level pre-motor systems.[20] Sensory inputs from visual, somatosensory, and vestibular systems are processed to provide integrated information that helps to stabilize the body. Data from these sensory systems has been used to develop body internal representation that is a map showing the location of the body or body schema in order to explore the correct relationship between various parts of the body. In addition, body internal representation helps determine the position of the body relative to the environment and gravitational force.[34]

Persons with effective postural control need to be able to stabilize the body before and during movement, so called anticipatory mechanism. Likewise, the adaptive mechanism is required to adapt the body when received an unexpected disturbance to the body. Adaptive mechanism selects appropriate neuromuscular synergies via motor processing. Internal representation, adaptive mechanism, and anticipatory mechanism are organized by using higher level processing.

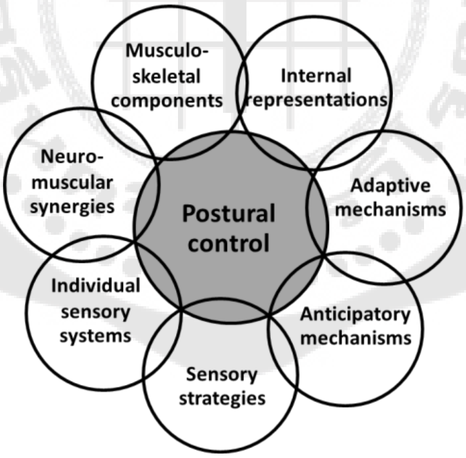


FIGURE 2 MULTIPLE SYSTEMS UNDERLYING POSTURAL CONTROL.[33]

2. Postural control deficits in stroke

Various systems involved in the control balance, including musculoskeletal components, neuromuscular synergies, individual sensory systems, sensory strategies, anticipatory mechanisms, adaptive mechanisms, and internal representation, are usually damaged after stroke. Details of impairments of each postural control component are presented in this review.

2.1 Musculoskeletal components

Muscle tone, muscle flexibility, and muscle strength contributes to the control of muscle to stabilize the body. Decreased joint ranges of motion and increased joint pain affect the control of balance. Biomechanical alignment of body segments is necessary for keeping the projection line of gravity within the base of support. Size and quality of the base of support is also important in balance control such that small area of the base of support leads to difficulty in the control of postural stability.[(1)-(2)] Impairments of musculoskeletal components often found in patients with stroke including muscle weakness, spasticity or paralyses, ankle or hip weakness,[(1-4)] decreased range of motion hip and ankle,[(5)] and joint pain limit the ability to control balance.[(2-4, 35)] Person with stroke demonstrated delayed postural responses to external perturbation such as inability to execute ankle strategies that are correlated with decreased ankle proprioception and ankle muscle weakness or decrease base of support.[(4, 6)]

2.2 Individual sensory system and sensory strategies

The central nervous system (CNS) maintains the body stability with respect to visual cues, gravitational direction, or body movement. Visual information is established from the retina to the CNS. The CNS interprets vision data for identifying position and motion of the head with respect to the surrounding objects as well as sense of verticality. In general, visual information is a main system to be used in postural control during low frequency of postural sway. The effect of postural control from the visual inputs depends on individual's visual acuity, visual contrast, distance of object, and room illumination. Moving visual field can induce misperception of vision cues, a powerful sense of self motion, and increase postural sway.[(36)] Most study demonstrated that vision information in patients with stroke is very crucial than somatosensory and vestibular systems because it disrupted learning and developing of a new skill.[(37)-(38)]

Patients with stroke were more dependent on visual inputs and they showed more difficulty in resolving conflict between the visual and somatosensory cues. The impairment of conflict resolution may underlie the rapid instability observed in patients with stroke.[39] Some studies suggested that a rehabilitation program employing visual deprivation to promote the use of somatosensory and vestibular inputs could reduce visual dependence in this patient group.[3, 9]

Vestibular system includes two types of sensors to detect head motion and position in space, otolith organs and semicircular canals. The otolith organs are sensitive to low frequency of head movement but the semicircular canals are sensitive to high frequency of the head motion. The CNS uses information from vestibular inputs to identify head position via gravitational reference. The otolith organs provide information of head linear acceleration and head position with respect to the gravitational direction. The role of semicircular canals is to detect information about angular acceleration and head rotation.[40-43] Vestibular system can differentiate exocentric and egocentric movement but has limitation in distinguishing head alone or whole body motion.[43]

Somatosensory inputs include exteroceptive and proprioceptive receptors that provide information about the relationship between the body segment and supporting surface. In patients with stroke, proprioception and stereognosis were more impaired than exteroceptive receptors as tactile sensations.[44] Proprioceptive deficits were negatively correlated with safety, motor function and postural stability.[45] Impaired proprioception has also been shown to have prognostic significance in self-care, likelihood of discharge to home and length of stay in hospital.[46]-[47] Loss of proprioception in the affected leg was correlated with loading asymmetry during while patients standing and walking.[48] Persons with stroke are able to use light touch sensory information cue to reduce the postural sway and maintain postural stability.[49-51]

Difference environmental conditions leads to the selection of sensory information.[52] Sensory reweighting is the process to set the priority of one important system above the other system due to its accuracy and usefulness to control balance performance. Reweighting of sensory information depends on the level of task difficulty, environment, and movement strategies apply in the task.[53] One of three sensory systems dysfunction is the cause of compensatory from other remaining sensory systems. The CNS relies more on information of vestibular and somatosensory systems when people or the population with stroke standing in the eyes closed condition.[(54)-(55)] Abnormal sensory reweighting between the three sensory systems is also evident in patients with stroke.[(7)-(8)] This is shown by excessive reliance on vestibular system more than another inputs when standing on the unstable surface and walking in the dark situation.[8] In contrast, excessive reliance on visual input more than another inputs when standing on the firm surface may be a compensatory response of sensory reweighting.[9, 53]

2.3 Movement strategies and adaptive responses

Adaptive mechanism aims to restore body's equilibrium during external disturbances. This mechanism operates through the feedback control using several movement strategies.[56] Three types of movement strategies are suggested for restoring equilibrium during standing; two in-place strategies that keep the feet in place and one stepping or reaching strategies that change the base of support.[2] The first in-place strategy is an ankle strategy that moves the CoM over the BoS with maximum movement occurred at the ankle joint in response to small disturbances. The second in-place strategy is a hip strategy as the primary movement occurs at the hip joint. The third movement strategy is stepping strategy that displaces the center of gravity beyond the limits of the base of support.[2, 57]

When ankle or hip strategies are insufficient to move the CoM back over the BoS base of support, the postural stability is need to regain by using the stepping or stumbling strategies.[2, 57] In general, the sequence of muscle activation began from ankle to hip when the contact surface was disturbed. People with stroke executed hip strategy more than ankle strategy as can be seen from early activation of quadriceps and hamstrings muscles before tibialis anterior and gastrocnemius muscles. Abnormal postural adjustments such as synchronous contraction of several or all lower extremity muscles, inconsistent patterns of muscle activations, longer and more varied response latencies, and unusual sequence of muscle activation, were evident.[58] Stepping strategy is also insufficient in persons with stroke such that the responses are delayed and inappropriate. The evoked steps were initiated primarily with the unaffected side where the step length and step duration were longer than the affected side.[59]-[60] Loss of balance control recovery step in patients with stroke is related to increased fall rates that were associated with increased use of external assistance and frequency of no-step trials, lower foot-floor clearance, and delayed time to initiate stepping responses.[61] As a result, patients with stroke preferred to use compensatory strategies such as stepping strategy or holding onto object more than healthy subjects when only in-place strategy was sufficient to regain balance in order to prevent a fall.[62]

2.4 Anticipatory postural adjustments

Anticipatory postural adjustments (APAs) is defined as the compensatory strategy for internal perturbation from voluntary movement.[63] The role of APAs is to stabilize the position of the body segment with respect to the environment while the other segments of the body move.[64] APAs help to enhance additional direct force for execution the movement.[65] The APAs are flexible and adaptive to instruction command or predication[66] prior experience, cognitive state, and data from intrinsic of the body and environment.[67] In the patients with stroke, APAs are abnormal or lesser in amplitude than age-match controls.[68-71] The evidence demonstrated the reduction of APAs on the paretic side and superficial trunk muscle.[72] The study showed that the pre-motor cortex lesion group of stroke exhibited a longer latency of tibialis anterior contraction and longer reaction time of the both lower limbs than the healthy and pre-motor cortex spared groups. The pre-motor cortex is involved in APAs associated with leg stepping movement, leading to impaired APAs of both contralateral and ipsilateral legs when stepping.[73] For the upper-extremity flexion movement, patients with stroke compensated by increasing the anticipatory activation of the nonparetic hamstrings[74] and impaired paretic muscle activation prior to upper limb flexion.[71]

2.5 Internal representation of the body

Internal body representation is the central control for body configuration that is formed by multisensory inputs, decision information inputs and integrated multimodal inputs.[75]-[76] One role of body internal representation is the same as body map that identifies position of each body relative to environment.[2] The other role of body internal representation is called perception of verticality to orient the body parts with concern to gravity, support surface, visual surround and internal references. The sense of verticality is linked to cues from extrapersonal and personal spaces.[77] Three types of perception of verticality have been suggested. The visual verticality (VV) is a perception of visual input estimated of gravitational line. The postural verticality (PV) is the estimate of the body tilt with respect to earth vertical. The haptic verticality (HV) is the estimate perception of haptic and touch sensation.[78] The internal representation of verticality establishes from the parietal-insular vestibular cortex of brain area that integrates visual, proprioception, and vestibular information.[79] Patients with stroke such as pusher syndrome (pushing the body away from sound side) and visuospatial neglect (ignore one side of the body) have inaccurate internal representation of verticality. Patients with pusher syndrome mistakes the estimation of the body tilt (postural verticality) with respect to gravitational direction whereas those with visuospatial neglect shows inaccurate perception of visual vertical with relate to gravitational line.[1]-[2]

The incidence of person with stroke and pusher syndrome is 10.4 percent.[80] The active pushing of unaffected limbs to the side of contralateral brain lesion is called as contraversive pushing.[81] The pusher patient with stroke had a normal visual perception in space but showed deformed perception of body orientation with respect to gravitational direction when eye closed.[82] The neural representation of graviceptive information to control upright position in person with pusher stroke is related to the lesion of superior parietal cortex, posterolateral thalamus, and the projection into the posterior limb of the internal capsule in the left side of brain.[83]

The prevalence rate of patients with visual neglect right and left hemispheric stroke is 43% and 20%, respectively.[84] This group of patient showed impaired visual awareness and attention deficit on the contralesional side of the body.[84] For example, the deviation of visual target approximately 15 degrees to nonparetic side[85]-[86] and misperception of visual verticality that disturb the peripheral into the non-retinal spatial reference frame of sensory information.[86] Person with visual neglect had the lesion of premotor frontal cortex, posterior thalamus, and medial thalamus in the right side of brain. Right visual neglect was associated with a left hemisphere stroke whereas left neglect had more severe and frequent than right that related to right hemisphere stroke.[85]-[86]

2.6 Cognitive processing

Healthy people require less attention in an automatic process to control balance, but patients with stroke showed greater attention demands for static postural control.[87] In dual task condition, more cognitive processes are required for postural control than normal situation.[2, 33] Limited attention during balance maintenance can be related to increased fall because the control of posture and cognitive processing share cognitive resources, reaction times.[1]-[2], [88] Many factor is associated with the attention demands for postural control such as age such that healthy older adult requires more attention demand than young adult.[33] It has been shown that attention demands for static postural control with task difficulty and cognitive task for dynamic postural control in patients with stroke are inadequate.[1]-[2] Gait speed was reported to be much slower during dual task in those with chronic stroke compared with controls.[89] Most studies have identified balance impairment with dual task such as walking while talking or holding object relating to higher risks of falling.[11-14, 90-95] Thus, cognitive impairment is a common cause in patients with stroke[96-99] that leads to disturbance balance performance and attention demand, impairs ability to plan, analyze, interpreted, and organize complex information,[100-102] increases fall risk and instability of postural control.[103]

3. Balance measurement tools

Balance measures are an important tool to analyze postural control problems.[20] The purpose of balance assessment is to identify balance problem and determine cause of problem or predict risk of falls. Acceptable characteristic of balance instruments should reflect the functional capabilities and quality of postural strategies, sensitive to detect abnormal postural equilibrium, reliable, valid, easy to use in clinical setting, and inexpensive.

3.1 Berg Balance Scale (BBS)

The Berg Balance Scale (BBS) is considered to be a reference standard for assessing balance, as it is one of the most commonly use balance assessments in the clinic and research.[21, 104] It is also a valid instrument used for assessing the effectiveness of balance training program.[105] The BBS is originally designed for using in the frail elderly and developed to measure balance among stoke with impairment in balance function by assessing the performance of functional tasks. This scale assesses the participant's ability to maintain a position and changing the base of support.[106] It consists of 14 items that evaluate functional working in activities of everyday living with the total score of 56 points. The scoring criteria for each item ranges from 0 to 4, where 0 represents incompetence and 4 represents competence.

Excellent internal consistency as well as intrarater and interrater reliability of the BBS in patients with stroke has been demonstrated with the Cronbach's alpha between 0.92 to 0.98[21] and intraclass correlation coefficient (ICC) = .95-.98.[107-109] BBS has been validated in stroke population. It was strongly correlated with other balance assessments in the convergent construct validity, such as Fugl-Meyer Assessment (FM) (r= 0.71), Functional Independent Measure (FIM) (r= 0.76), Barthel Index (r= 0.8 to 0.94), Postural Assessment Scale for Stroke (PASS) (r= 0.92 to 0.95),[21] Functional Reach (r= 0.78),[110] and the Static Balance Test (r= 0.91).[111] The convergent validity of BBS was also adequately correlation with the balance master (r= -0.48 to -0.67).[109]

BBS can differentiate between three groups (acute unit in hospital, rehabilitation setting, and home) that based on the place at follow up assessment. The BBS has been reported to have predictive validity that predicted score of the motor assessment scale at 180 days post stroke (Spearman correlation ranged from 0.82 to 0.91),[107] and walking ability of FIM level 6 or 7 among inpatient stroke after 3 months with optimal cutoff score equal or less than 13 (sensitivity 63% and specificity 90%).[112] The BBS can also predict level of disability as examined by the Barthel Index,[113] and length of stay (*r* = -0.39 to -0.53).[114]-[115] The accuracy of discriminate analysis in this scale was 81.1% that differentiated fallers and non-fallers participants with stroke with the discriminated score of 21 points.[116] The score of BBS less than 49 points was used to predict recurrent falls in six months after discharge from stroke rehabilitation with sensitivity 92%, specificity 65%, positive predictive value (PPV) 42% and negative predictive value (NPV) 97%.[13] The evidence showed moderate to excellent of the BBS to detect change in patients with acute stroke. The effect size was varied depending on the duration post stroke (effect size (ES)= 0.21 to 1.28), suggesting the responsiveness reduced when duration post stroke increases with the greatest ES at 14 to 30 days post stroke.[21] Change in BBS score of 6 and 7 points means 90% real clinical balance change certainly and 95% real clinical change in participants with acute stroke, respectively.[115] The BBS was also sensitive to detect real change over time in population with chronic stroke.[112] MDC_{95} is 5 points in patients with chronic stroke.[117]

However, BBS has been demonstrated to have a floor and ceiling effect in patients with stroke as well as other population. This scale has significant floor effect in patients with stroke onset after 14 days[105] and large ceiling effect in community dwelling and high functioning of stroke at 90 and 180 days after stroke.[105] Floor and ceiling effect might affect responsiveness to detect change in different severity of stroke.[1, 21, 113] Moreover, BBS is not designed to evaluate adaptive postural responses that are commonly related to fall in patients with stroke.

3.2 Postural Assessment Scale for Stroke Patients (PASS)

Postural Assessment Scale for Stroke Patients (PASS) was originally designed to measure balance function in persons with stroke.[118] It was developed from the Fugl Meyer Assessment Scale (FM) to evaluate 12 items of postural control categorizing into 3 different positions; lying, sitting, and standing. The total score of the PASS is 36; scoring is based on a 4-point ordinal scale ranging from 0 to 3, with 0 indicating inability to perform the task and 3 indicating ability to complete the task. The psychometric properties of the PASS were high for interrater and test-retest reliability (average k = 0.88 and 0.72) and for internal consistency (Cronbach's alpha coefficient =.95). The PASS has strong construct validity that correlated with lower-limb motricity score (r=0.78), FIM score (r=0.73), and adequate correlation with the balance master (r=0.48).[118] This scale was excellently correlated with BBS (r= 0.9) during approximately 10 days post-stroke.[119] The PASS demonstrated high accuracy to predict independent ambulation for stroke population at discharge with a cutoff score equal 12.5 points.[120] The smallest real differences (SRD) of the PASS was 4 points that represents a real improvement only on chronic stroke patients with mild to moderate disability.[121] The PASS has good internal responsiveness (effect size as 0.87) in stroke patients with low level of postural performance[122] and ceiling effects shown after 3 months post-stroke.[123]

3.3 Community Balance and Mobility Scale (CB&M)

The Community Balance and Mobility Scale (CB&M) was developed because the BBS and PASS have ceiling effect to detect improvement later after 3 months post stroke. This scale evaluates balance abilities and mobility activities in only moderate to high functioning individual after stroke who live in community. The assessment contains the challenging task with high skill of postural control and mobility such as running with controlled stop and jumping forward on one leg. It consists of 19 tasks and the score for each task ranges from 0 to 5, where 0 means incompetence and 5 means competence. Only the task carrying a laundry basket while descending stairs has scoring from 0 to 6. Total score of the CB&M ranges from 0 to 96 points with higher scores represent better balance and mobility.[(124)] The convergent validities of CB&M were moderate to high correlated with BBS and TUG (p= 0.70 to 0.83) and moderate correlation with Chodoke McMaster stroke assessment (CMSA) leg and foot score (p= 0.61 to 0.63) and the paretic limb strength (p= 0.67). Ability to detect change of the CB&M showed the greatest change (SRM= 0.83).[(125)] However, the CB&M is limited to evaluate balance in persons with subacute stroke, as patients in this stage usually have low functional level.

3.4 Dynamic Gait Index (DGI)

The Dynamic Gait Index (DGI) is developed to evaluate postural control during walking.[(126)] It consists of 8 items of walking related task, including changing in gait speed, turning head horizontal and vertical while walking, turning in pivot position during walking, moving over and around obstacles, and stair climbing. Items are scored on ordinal scale 0 to 3, where 0 represents severe impairment and 3 represents normal ability.[(126)] The perfect performance total score of DGI is 24. A low composite DGI score means greater deficit in functional mobility.[(126)] These functional balance measurement tool has good psychometric properties in person with chronic stroke, good reliability (ICC for test-retest and interrater reliability equal 0.94 to 0.96)[(126)] and moderate to good concurrent-construct validity and convergent validity with other disability assessment tools or functional postural control testing tools[(126)] and moderate validity with computerized posturography.[(126)] The DGI has no floor and ceiling effect among individual chronic stroke after first week, 2 months, and 5 months of therapy. This scale shows moderate ability to detect change within 5 months, ES ranged from 0.56 to 0.62.[126] The MDC of DGI was 4 points for detecting improvement in person with chronic stroke.[126] The limitation of this scale is that it can evaluate dynamic balance during gait only and may have floor effect in patients with subacute stroke who have low functional ability.

From this review, it can be seen that there is no single balance assessment scale that can be applied to different functional levels of patients with stroke, and therapists need to administer more than one clinical balance scales to capture the balance performance across functional levels of patients with stroke. Moreover, clinical balance scales available at present report the information regarding whether or not a patient has balance problems in performing a particular testing activity. However, those scales do not identify the underlying causes of balance deficit in order to treat it effectively. As a result, there is an urgent need for clinical balance evaluation tool that can identify the underlying causes of balance impairment in order to target the specific and effective balance training protocols for patients with stroke.

3.5. Physiological Balance Profile (PPA)

The Physiological Balance Profile (PPA) is one of the balance assessment scales that aim to evaluate the cause of balance impairments. This scale focuses on several factors related to balance performance, such as visual acuity, cutaneous sensation on the feet, leg muscle power, reaction time, and postural sway in standing position.[22] The PPA has reliability and validity. It has been used mainly to differentiate risk for falling between older fallers people and older non-fallers people.[22, 24] Composite PPA scores below 0 represents a low fall risk, scores between 0 and 1 represent a mild fall risk, scores between 1 and 2 represent a moderate fall risk, and scores above 2 represents a high fall risk. This scale was widely useful in female more than male for fall risk prediction. However, PPA does not identify all underlying causes of balance deficits and cannot help in guiding specific treatment for balance impairment.[20, 22, 24]

3.6 Balance Evaluation System Test (BESTest)

The Balance System Evaluation Test (BESTest) is one of the systems assessment designed to specify the underlying cause of balance impairments for guiding balance training specific to the systems that are impaired.[20] Construct of the BESTest covers six interaction systems of postural control including biomechanical constraints, stability limits/verticality, anticipatory postural adjustments, postural response, sensory orientation, and stability in gait. This scale consists of 36 items of which scored on 4 levels, ordinal scale from 0 to 3 where 0 indicates poor performance and 3 indicates high performance. Total score for the test, as well as for each section, are provided as a percentage of total points.[25]

The first category of the BESTest is biomechanical constraints that include 5 items. This category tests in standing position that observed quality of base of support, postural alignment, function of strength in hip and ankle, and rise heel from the ground.[25] The second category is stability limits and verticality that consist of 3 tasks. This category examines limit of stability and internal representation. In sitting position with eyes closed, person leans as far as possible the ability to lateral limit of stability and perception of verticality. Functional limit of stability provides a measure of maximum reaching in forward and lateral directions when participant standing.[25] The third category is anticipatory postural adjustments that compose of 5 items. This category evaluates the ability to control CoM movement before voluntary control during changing position from sitting to standing, stance to rise on toes, double limb support to single limb support, two legs alternative weight shift while touching a forefoot on stair, and bilateral arm parallel trunk to both arm raise with weight-lifting.[25] The forth category is reactive postural response that includes 5 items. This category tests in-place responses and compensatory stepping strategies from external disturbance by using “push and release" techniques from both hands of the tester. The examiner pushes (isometric force) in front and back of the participant's both shoulders until the heels or the toes lift without changing the starting position to induce in-place response in term of ankle strategies. To induce rapid compensatory automatic stepping response, the tester pushes the body's center of mass over the base of support in forward, backward, and lateral lean prior to release compression.[25] The fifth category is sensory orientation that consists of 2 items. This category integrates and selects sensory inputs to response sensory information from CNS that required sensory organization test in standing position. Two items consist of the modified clinical test of sensory integration for balance (CITSIB) and stand on 10-degree incline surface with eyes closed. The last category is stability in gait that composes of 7 items. This category examines dynamic balance control during walking and cognitive dual-task processing. Items in this category were developed based on the concept that walking requires control of the body's CoM and changes BoS. Balance performance can be challenged in the test by increasing or decreasing gait speed, changing head rotation, pivot turn, stepping over obstacle, adding the Time Up&Go test (TUG) and the TUG with secondary subtraction cognitive task.[25]

The BESTest have been validated in healthy subject and several patients with neurological diagnoses such as Parkinson's disease, unilateral and bilateral vestibular loss.[25] Similar to the validation of this scale in patients with several neurological conditions, the psychometric properties of the BESTest in patients with subacute stroke demonstrated excellent intrarater reliability and interrater reliability (intraclass correlation coefficient (ICC)= .99). Excellent convergent validity with the Berg Balance Scale (BBS) (Spearman r= .96), Postural Assessment Scale for Stroke (PASS) (r= .96), Community Balance and Mobility Scale (CB&M) (r= .91), and the Mini-BESTest (r= .96) has been reported.[26] Moreover, unlike the BBS, the BESTest demonstrated no floor, ceiling or responsive ceiling effects. This scale was able to classify the patients with stroke who had high or low motor functional ability at the cutoff score of 49%

(sensitivity of 0.71, specificity of 0.91, accuracy of 81%). The BESTest was the most sensitive scale to detect postural control improvement when compared with the Mini-BESTest and CB&M in term standardized response mean (SRM), 1.2 ($p<0.01$).[127] This scale can differentiate patients who have balance improvement; change in the BESTest score of 10 percent or more indicates balance ability of patient is improving.[127] Thus, the BESTest is reliable, valid and sensitive to detect real changes for evaluating balance ability in persons with subacute stroke.[26, 127] However, the only drawback of the BESTest is that it requires 30 minutes to complete the evaluation, thus, this scale may not be practical to implement in routine clinical practice. Therefore, there is a need for the shortened version of the BESTest. In addition, the previous study found that some items in the BESTest such as verticality and base of support were not commonly impaired in the patients with subacute stroke, thus, those items may be omitted to reduce the assessment time.[26]

3.7 Mini Balance Evaluation System Test (Mini-BESTest)

Franchignoni and coworker[27] developed short form of the BESTest called the Mini-BESTest. The performance of the BESTest was examined in 115 consecutive adult persons with various neurological conditions and severity of disease, referred to restitution for postural control disorders. Data processing to reduce items of the BESTest was evaluated by using Factor (both exploratory and confirmatory), resulting in a total of 24 from the 36 original BESTest items to illustrate only dynamic balance. [27] The Rasch analysis was then used to omit 10 items that were mis-fitting or demonstrating local coherence and reduced rating criteria from 4 levels to 3 levels of rating scores. As a result, the Mini-BESTest includes 14 items from the 3^{rd}-6^{th} system of the BESTest. Each item scored on 3 levels, from 0 to 2, where 0 represents severe dynamic balance and 2 represents normal dynamic balance. The total score from original shorter version is 28 points.[128, 129] The test can be completed within 10-15 minutes. Moderate concurrent validity with the Activities-Specific Balance Confidence

Scale (ABC) (r= 0.63) has been reported.[27] The psychometric properties of the Mini-BESTest in 106 people with chronic stroke were examined by Tsang and colleagues.[28] They presented that the Mini-BESTest had excellent intrarater reliability (ICC= 0.97), interrater reliability (ICC= 0.96), and internal consistency (Cronbach alpha = 0.89–0.94).[28] It was also strongly correlated with BBS and one-leg standing (OLS). Prediction of falls in persons with stroke was reported using the cut-off score 17.5 points out of total score of 28.[28] The minimal detectable change of the Mini-BESTest at 95% confidence interval was 3.0 points.[28] In contrast, Chinsongkram and colleagues demonstrated that the Mini-BESTest had a floor effect in the low functional group of persons with subacute stroke, suggesting the limited ability of the Mini-BESTest to assess balance in people with subacute stroke who had low motor functional ability.[26, 130, 131]

3.8 Brief Balance Evaluation System Test (Brief-BESTest)

Recently, another shortened version of the BESTest was developed as the Brief-BESTest.[29] The Brief-BESTest included 6 items that derived from each component of the BESTest, including muscle strength of hip abductor, functional reach forward test, single-leg stance, lateral push-and-release, standing on uneven support with eyes closed, and the TUG. This scale was validated in people with neurological disorders (1 patient with stroke included), it cannot be fully used in patient with stroke without further validation. The Brief-BESTest demonstrated excellent interrater reliability with ICC of greater than 0.98. The accuracy of identifying persons with or without a neurological disorder was 72%. The sensitivity to fallers was 100%. The specificity ranged from 95% to 100% to identify nonfallers. It requires less equipment and less time than the Mini-BESTest and BESTest.[29] Nevertheless, this scale may be insufficient to cover all of balance problems because only one item represents each category.[132]

Summary of the items in three types of the BESTest is shown in Table 1.

TABLE 1 SUMMARY OF THE ITEMS IN THREE TYPES OF THE BESTEST.

Items\Types of the BESTest	BESTest	Mini-BESTest	Brief-BESTest
I. Biomechanical constraints			
1. Base of support	/		
2. CoM alignment	/		
3. Ankle strength& range	/		
4. Hip/trunk lateral strength	/		/
5. Sit on floor and stand up	/		
II. Stability limits			
6. Lateral lean (Lt./ Rt.)	/		
Verticality (Lt./ Rt.)	/		
7. Functional reach forward	/		/
8. Functional reach lateral	/		
III. Transitions-anticipatory postural adjustment			
9. Sit to stand	/	/	
10. Rise to toes	/	/	
11. Stand on one leg	/	/	/
12. Alternate stair touching	/		
13. Standing arm raise	/		

TABLE 1 (CONTINUED).

Items\Types of the BESTest	BESTest	Mini-BESTest	Brief-BESTest
IV. Reactive postural response			
14. In place response-forward	/		
15. In place response-backward	/		
16. Compensatory stepping correction-forward	/	/	
17. Compensatory stepping correction-backward	/	/	
18. Compensatory stepping correction-lateral	/	/	/
V. Sensory orientation			
19. Sensory integration for balance (modified CTSIB)	/		
Eye open/firm surface	/	/	
Eye close/firm surface	/		
Eye open/foam surface	/		
Eye close/foam surface	/	/	/
20. Incline eyes closed	/	/	
VI. Stability on gait			
21. Gait-level surface	/		
22. Change in speed	/	/	
23. Walk with head turns-horizontal	/	/	
24. Walk with pivot turns	/	/	
25. Step over obstacle	/	/	
26. Timed “Get Up & Go”	/		/
27. Timed “Get Up & Go” with dual task	/	/	

From the review of clinical scales, it can be concluded that the BESTest is far more superior than other balance scales to assess the impairments of postural control systems underlying balance deficits in patients with stroke. However, the review emphasizes the necessity for the short form of the BESTest that is suitable for the patients with stroke. This study aims to develop the short form of the BESTest by using Rasch analysis on the data previously obtained in the stroke group. Therefore, next part of the review is focusing on the process of shortening the scale and its related psychometric properties testing.

4. Method to shorten scale and its related psychometric properties testing

The development shortening instruments focuses on shortening existing measurement scale, processing items reduction and contributing to improve psychometric properties. Principle and methodological of shortening composite measurement scale divides into 3 approaches; expert-based approach, statistical approach, and both approaches combined.[133] [134]

Expert-based approach depends on expert opinions in the field. The shortening process using this approach provides scale that deletes unresponsive items in the scale. The scale will be sent to expert who will decide to add or reduce the items. After the shortening of the scale, it will be tested in sample subjects. This approach has the advantage when there is no gold standard situation comparison. Expert-based method is preferable to be used in evaluation of content validity. The number of expert should be an odd number equal or more than 3 persons. Responses from all experts are pooled and the number representing "essential" for each item is examined. Any item, performance on which is considered to be "essential" by more than half of the experts, has some degree of content validity. The more experts (> 50%) who consider the item as "essential", the greater the extent or degree of its content validity. Content Validity Ratio (CVR) is used to represent the extent of content validity. CVR is calculated by using this formula: (ne-N/2)/(N/2), in which 'ne' mean the number of experts that considered the item is essential and N mean the total number of experts in the panel. The CVR ranges from -1.00 to +1.00. CVR of 0.00 indicates that 50% of all experts convince the item to be essential. CVR of +1.00 indicates that 100% of all experts convince the item to be essential whereas CVR of -1.00 indicates that 0% of the all experts convince the item to be essential.[(135)-(136)]

Statistical approach employs several methods that include correlation of long version with short version scores or correlation of items and composite scores, cronbach's alpha coefficient per dimension to measure internal consistency, factorial analysis, and item response analysis. [(133) (134)] Correlation approaches between long and short version scores can inflate the amount of correlation as the short version scores yield less measurement errors due to their fewer items. In contrast, correlation between items and composite scores can lead to misperception the item importance as item with high correlation may not be the best representative of that domain. Cronbach's alpha may be misleading when there are item redundancy in the scale. The most popular method is factor analysis.[(133) (134)] Item response method is widely considered for evaluating construct validity and revising shorten version of the scale.[(134)] Data analyzes by using statistic method that performs fast and conveniently to delete redundancy items.

Both approaches combined is expert-based method plus statistical approach.[(133)] Shortening scale in this approach is reduced unnecessary or redundancy items and confirmed items that represent each section by using item response method and confirmatory factor analysis, respectively. Short version has been established from statistical methods. Then the draft short form is sent to experts in the field for content validity. Therefore, the final version of shortening scale is constructed based on theoretical and expert's opinions. This approach has more benefit, reduced disadvantage when used only expert-based method or statistical method. Thus, this study selects "both approaches combined" to analyze data for avoiding the main pitfalls concerning the shortening process.

4.1 Rasch analysis

Rasch analysis is one of the methods used to test internal validity of instrument. This method bases on item response theory (IRT) or latent trait theory, relationship between person's response and the construct called latent variable or ability or trait variable.[(137)] The IRT provides information about how examiners at different ability levels on the trait have performed on the item. IRT models measure scale precision across the underlying latent variable being measured by instrument.[(137)-(138)] This theory is being applied in health outcomes research to develop new instruments or improve existing measures, to investigate group differences in item, to equal scales for across participant scores, and to develop computerized adaptive tests. The latent variable is a continuous unidimensional construct that explains the covariance among item responses. It may be any measurable construct such as physical functioning or balance performance. People at higher levels of latent trait have a higher probability of responding correctly an item. Each variable is characterized by one or more model parameters. The item difficulty or threshold describes the point on the latent scale where individual has a 50% chance of responding positively to the question.[(137)] The slope or discrimination is the strength of an item's differentiation between persons with ability levels above or below the threshold.[(137)] Discrimination may also be interpreted as explaining how an item may be led to the latent measured by the scale and is directly related, under the assumption of a normal distribution.[(137)]

Concept of IRT includes the item characteristic curve (ICC), unidimensional, and local independence. An item characteristic curve plots the probability of responding correctly to an item as a function of the latent trait underlying performance on the items on the test. The most IRT in research is assumed to have S shape and a normal ogive or logistic function.[(139)-(140)]

It describes the relationship accurately and fit the data. The score on a person's trait level increases showing the probability of answering correctly.

Unidimensional is defined in term of the statistical dependence among items that can be accounted for by a single latent trait. Local independence is defined for a subpopulation of examinees located at a single point on the trait scale.[(139)-(140)]

IRT model have two approaches towards measurement. First approach is to develop a well-fitting model to reflect the item response data by parameterizing trait of interest or the ability level as well as the properties of the items. Fairly well-fitting model is shown in Figure 3. Second approach follows that of the Rasch models, specific measurement properties defined by the model to which the item response data must fit. A person or the item is discarded when the data does not fit within the measurement properties of the IRT model.[(137)]

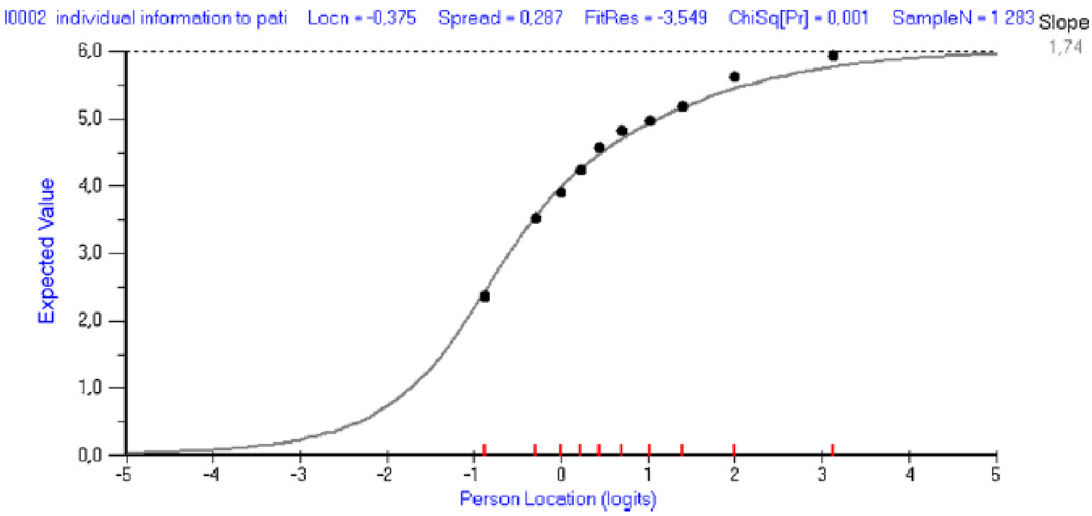
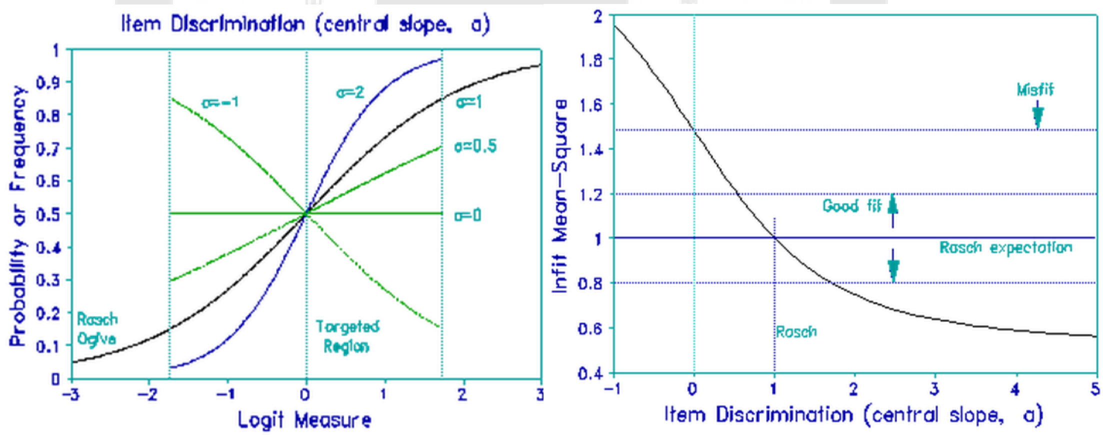


FIGURE 3 FAIRLY WELL-FITTING MODEL.

Note: item fit can also be evaluated by the ICC. The X axis means the latent nursing self-efficacy estimate on an interval 'logit' scale or a person's trait level and the axis Y indicates the expected response value of the item. The s shape is the relationship expected by the model. The dots on the line represent the average response for groups at different ability levels. The dots closely follow the expected curve of the item interprets a good fit to the model expectations but that there are some misfit at the upper end of the curve.[141]

Seven common IRT models present the potential application to health research.[137] Two models, partial credit model and rating scale model, are related to use for discrimination and item threshold steps equal across items in polytomous item response format. The partial credit model is characterized the discrimination power constrained to be equal all items. The rating scale model have objective as same as the partial credit model.[137, 139] Additional advantage of the rating scale model is evaluated the distance between difficulty levels from category to category within each item across the same all items. Constraint of this model is a fixed set of rating scores, all items have equal response categories.[140]



A) B)

FIGURE 4 A) INFIT AND OUTFIT B) GOOD FIT OF THE RASCH MODEL.

Note: A) Ideal of ICC is black line, plotted in the measure of the latent trait variable on which the item is targeted. Infit is shown extending only the s curve in the black line. Empirical ICCs of green lines are better diagnosed by the Outfit Mean-square statistics. B) Central item discriminations from 0.6 to 1.4 produce good fit to the Rasch model, provided the part of the ICC away from the center is in reasonable conformance.

Rasch model indicates how accurately or predictably data fit the model.[(139)-(140)] Interpretation for the Rasch model, items with extreme discrimination power both at the low as well as high values will be identified as misfit and will be deleted from the scale. Infit identifies inlier-sensitive or information-weighted fit. This term is defined more sensitive to the pattern of responses to items targeted on the person. Outfit determines outlier-sensitive fit. It is more sensitive to responses to items with difficulty far from a person. Figure 4 A) is shown infit and outfit. Mean-square fit statistics demonstrate the size of the randomness. The infit and the outfit can be analyzed with the results presented in mean-square format (MnSq). Figure 4 B) is shown appropriate scores that ranged from 0.6 to 1.4 for polytomous items, with associated scores of t-statistics= ± 2.0. Score of MnSq more than 1.4 indicates errors in item scores. Too low 0.6 score of MnSq may indicate little variance in item scores or a very predictable standard of respond.[(140)] Data is processed by Rasch analysis using WINSTEPS software.[(142)] Finally, scale improves the rating point and delete unnecessary of the item.[(143)]

4.2 Factor analysis

Factor analysis is a statistical method commonly represents construct validity. The idea of factor analysis comes from theoretical concept that one or multiple constructs underlie dimension or different components. This approach groups the same construct items together. Factor analysis consists of 2 method; exploratory factor analysis (EFA) and confirmatory factor analysis (CFA).[(144)] EFA has been commonly used in the initial process of scale development where there are scattered pool of items from literature review and theory. This method will help to categorize those items into factors or domains.[144] CFA is a factor model based on an explicit hypothesis about the number of latent traits underlying measures and variables of the model that affect the factors weighting or loadings on the measures. The model of instrument should be consistent with substantive theory for conducting CFA.[144] CFA has three prototypical models; single-factor model, correlated factors model, and bifactor model.

The simplest CFA model is a one-factor model. A single-factor model is related to structural equation modeling (SEM) in a path diagram, figure 5. The SEM is a data analysis approach for evaluation of models that specify relationships among variables.

Path Diagram:

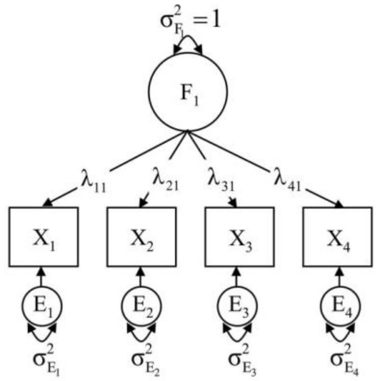


FIGURE 5 A ONE FACTOR MODEL OF CFA.[144]

In Figure 5, a diagram of a model with a single factor (F_1) underlying four parameters that include X_1, X_2, X_3, and X_4. The factor is defined as a circle, which means a latent variable. The observed measures are depicted as squares pattern which mean observable or indicator variables. A single-headed arrow between two variables represents the direction of the effect from the one variable to the other variable. The lambda indicates factor loading. E indicates error of measurement.[144] This diagram uses to analyze each section of the scale.

The correlated factors model of CFA is two or more factors underlie a set of measured latent variables and that these factors are correlated. Figure 6 showed another one circle (F_2) in the additional latent variable.[144] This graphical demonstrated the relationship between one and another components of the scale.

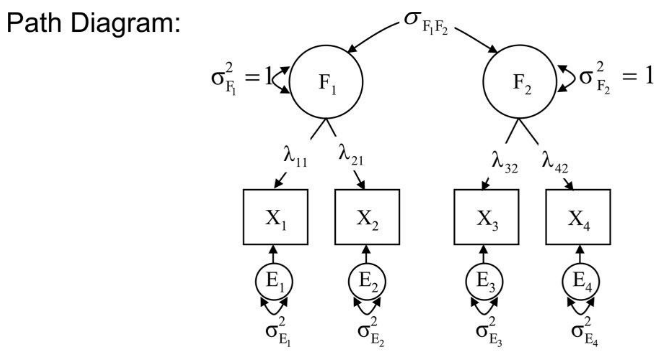


FIGURE 6 CORRELATED FACTORS MODEL.[144]

A bifactor model of CFA is one or more observed variables underlie two factors. Figure 7 demonstrated two circles (F_1 and F_2) that indicate latent variables or unobserved variables.[144] This diagram showed three indicator variables association with two factors of the scale.

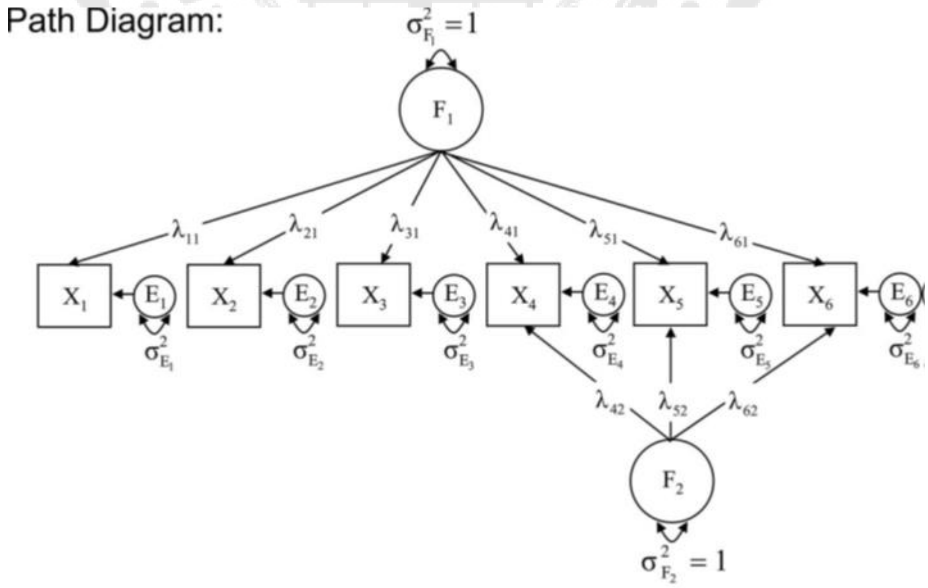


FIGURE 7 A BIFACTOR FACTORS MODEL.[144]

It is recommended that a sample size for CFA is equal or more than two hundreds data set to be distributed approximately as a $\chi 2$. Number of sample size may be related to power that accept or reject models.[144] Interpretation of CFA is using the perfect fit model. Two indices that are often used for interpretation, Bentler's comparative fit index (CFI) and the root mean square error of approximation (RMSEA).[144] CFI compares default model to the independent model and uses the goodness of fit index, GFI, to explain what proportion of the variance in the sample is accounted for by the model. This GFI should exceed 0.9 for a good model. The RMSEA is a fit index that evaluates lack of fit of a model but not compare with another model. A value of RMSEA less than 0.08 represents good fit. All these model fit statistics show that the dataset fits the current conceptual model well.

The next section of the reviews will cover related psychometric properties testing that will be performed on the short form of the scale.

4.3 Reliability

Measurement error can appear in general situation.[145] The source of error can be derived from participants, raters, and environment. The good feature of reliability is necessary to ensure consistent and free from error. Statistical concept of reliability based on the variance of score in representative sample, reliability coefficient that is a ratio of participant variance (true score) and observed score. The reliability coefficient ranges from 0-1, where 1 represents zero error.[146]

Clinical measurement tools require rater to measure variable of instrument, application and interpretation tool. Thus, rater reliability is necessary to valid observer or tester in every research study. Two ways of rater reliability include intrarater reliability and interrater reliability. Intrarater reliability is one rater to assess two or more trials test for the stability of scoring. Short time period should be enough to avoid fatigues and memory effect. Intrarater reliability should be created for each rater before comparing other rater. Data from intrarater reliability is providing strength and accurate of measurement and research conclusion. ICC should be used to assess rater reliability for intrarater reliability, ICC model 3 can be use that represent one rater.[145-147]

4.4 Criterion- related validity

The most practical of validity testing is criterion validity approach. The scale should examine the same thing with target criterion test and target rating score independence. Good characteristic of test must have excellent test retest reliability and free from bias. The target test results are compared with gold standard. The criterion measure or a gold standard must have a valid indicator of variable of interest and recognize a degree of validation as same as a reference standard.[148]-[149] There are two types of criterion validity; concurrent validity and predictive validity. Concurrent validity tests a new or untested instrument comparable with reference standard or gold standard measurement. The results of a new measurement tool will have practical and effective to use, easy and safety to administration. Thus, the target test or a new test is related to reference standard with the same time and reflect the same incidence of behavior.[149] Predictive validity examines a target test that will predict valid of same criterion score in the future. Starting predictive validity testing with a target of interest applied at the first session and test criterion score followed time frame after success the first session. Predictive validity is helpful to screening risk factor of interest, prognosis, and planning long term goal.[148]

4.5 Responsiveness

The ability to evaluate effectiveness of intervention is another important characteristic of the scale. A basis analysis of treatment effect is to detect change score between the difference in initial score and outcome score, known as responsiveness. Responsiveness is essential for detecting minimal change over time.[150] Characteristic of responsiveness can be considered from change of score; the score must change in proportion to the patient's status change and must remain stable when the patient unchanged.[151] This change must also be large enough to be statistically significant for research aims and accurate enough to appear increments of meaningful change for clinical practices.

Responsiveness is dividing into 2 approaches that include internal responsiveness and external responsiveness.[152]

4.5.1 Internal responsiveness

Internal responsiveness indicates the ability of a measure to change over a pre-specified time period.[152] Distribution-based approaches for determining clinically meaningful change are based on the statistical significance assess change in relation to the probability by random variation.[153] Distribution-based approaches compare the variability or the measurement error of the measurement instrument such as the effect size (ES) and minimal detectable change (MDC).[153]

Three features of effect size have been used.[152] The first approach of calculating the effect size index is a ratio of the mean change score divided by the standard deviation of initial score.[152] This value may vary among people with different baseline variability. Therefore, interpretation value is relative to baseline variability. The effect size of 0.2 or less represents a small change, 0.5 represents moderate change, and 0.8 or more represents a large change. The second form of effect size is standardized response mean (SRM) or sometimes referred to as the efficiency index that a ratio of change from initial test to final test divided by the standard deviation of change scores.[154]-[155] The magnitude of change in standardized units is relative to variability of change. It will vary as a function of effectiveness intervention.[153] High variability in the degree of change can be led to small SRM. The criterion of interpretation size of SRM is the same as effect size index. The third form is Guyatt's responsiveness or responsiveness index, change measurement relative to variability in scores among groups who are clinical status has stable.[156] The denominator consists of the mean square error from an ANOVA, which may be acquired from test retest reliability scores. For the variability in score changes among clinically stable participants to be responsiveness, the measure must also be able to detect minimal clinically important different that exceeds any false change.[157] However, the aforementioned method lacks information whether the observed changes are minimally important and provide supportive evidence.[158]-[159]

MDC is the smallest detectable change that determines treatment effect. It can be considered above the measurement error with a level of confidence such as usually 95 % confidence level. The formula of MDC can be calculated by 1.96 multiply $\sqrt{2}$ and multiply the SEM.[154] The SEM is value of score difference or deviated from true score. SEM is calculated by SD multiply $\sqrt{1-\text{reliability}}$. Reliability affects MDC that high reliability involves low MDC whereas low reliability involves high MDC [153] However, MDC may not indicate a meaningful difference in patient's response.

4.5.2 External responsiveness

External responsiveness represents the extent to which change in a measure over a specified time frame relates to corresponding change in a reference criterion tool of clinical or health status.[152] External responsiveness examines the relationship between change in the measure and change in the external standard such as minimal important difference (MID) or minimal clinically important difference (MCID).[152] MCID is defined as "the smallest difference in score in the domain of interest which patients perceive as beneficial".[30] Anchor based approaches consider the anchor or reference or external criteria for MCID assessment. Global rating of change (GRC) is used as independent criteria measure to evaluate perception of change from individual person's perspective.[153, 160] Anchor-based method compares the change in patient-reported outcomes score to some other measures of change[161], for example, the BBS[21] [104] [162] has been commonly used as an external criterion for evaluation postural control ability where the BBS score >7 indicates real improvement over time.[117]

[104] Others select the more general 15-point Global Rating of Change (GRC) scale as the external criterion.[161] The GRC is designed to detect quantitative data of participant's deterioration or improvement over time.[30] Patients or care providers independently rate the overall change in patients' balance performance at the end of treatment using a 15-point scale ranging from -7 (a very great worse) to +7 (a very great better). 0 indicates unchanged.[30, 161] Receiver operating characteristic (ROC) curves is then used to identify the score with equal sensitivity and specificity to discriminate between improves and unchanged participant. An area under the curve ranging from 0.7 to 0.8 is acceptable and 0.8-0.9 is excellent.[163] The external criteria using both BBS and GRC will complement each other. BBS reports patients' real improvement of performance, while the GRC detects patients' perception of their clinical improvement. Using both criteria will enable the clinician to receive both aspects of information.

Summary of the psychometric properties testing of clinical balance measurement tools between the BBS and the BESTest family scale is demonstrated in Table 2.

TABLE 2 SUMMARY OF THE PSYCHOMETRIC PROPERTIES OF CLINICAL BALANCE MEASUREMENT TOOL BETWEEN BBS AND THE BESTEST FAMILY SCALE.

	Subject (N)	Mean ± SD age (years)	Scale assessment	Reliability				SEM
				Test-retest	Intrarater	Interrater	Internal consistency	
Berg, 1995[108]	113 participants - Acute stroke (70)	84.4 ± 5	BBS	-	ICC = .97	ICC = .98	α > .97	-
Liston and Brouwer, 1996[109]	Chronic stroke (22)	64 ± 8.5	BBS	ICC = .98	-	-	-	1.79
Stevensen, 2001[117]	Acute stroke (48)	73.5 ± 7	BBS	-	-	-	-	2.49
Mao, 2002[107]	Acute stroke (123)	96.3 ± 11.2	BBS	-	ICC > .90	ICC = .95	α = .92- .98	-
Flansbjer, 2012[164]	Chronic stroke (50)	58 ± 6	BBS	ICC = .72	-	-	-	1.49
Hiengkeaw, 2012[165]	Chronic stroke (61)	63.5 ± 10	BBS	ICC = .95	-	-	-	1.68
Franchignoni, 2010[27]	115 participants - Inpatients stroke (22)	62.7 ± 16	Mini-BEST	-	-	-	-	-
Tsang, 2013[28]	Chronic stroke (106)	57.1 ± 11	Mini-BEST	-	ICC = .97	ICC = .96	α = .89- .94	-
Padgett, 2012[29]	20 participants - Stroke (1)	Range 51 – 83	BESTest Mini-BEST Brief-BESTest	-	-	ICC = .98 (.95 - .99) ICC = .99 (.98 - .99) ICC = .99 (.98 - .99)	α= .62-.92	-
Chinsongkram, 2014[26]	Subacute stroke (12)	57.01 ± 12.23	BESTest	-	ICC = .99	ICC = .99	-	-

Abbreviation: SD= Standard Deviation, SEM= Standardized Error of Measurement, ICC= Intraclass Correlation Coefficient, α = Cronbach's alpha, BBS= Berg Balance Scale, BESTest= the Balance Evaluation System Test, Mini-BEST= Mini-Balance E valuation System Test, and Brief-BESTest= Brief-Balance Evaluation System Test.

TABLE 2 (CONTINUED).

	Subject (N)	Mean ± SD age (years)	Scale assessment	Validity				
				Criterion- related			Construct	
				Concurrent	Predictive	FA	Convergent	Discriminative
Liston and Brouwer, 1996[109]	Chronic stroke (22)	64 ± 8.5	BBS	-	BI r = .76	-	Balance master r = -0.48 to -0.67	-
Mao, 2002[107]	Inpatients stroke (123)	96.3 ± 11.2	BBS	PASS r =.92– .95	MAS r = .8	-	BI > 0.86	-
Smith PS, 2004[110]	Stroke (75)	-	BBS	FR r = 0.78	-	-	-	-
Pickenbrock HM, 2016[111]	Acute stroke (53)	70 ± 11	BBS	Static Balance Test r = 0.91	-	-	-	-
Franchignoni, 2010[27]	115 -Inpatients stroke (22)	62.7 ± 16	Mini-BEST	ABC r =.64	-	24 put of 36	-	-
Tsang, 2013[28]	Chronic stroke (106)	57.1 ± 11	Mini-BEST	BBS r = .83 FR r = .55 TUG r = -.82 $OLS_{paretic}$ r = .82 $OLS_{nonparetic}$ r= .54	-	-	$CMSA_{leg}$ r = .53 $CMSA_{foot}$ r = .64 MAS r = -.22 ABC r = .5	GDS r = -1.7 AMT r = .08
Chinsongkram, 2014[26]	Subacute stroke (70)	57.01 ± 12.23	BESTest	BBS r = .96	?	-	BBS r =.96, PASS r =.96, CB&M r = .91, Mini-BESTest r = .96	-

Abbreviation: BBS= Berg Balance Scale, MDC90= Minimal Detectable Change at 90 % confidence interval, MDC95= Minimal Detectable Change at 95 % confidence interval, ES= Effect size, DAS= days after stroke onset, SRD= Smallest real difference, BESTest= the Balance Evaluation System Test, Mini-BEST= Mini-Balance Evaluation System Test, Brief-BESTest= Brief-Balance Evaluation System Test, PASS= Postural Assessment Scale for Stroke Patients, CB&M= Community Balance and Mobility Scale, SRM= Standardized Response Mean, and MIC= Minimal Important Change.

CHAPTER 3
METHODOLOGY

The study has three sections comprising of scale development, reliability testing, validity and responsiveness testing. The new scale was developed as a short form BESTest for patients with subacute and chronic stroke (S-BESTest) using the Rasch analysis combined with expert agreement. The reliability testing covered the assessment of intrarater and interrater reliability of the S-BESTest in persons with subacute and chronic stroke. The validity testing covered the concurrent validity and predictive validity of the S-BESTest in patients with subacute stroke and responsiveness testing covered the minimal clinically important difference (MCID) of the S-BESTest in patients with subacute stroke.

1. Research design

The first study; scale development, was a cross- sectional study aiming to develop the S-BESTest for patients with subacute and chronic stroke using the Rasch analysis combined with expert agreement. The second study is a reliability study to assess the reliability of the S-BESTest in persons with subacute and chronic stroke. The third study; a validity and responsiveness study; was a prospective study evaluating the MCID of the S-BESTest in persons with subacute stroke.

2. Participants

Different number of participants were required in each part of the study. For scale development study, the sample size calculation was based on 99% confidence interval with person measures stable within ± 0.5 logit, resulting to a minimum of 150 persons.[166] One hundred ninety-five participants were recruited from the physical therapy departments from multi-sites including Lerdsin hospital and Prasat neurological institute, Thailand, and the Hong Kong Polytechnic University, Hong Kong from November 1, 2012 through October 25, 2016. The inclusion criteria for the scale development study were persons with first unilateral hemispheric stroke in subacute or chronic stage; stable vital sign and able to follow instructions to complete the assessment. The subacute stage was classified by onset within 4-months post-stroke and the chronic stage was more than 4-months post-stroke. Participants were excluded if they had a neurological disorder other than stroke, unstable epilepsy, lesion at the brainstem which involves sleep-wake and respiratory control center or cerebellum, cerebral aneurysm, visual problems that have not been resolved with glasses and cognitive impairment as measured by the Mini-Mental Stage Examination (MMSE score<23) in Thai or Cantonese version based on collection sites.(201, 202) All participants gave written consent prior to participation. Study was approved by ethic committee at all data collection sites.

For the reliability study, participants were recruited from the physical therapy department at Lerdsin hospital and the Hong Kong Polytechnic University. The sample size for reliability testing was based on COSMIN checklist with 4-point scale. As a result, a sample size of 30 would be sufficient to permit for reliability study.(167) The participants for the reliability study were having first unilateral hemispheric stroke; stable vital sign and able to follow instructions to complete the assessment. Thirty-two participants with stroke were divided into two groups, 12 persons with subacute stroke and 20 persons with chronic stroke. The subacute stage and the chronic stage were classified using the same criteria as in the scale development study. Participants were excluded if they had a neurological disorder other than stroke, unstable epilepsy, lesion at the brainstem which involves sleep-wake and respiratory control center or cerebellum, cerebral aneurysm, visual problems that have not been resolved with glasses and cognitive impairment as measured by the MMSE score<23 in Thai or Cantonese version based on collection sites. Prior to participation all participants gave written an informed consent.

Study was approved by ethic committee at Lerdsin hospital and the Hong Kong Polytechnic University.

For the validity and responsiveness study, participants were recruited from the physical therapy department at Lerdsin hospital. The sample size for validity and responsiveness testing was calculated by the following equation.

$$n = \left(\frac{Z_{\alpha} + Z_{\beta}}{Z_{(r)}} \right)^2 + 3$$

Sample size calculation for validity and responsiveness study depended on a power of 0.80 and alpha level of 0.05. In the previous study, a correlation coefficient (r) of balance measure ranged from 0.62 to 0.94 and the average is 0.78[(1)], therefore, an expect correlation coefficient of this study was 0.8. A correlation coefficient for null hypothesis was at least 0.5 that represents adequate correlation.[(168)] As a result, a sample size of 29 would be sufficient to permit a correlation for concurrent validity study. Predictive validity and responsiveness study were calculated for the inflation of 20% for the drop out, therefore, a sample size of 35 was included. However, another confounding factor of patient with stroke is the functional ability, thus, the subjects were divided into 2 groups of functional ability, namely low functional ability and high functional ability. Finally, total participants for each validity and responsiveness study were 70 persons (35 persons in each group). Participants were included if they had the first unilateral hemispheric stroke in subacute stage; stable vital sign and able to follow instructions to complete the assessment. Participants were excluded if they had a neurological disorder other than stroke, unstable epilepsy, lesion at the brainstem which involves sleep-wake and respiratory control center or cerebellum, cerebral aneurysm, visual problems that have not been resolved with glasses and cognitive impairment as measured by the MMSE score<23 in Thai version. All participants gave written an informed consent before participating in this study. Study received ethical approval from the Human Research Protection Committee at Lerdsin Hospital.

3. Outcome measures

The lower extremity motor function domain of the Fugl-Meyer Assessment (FM-LE) was used to assess lower limb function. FM-LE was used to classify the patients with subacute stroke into 2 groups.(169) FM was a measure that evaluated motor recovery from stroke in quantitative method with excellent reliability, validity, and sensitive to change.(170) This scale was divided into 5 domains consisted of motor function, sensory function, balance, joint range of motion, and joint pain. The rating ranged from 0-2 ordinal scale where 0 indicating cannot perform, 1 indicating performed partially, and 2 indicating performed fully. The total scores of motor-lower extremity was 34 points.(170) This study classified subject into 2 functional ability group by using FM lower extremity motor domain score, FM lower extremity motor domain score 0-14 represented low functional ability (LFA group) and scores greater than 14 represented high functional ability (HFA group).(169)

The Stroke Rehabilitation Assessment of Movement (STREAM) was used as an external criterion for the assessment of predictive validity to evaluate the performance of motor outcome after rehabilitation at 2 and 4 weeks. This scale was supported to use because it have reliable(171), valid(172), and sensitive to change.(173)-(174)

To examine whether the S-BESTest could be used in participants with stroke. For reliability, validity, and responsiveness study, the BBS was selected as the external criterion for balance domain and the STREAM and 15-point Global Rating of Change (GRC) scale were selected as the external criteria for responsiveness test. Descriptions of these assessment tools were explained in Chapter 2.

4. Procedure

4.1 Scale development

One hundred and ninety-five participants with stroke were recruited from the physical therapy departments from multi-sites including Lerdsin hospital and Prasat neurological institute, Thailand, and the Hong Kong Polytechnic University, Hong Kong.

Baseline demographic and clinical characteristics were obtained from the participant and hospital chart. The subacute stage was classified by the onset of within 4-month post-stroke and the chronic stage was that of more than 4-month post-stroke. The lower extremity motor function domain of the Fugl-Meyer Assessment (FM-LE) was used to assess lower limb function in persons with stroke. The Balance System Evaluation Test (BESTest) was administered to all persons with stroke. Three raters with excellent inter-rater reliability and intra-rater reliability administered the test. All participants received the same verbal instruction during the test and vital sign was monitored throughout the test for ensuring the stable medical status. Rest between testing items was allowed for as long as the participants required. Total time of assessment was approximately 1.5 hours. If the test could not complete in one day then it would be continued on the next day.

The S-BESTest was then developed from the BESTest data using Rasch analysis through WINSTEPS software for determining item difficulty and deleting unnecessary items. The internal construct validity, reliability, unidimensionality, and differential item functioning (DIF) were performed in this study.

After item reduction using Rasch Analysis, the draft S-BESTest was developed and sent to 20 experts in the neurological physical therapy. Twenty physical therapists specialized in neurological physical therapy with stroke rehabilitation experience of 5-13 years worked at the tertiary care facilities to determine whether the selected items were highly pertinent to patients with stroke. Content Validity Ratio (CVR) was calculated for each item to represent the extent of content validity. The item with acceptable CVR (0.5) was included in the final S-BESTest.[175]

Finally, construct validity of the S-BESTest was assessed by performing hypothesis testing on the known group (low and high functional ability) as classified by FM-LE score.

4.2 Reliability study

In this study, the rating from videotape was selected to ensure consistency of performance and reduce the error from movement variability. Intrarater reliability of validation for using the videotapes was determined using 1 physical therapist who has 10 years of experience in stroke rehabilitation.

Intrarater and interrater reliability of subacute and chronic stroke were determined using 6 physical therapists. Raters were included a convenient sample of 3 physical therapists from Lerdsin hospital for subacute stage or from the Hong Kong Polytechnic University for chronic stage, with stroke rehabilitation experience of 1, 5, and 10 years, respectively. Another two (for subacute stage) or three (for chronic stage) raters were obtained from students. One bachelor degree student was recruited from the Hong Kong Polytechnic University. Two PhD. physical therapy students were recruited from Srinakharinwirot University.

All raters practiced using the S-BESTest and Brief-BESTest to measure balance performance in healthy subjects and patients with stroke. They were provided with the BESTest written instruction and video for administering the test 1-month prior to training. The S-BESTest and Brief-BESTest scores were extracted from the relevant subset of BESTest items. The training started with testing in healthy subject in order to assess and discuss tests instruction and rating criteria, followed by the training to use the S-BESTest in persons with stroke (figure 8).

Each subject signed an informed consent before participating in this study. The first rater recorded the baseline demographic and clinical information from the participant and hospital chart. The Thai and Chinese version of Mini-Mental State Examination (MMSE-Thai)[116] (MMSE-Chinese) was used to screen the cognitive impairment in each subject. The MMSE assesses a person in five domains including orientation, memory, language, calculation, and attention. This test consists of 11 items of which score ranges from 0-30 where a score below 24 represents cognitive impairment, score ranged from 18 to 23 represent mild cognitive impairment, and score below 18 represents severe cognitive impairment.[176]

The first rater administered the S-BESTest and Brief-BESTest. The patients' performance was videotape recorded in the same view for all participants. The evaluation was performed in a room setting at Lerdsin hospital and the Hong Kong Polytechnic University. Videotapes were recorded by using 2 cameras and 2 tripods. The location for the videotape placement was marked on the floor to obtain consistency of video views across patients. The vital sign of participants was monitored for ensuring the stable medical status before testing and all participants received the same verbal instruction. The participant was allowed to take a rest as long as they required if they feel fatigue during the test. If the test could not complete in one day then it will be continued on the next day.

The first rater was concurrently score the patient's performance and repeated scoring the patient's performance from videotape at least 7 days apart to confirm that the result of scoring from concurrent test and from videotape were not different. Then the videotape was sent to other raters for further reliability testing.

Other 5 (for subacute stage) or 6 (for chronic stage) raters scored each participant's performance from videotape on 2 separate occasions. After the first scoring, the second scoring was performed within 7 days (figure 9). Intrarater reliability of total scores and section scores were assessed by comparing the score of occasion 1 and occasion 2 for each rater. Interrater reliability was determined by comparing the scores from occasion 1 for all raters. Each rater scored the participants' performance from the videotape on separate scoring sheets for each occasion and did not discuss scoring among participants and occasions.

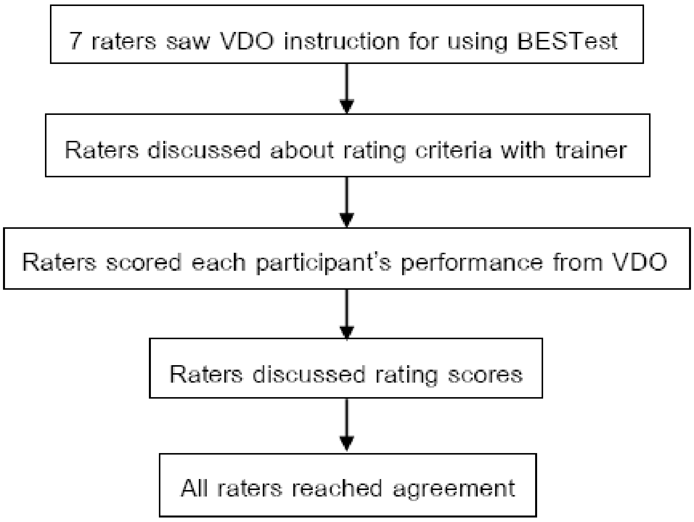


FIGURE 8 PROCEDURES OF RATER TRAINING.

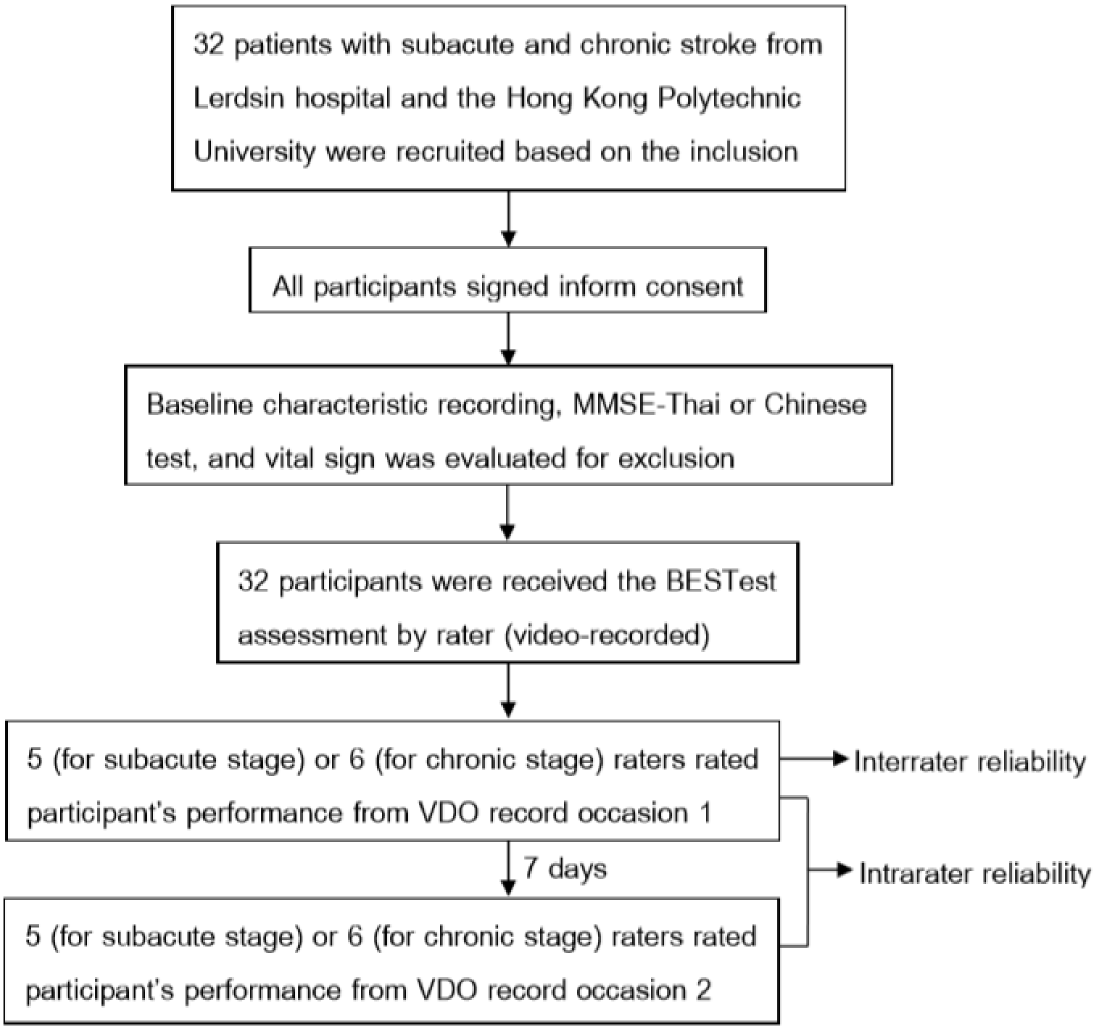


FIGURE 9 PROCEDURES OF RELIABILITY STUDY.

4.3 Validity and responsiveness study

Seventy participants were enrolled from patients who received physical therapy rehabilitation at Lerdsin hospital. Baseline demographic and clinical information were gathered from the participant and chart. Then the Thai MMSE and the lower extremity motor function domain of the Fugl-Meyer Assessment (FM-LE) were administered. The MMSE was used to screen a cognitive impairment. FM-LE-Motor was used to classify the patients with subacute stroke into 2 groups by using FM lower extremity motor domain score, FM lower extremity motor domain score 0-14 represented low functional ability (LFA group) and scores greater than 14 represented high functional ability (HFA group).[169] Before testing, vital sign of participants was monitored for ensuring stable medical status. All participants were received the same verbal instruction and allowed to rest as long as they required . Total time of assessment was approximately 1.5 hours. If the test could not complete in one day then it will be continued on the next day.

In this study, the participants received the BBS, S-BESTest, Brief-BESTest, and STREAM evaluation from rater TW from reliability study who received additional training for using the Berg Balance Scale (BBS), FM-LE-motor and the Stroke Rehabilitation Assessment of Movement (STREAM). The BESTest was administered and the score of the S-BESTest and Brief-BESTest were then extracted from the relevant domain of BESTest items. The S-BESTest and the Brief-BESTest was performed only once when any item of the 2 tests duplicated and scoring using criteria from each test.[177] The concurrent validity of the S-BESTest with BBS and the Brief-BESTest with BBS was evaluated by using the total scores. The BBS was used as the external criteria for the assessment of concurrent validity.

The S-BESTest and Brief-BESTest scores were used to predict motor outcome at discharge. The STREAM was used as an external criterion (for the assessment of predictive validity) to evaluate the performance of motor outcome after rehabilitation at 2 and 4 weeks. S-BESTest, Brief-BESTest, and STREAM were administered again to patients after 2 and 4 weeks.

The minimal clinically important difference (MCID) of the S-BESTest and Brief-BESTest was assessed using both distribution-based and anchor-based methods in each participant. Distribution-based method compared the change in patient-reported outcomes scores to some measure of variability such as the effect size (ES) in term of standardized response mean (SRM) and minimal detectable change (MDC).[159, 178-180] Anchor-based method was used to compare the change in patient-reported outcomes score to some other measure of change.[161] Anchor-based approach was evaluated by using BBS and 15-point Global Rating of Change (GRC) scale, which was designed to detect quantitative data of patient's improvement or deterioration over time.[30] The BBS was administered to participants at 2 and 4 weeks after rehabilitation. Each participant completed the GRC after the rehabilitation treatment at 2 and 4 weeks. Score of BBS more than 7 points was used to indicate real clinical improvement over time.[104, 117] Patients independently rated the overall change in their balance when they completed treatment using a 15-point scale ranging from -7 (a very great worse) to +7 (a very great better), with 0 representing unchanged[30, 161] (figure 10). Both distribution-based method and anchor-based method were employed in this study to reduce bias.[159, 161] The mean value of the GRC scores from patient was used as an external criterion. The participants were being unaware of each other's responses.

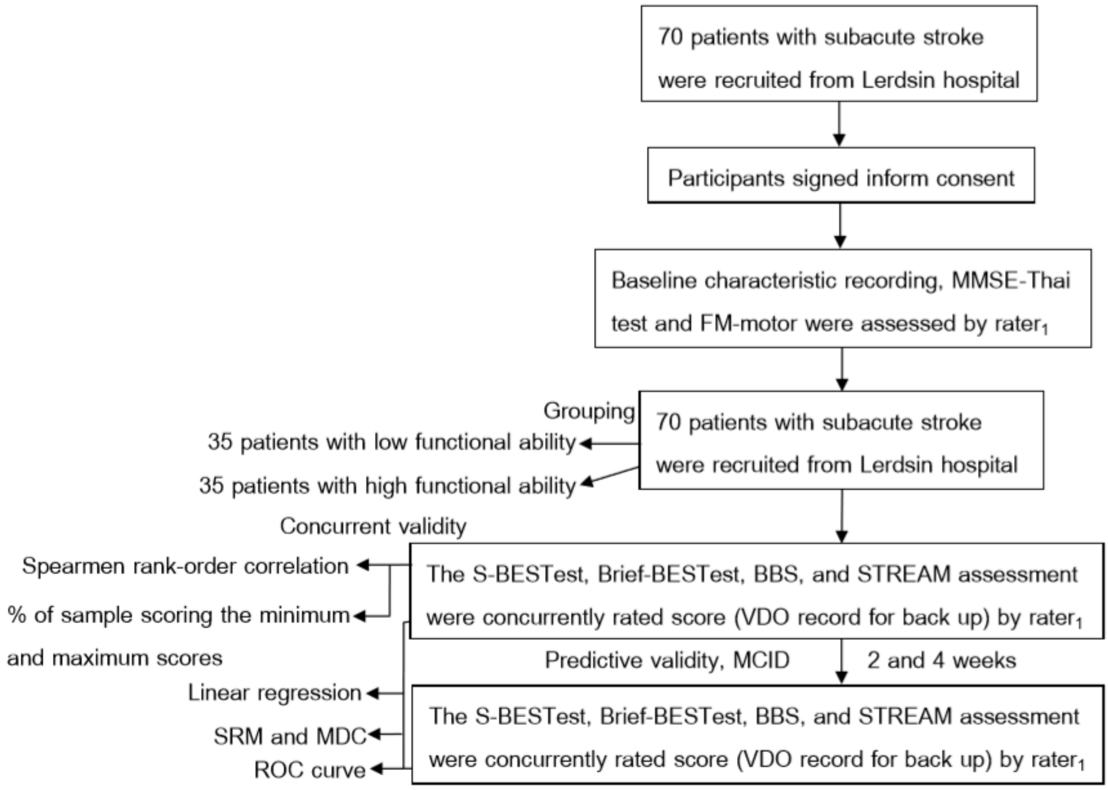


FIGURE 10 PROCEDURES OF VALIDITY AND RESPONSIVENESS STUDIES.

5. Data analysis

Descriptive statistical analysis was used to report demographic and baseline clinical characteristic of participants. Comparison o f age between patients with subacute and chronic stroke was evaluated by using independent-sample t test whereas comparison of time since stroke and FM-LE score was analyzed by using Mann-Whitney U test.

The Rasch's model was calculated by the following equation.

$$\ln (P_{nik} (1- P_{nik}))=\beta_n - (\delta_i - \tau_k)$$

β_n indicates the ability of person n, δ_i indicates the average difficulty of item i, and τ_k indicate the difficulty of the k_{th} threshold (same for all items).

The short form BESTest for stroke (S-BESTest) was developed from the BESTest data using Rasch analysis (partial credit model)[181] through WINSTEPS software (version 4.0.1, SWREG Inc., MN, USA.). The internal construct validity, reliability, unidimensionality, and differential item functioning (DIF) were performed in the following steps:

1. Internal construct validity was assessed through infit/outfit mean-square (MnSq) and infit/outfit standardized z-score (ZSTD). Infit identifies a pattern of responses that fit targeted items, whereas outfit determines misfit items as compared to person ability. Infit and outfit can be presented in MnSq format to demonstrate the size of randomness. Infit MnSq and outfit MnSq ranging from 0.6 to 1.4 represent good data fit of the Rasch model.[140] Infit ZSTD demonstrates how well the item measures response to person ability, whereas outfit ZSTD determines how well the item measures response at the outer range of person ability. Infit or outfit ZSTD of more than 3 represents inaccuracy, for example, a person with low balance ability is able to perform the difficult balance item.[182] Mean difficulty was used to indicate level of item difficulty of the S-BESTest and was presented in logit measure format. The highest logit measure represents the hardest item, and the lowest logit measure represents the easiest item.[183] Standard error (SE) indicated a loss of precision of the item measure. Category outfit MnSq explained the score category data of the test. Category outfit MnSq for each category of greater than 2.0 indicates more misfit information than true information of the score category. This reflects inconsistency of the score category so that the score category will be combined or omitted.[184]

2. Reliability was measured from both persons and items. The person reliability and item reliability were important indicators for the measurement accuracy of person performance and test items. Reliability values of 0.8 and above are interpreted as excellent reliability, from 0.79 to 0.6 interpreted as moderate, and from 0.59 to 0.4 interpreted as weak.[185] Score correlation between each item and the S-BESTest was examined using the Spearman rank-order correlations. Correlation coefficients of 0.00 to

0.49 indicate poor correlation, 0.50 to 0.79 indicate moderate, and 0.80 or higher indicate excellent.[185] Person separation index differentiated person into group based on balance performance score, ranged from 0 to infinity logits. Item separation index differentiated item scores of the test ranged from 0 to infinity logits.[182] Separation index (G), as calculated by (reliability/ (1-reliability)½), of equal 2 or more is a good separation between groups of measures. The score of the S-BESTest was further analyzed using the separation index through this equation (4*G+1)/3 to yield the number and score range of balance impairment category.[203, 204] The cutoff point of balance impairment categories was processed by WINSTEP software.

3. Unidimensionality examined items consistency underlying the same construct by using residuals from Rasch analysis. Principle component analysis (PCA) was analyzed to confirm sufficient unidimensionality by using these criteria; variance explained by the measured construct > 50% and variance explained by the first residual factor < 10% with eigenvalue of the first residual factor < 2.[186]

4. DIF was used to analyze item bias between a certain characteristic such as affected side and age by using pair-wise t tests with two-sided α of <0.05 and Bonferroni correlation. No significant DIF is preferred to indicate that test item measure is the same between 2 groups at a given characteristic.[187] Affected side and age were divided into 2 groups: left versus right and age <median age (59 years) versus ≥median age.

The content validity ratio (CVR) was calculated for each item to represent the extent of content validity. CVR was calculated by using this formula: (ne-N/2)/(N/2), in which ‘ne’ means the number of experts that considered the item is essential and N means the total number of experts in the panel. The CVR ranges from -1.00 to +1.00 where CVR of +1.00 indicates that 100% of all experts believe the item is essential, whereas CVR of -1.00 indicates the opposite.[135] The items with acceptable CVRs (0.50) from 20 experts were included in the final S-BESTest.[175]

Construct validity of the S-BESTest was assessed by performing hypothesis testing on the known group (low and high functional ability) as classified by FM-LE score using Mann-Whitney U test. Null hypothesis was set where the S-BESTest cannot differentiate between persons with stroke who had low and high functional ability.

Intrarater and interrater reliability were calculated by using interclass correlation coefficient (ICC)[185] model 3, k and 2, k, respectively, for the S-BESTest and Brief-BESTest. ICC values of 0.8 and above are interpretation as excellent correlation (good reliability), ranged from 0.8 to 0.6 are interpretation as adequate correlation (moderate reliability) and 0.6 to 0.4 are interpretation as poor correlation (weak reliability).[188, 189]

The correlation between the scores from concurrent test and videotape was examined using the Spearman rank-order correlations. Correlation coefficients of 0.80 or higher indicate excellent correlation. Those of 0.50 to 0.79 are indicating as moderate and those 0.00 to 0.49 are indicating poor correlation.

To examine the concurrent validity of the S-BESTest and Brief-BESTest with the BBS were determined using the Spearman rank-order correlations. Correlation coefficients of 0.00 to 0.49 were indicated as poor, those of 0.50 to 0.79 were indicated as moderate, and those 0.80 or higher were indicated as excellent.

To determine the predictive validity of the S-BESTest and Brief-BESTest with the STREAM at discharge at 2 and 4 weeks were evaluated using the linear regression. R square value of 0 was interpreted as poor and that value of 1 was interpreted as excellent.

Floor and ceiling effect of S-BESTest and Brief-BESTest were calculated as the percentage for minimum or maximum possible scores of the sample scoring, respectively. Floor and ceiling effects greater or equal 20% were interpreted significant.[190]

The distribution-based method was examined with the effect size (ES) in term of standardized response mean (SRM), and the minimum detectable change (MDC).[179, 180] SRM is a measure of change by dividing the mean change scores by the SD of change score. Comparison of balance scores change between before and after rehabilitation was analyzed by using paired *t* test. The value of 0.8 or greater represented a large change, values ranged from 0.5 to 0.8 represented moderate, and values of 0.2 to 0.5 represented small change. Large and moderate SRM indicated sufficient internal responsiveness. MDC is the smallest detectable change that could be considered above the measurement error with a given level of confidence such as usually 95 % confidence level[191], but it does not indicate a meaningful difference in patient's response. MDC was calculated by the SEM multiply 1.96 and multiply $\sqrt{2}$.[179, 180] The SEM is value of score difference or deviate from true score. SEM was calculated by SD multiply $\sqrt{1 - \text{reliability}}$.

The minimal clinically important difference (MCID) was examined using anchor-based methods. The anchor-based method was based on BBS and GRC evaluation as an external criterion. BBS score more than 7 points represented real clinical improvement over time.[104, 117] The receiver operating characteristic (ROC) curve approach was used to differentiate the score of participants based on BBS $\leq$ 7 as no change and the BBS > 7 as meaningful change. Similarly, the receiver operating characteristic (ROC) curve approach was used to differentiate the score of subjects based on a GRC $\leq$ 5 as no change and a GRC > 5 as meaningful change.

The optimal cutoff score was also calculated from the best balance score between high sensitivity and high specificity.[185] Sensitivity was the probability for measure correct classifying patients who had change in an external criterion as indicator change. Specificity was the probability for measure correct classifying patients who did not show change in the external criterion. These values were the ability of measure to consider both change (sensitivity) and no change (specificity) in the external criterion.[152] The area under the curve (AUC) of an ROC was used to interpret the probability of correctly discriminate between improved and unimproved patients with subacute stroke.[179] An AUC of 0.8 or greater indicated excellent discrimination.[185] A likelihood ratio demonstrates accuracy of posttest probabilities that determined to enhance the diagnosis for confirming or rejecting it. A positive likelihood (LR+) ratio was the precision of probability for person having a score over the optimal cutoff point, in contrast with a negative likelihood (LR-) ratio was the exactness of probability for person having a score beneath the best cutoff point. Value of LR+ above 5 and value of LR- below 0.20 interpret that the testing is valuable as its high probability to precisely diagnose people into the correct balance performance improvement group, whereas value of LR- close to 1 interprets that the test is useless due to the probability to accurately and inaccurately identify people into the correct group is the same.[185]

6. Ethical considerations

For scale development, study was approved by human research protection committee at Lerdsin hospital research center (number 591015), Prasat neurological institute research center (number 54053 and 59030) and by ethic committee of the faculty of Physical Therapy at Srinakharinwirot University (number HSPT2016-001) and the Hong Kong Polytechnic University (number HSEARS20160225002).

Study for reliability testing received ethical approval by human research protection committee at Lerdsin hospital research center and was approved by ethic committee of the faculty of Physical Therapy at Srinakharinwirot University and Department of Rehabilitation Sciences, the Hong Kong Polytechnic University.

Study for validity and responsiveness testing received ethical approval by human research protection committee at Lerdsin hospital research center and was approved by ethic committee of the faculty of Physical Therapy, Srinakharinwirot University.

CHAPTER 4
RESULTS

This study aimed to develop the S-BESTest for patients with stroke and evaluated the reliability, validity, floor/ ceiling effects, and responsiveness of the S-BESTest in persons with subacute stroke. The results of this study are demonstrated in the following.

1. Scale development

There were 195 persons with stroke participated in this study. Their demographic and clinical characteristics are shown in Table 3. Of one hundred ninety-five participants with stroke, two third of them were at the subacute stage. Participants with chronic stroke were significantly older and having higher lower limb functions than those with subacute stroke. Demographic and clinical characteristics of participants with stroke used for development of S-BESTest are presented in Table 3.

Out of 36 items on the BESTest, 13 items with a total score of 39 were included in the S-BESTest based on the criteria of infit/outfit MnSq from 0.6 to 1.4 and infit/outfit ZSTD of less than or equal 3 (Table 4, Figure 11). The items of the S-BESTest covered all six domains of the BESTest. Item difficulty ranged from -2.23 to 1.57 logits (Table 5, Figure 11). “Standing on paretic leg” was the highest logit measure (representing the hardest item) and “eyes closed, firm surface” was the lowest logit measure (representing the easiest item). Four levels rating score of the S-BESTest fulfilled the functioning category criteria (Table 6). All category outfit MnSq were smaller than 2.0 indicating the consistency of the score category, except “functional reach test in non-paretic side” and “standing on paretic side” which had larger SE.

The person reliability of 0.87 and item reliability of 0.99 indicated excellent reliability of person performance and items of the test. Score correlation ranging from

0.63 to 0.89 indicated moderate to excellent correlation between the item and the S-BESTest. The item separation index of 9.18 logits represented a good separation from items of the S-BESTest. The person separation index was 2.64 logits. Using this equation [4*G+1)/3] resulted in 3.85, indicating that the participants can be differentiated into four groups of balance impairment using the S-BESTest score: mild (31–39), moderate (19–30), severe (10–18), and very severe (0–9) balance impairment (Table 7).

The S-BESTest was confirmed to be unidimensionality. The PCA of standardized residual from Rasch factor showed that variance explained by measures construct was 64.5% and variance explained by the first residual factor was 5.3% with eigenvalue of the first residual factor was 1.91. No significant DIF was found among paretic side and age groups, except item 8 “eyes closed, firm surface” that showed significant DIF as comparison by age groups. CVRs received from the twenty experts were 0.60 to 1 for each of the final items in S-BESTest (Table 8). Construct validity was confirmed ($p<0.001$), indicating that the S-BESTest can distinguish persons with stroke who had low and high functional ability.

TABLE 3 DEMOGRAPHIC AND CLINICAL CHARACTERISTICS OF PARTICIPANTS WITH STROKE (N=195).

Characteristics	Participants with stroke (n = 195)		Participants with subacute stroke (n=132)		Participants with chronic stroke (n=63)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Age (years):	58.26 (11.08)		56.6 (11.9)*	27-82	61.7 (8.01)	40-77
Gender: M/ F, n	111/84		76/ 56		35/ 28	
Time since stroke (months):	25.50 (46.85)	7 days–240 months	0.64 (0.67)*	7 days-4 months	77.57 (52.89)	6-240
Type of stroke: I/ H, n	159/36		111/ 21		48/ 15	
FM-LE (/34)	22.24 (9.29)	2–34	20.97 (10.10)*	2-34	24.89 (6.59)	11-34

Significant difference between participants with subacute stroke and participants with chronic stroke (* p < .001). SD= Standard Deviation, I= Ischemic, H= Hemorrhage, and FM-LE= the lower extremity motor function domain of the Fugl-Meyer Assessment.

TABLE 4 RASCH ITEM-FIT STATISTICS (N= 195).

Domain and item of the S-BESTest	Item Infit		Item Outfit		Score correlation
	MnSq	ZSTD	MnSq	ZSTD	
Biomechanical Constraints					
1. Hip/ Trunk Lateral Strength	0.83	-1.50	0.82	-0.90	0.69
Stability Limits					
2. Functional Reach- Lateral_Non-paretic side	0.81	-1.80	1.09	0.60	0.83
Anticipatory Postural Adjustment					
3. Rise to Toes	0.89	-1.00	0.88	-0.70	0.76
4. Stand on Paretic Leg	0.79	-1.90	0.82	-0.70	0.63
5. Stand on Non-Paretic Leg	1.17	1.50	1.30	1.70	0.71
6. Standing Arm Raise	1.24	1.60	1.32	1.50	0.85
Reactive Postural Response					
7. Compensatory Stepping Correction-Lateral_Paretic side	1.33	2.80	1.09	0.50	0.65
Sensory Orientation					
8. Eyes Closed, Firm Surface	1.02	0.20	0.89	-0.30	0.89
9. Eyes Open, Foam Surface	1.04	0.40	0.91	-0.50	0.77
10. Incline-Eyes Closed	1.03	0.30	0.78	-1.30	0.87
Stability in Gait					
11. Change in Gait Speed	0.89	-1.00	0.80	-1.40	0.84
12. Walk with Head Turns	1.14	1.20	0.99	0.00	0.73
13. TUG with Dual Task	1.08	0.80	1.16	0.80	0.68

Abbreviation: MnSq= mean-Square, ZSTD= standardized z-score, TUG= Timed Up and Go.

```
MEASURE                         PERSON - MAP - ITEM
              <best balance performance>|<hard item>
   4                                    +
                                        |
                                        |
                                        |
                                        |
                                       T|
                                    ##  |
   3                                    +
                                        |
                                      . |
                                        |
                                     .# |
                                        |
                                      .  |T
   2                                    +
                                     .# |
                                     .# S|
                                        | Stand on Paretic Leg
                                    .## |
                                    ### |
                                      #  |S
   1                                .## +  TUG with Dual Task     Hip/Trunk Lateral Strength
                                    .## | Compensatory Stepping Correction-Lateral Paretic Side
                                    .## |
                                    .## |
                                    .## | Stand on Non-Paretic Leg     Walk with Head Turns
                                     ## | Rise to Toes
                                   ## M|  Eyes Open, Foam Surface
   0                                 .#  +M Functional Reach-Lateral Non-Paretic Side
                                    .## |
                                      . |
                                    .## |
                                     .# | Change in Gait Speed
                                     .# |
                                     ## |
  -1                                  # +
                                        |S
                                      . | Incline-Eyes Closed
                                     .# S|
                                     .# |
                                      . | Standing Arm Raise
                                        |
  -2                                  # +
                                        |T
                                      # | Eyes Closed, Firm Surface
                                        |
                                     .# |
                                        |
                                      . |
  -3                                    +
                                       T|
                                     .# |
                                        |
                                        |
                                        |
                                        |
  -4                          .###########  +
            <worse balance performance>|<easy item>
```

FIGURE 11 PERSON ABILITY AND ITEM DIFFICULTY MAPS OF THE S-BESTEST (N= 195). EACH “#” REPRESENTS THREE PARTICIPANTS, EACH “.” REPRESENTS ONE TO TWO PARTICIPANTS, “M” INDICATES MEAN VALUE, “S” INDICATES SD, AND “T” INDICATES 2 SD.

TABLE 5 LEVEL OF ITEM DIFFICULTY OF THE S-BESTEST.

Item of the S-BESTest	Mean difficulty	Standard Error (SE)
4. Stand on Paretic Leg	1.57	0.11
1. Hip/Trunk Lateral Strength	1.06	0.11
13. TUG with Dual Task	0.93	0.11
7. Compensatory Stepping Correction-Lateral Paretic Side	0.91	0.11
5. Stand on Non-Paretic Leg	0.45	0.10
12. Walk with Head Turns	0.42	0.10
3. Rise to Toes	0.34	0.10
9. Eyes Open, Foam Surface	0.10	0.11
2. Functional Reach-Lateral Non-Paretic Side	0.00	0.11
11. Change in Gait Speed	-0.55	0.11
10. Incline-Eyes Closed	-1.33	0.13
6. Standing Arm Raise	-1.67	0.13
8. Eyes Closed, Firm Surface	-2.23	0.15

TABLE 6 SUMMARY OF THE S-BESTEST ITEMS CATEGORY AND FREQUENCY.

Items of the S-BESTest and score categories	Number of people	% of subject	Category outfit MnSq
1. Hip/ Trunk Lateral Strength			
0	97	50	1.0
1	45	23	0.7
2	36	18	0.5
3	17	9	1.2
2. Functional Reach- Lateral_Non-paretic side			
0	51	26	0.6
1	39	20	0.4
2	89	46	0.9
3	16	8	*2.9*
3. Rise to Toes			
0	80	41	0.9
1	22	11	0.5
2	67	34	0.7
3	26	13	0.9
4. Stand on Paretic Leg			
0	114	58	0.7
1	54	28	0.3
2	9	5	*2.6*
3	18	9	0.9
5. Stand on Non- Paretic Leg			
0	77	39	1.0
1	53	27	1.0
2	24	12	0.9
3	41	21	1.1

TABLE 6 (CONTINUED).

Items of the S-BESTest and score categories	Number of people	% of subject	Category outfit MnSq
6. Standing Arm Raise			
0	44	23	0.7
1	19	10	1.7
2	27	14	1.2
3	105	54	1.2
7. Compensatory Stepping Correction- Lateral_Paretic side			
0	114	58	1.1
1	8	4	0.2
2	45	23	0.6
3	28	14	1.1
8. Eyes Closed, Firm Surface			
0	34	17	1.2
1	21	11	1.2
2	25	13	0.5
3	115	59	0.9
9. Eyes Open, Foam Surface			
0	87	45	1.2
1	22	11	0.5
2	24	12	0.8
3	62	32	0.9
10. Incline- Eyes Closed			
0	54	28	1.5
1	14	7	0.8
2	27	14	0.7
3	100	51	1.0

TABLE 6 (CONTINUED).

Items of the S-BESTest and score categories	Number of people	% of subject	Category outfit MnSq
11. Change in Gait Speed			
0	61	31	0.9
1	23	12	0.7
2	44	23	0.5
3	67	34	0.8
12. Walk with Head Turns			
0	90	46	1.6
1	27	14	0.3
2	34	17	0.7
3	44	23	0.9
13. TUG with Dual Task			
0	93	48	1.5
1	31	16	1.2
2	64	33	0.9
3	7	4	0.7

Abbreviation: MnSq= mean-Square and TUG= Timed Up and Go.

TABLE 7 SCORE TO MEASURE AT CATEGORIES FOR THE S-BESTEST AND STANDARD ERROR (SE).

Score	Measure	SE	Categories of balance impairment
0	-5.14	1.81	
1	-3.95	0.99	
2	-3.26	0.72	
3	-2.82	0.61	
4	-2.50	0.54	Very severe
5	-2.22	0.50	
6	-1.99	0.47	
7	-1.77	0.45	
8	-1.58	0.43	
9	-1.40	0.42	
10	-1.23	0.41	
11	-1.07	0.39	
12	-0.92	0.38	
13	-0.77	0.37	
14	-0.64	0.37	Severe
15	-0.50	0.36	
16	-0.38	0.35	
17	-0.25	0.35	
18	-0.13	0.35	

TABLE 7 (CONTINUED).

Score	Measure	SE	Categories of balance impairment
19	-0.01	0.34	
20	0.10	0.34	
21	0.22	0.34	
22	0.34	0.34	
23	0.46	0.34	
24	0.57	0.35	
25	0.70	0.35	Moderate
26	0.82	0.36	
27	0.95	0.36	
28	1.08	0.37	
29	1.22	0.38	
30	1.37	0.39	
31	1.53	0.41	
32	1.71	0.43	
33	1.91	0.46	
34	2.13	0.49	
35	2.40	0.54	Mild
36	2.73	0.62	
37	3.18	0.74	
38	3.92	1.02	
39	5.16	1.84	

Measure is unit in logits.

TABLE 8 CONTENT VALIDITY RATIO (CVR) OF THE S-BESTEST.

Domain and item of S-BESTest	CVR
Biomechanical Constraints	
1. Hip/Trunk Lateral Strength	0.9
Stability Limits	
2. Functional Reach-Lateral Non-paretic side	0.9
Anticipatory Postural Adjustment	
3. Rise to Toes	1
4. Stand on Paretic Leg	1
5. Stand on Non-Paretic Leg	1
6. Standing Arm Raise	0.6
Reactive Postural Response	
7. Compensatory Stepping Correction-Lateral Paretic Side	0.7
Sensory Orientation	
8. Eyes Closed, Firm Surface	0.9
9. Eyes Open, Foam Surface	0.9
10. Incline-Eyes Closed	0.9
Stability in Gait	
11. Change in Gait Speed	1
12. Walk with Head Turns	0.8
13. TUG with Dual Task	0.6

Abbreviation: TUG: Timed Up and Go.

2. Reliability

Twenty-one males and eleven females were included in the reliability study. The age of thirty-two people with ischemic or hemorrhagic stroke ranged from 32 to 77 years. Onset time since stroke ranged between 7 days to 12 years. Demographic data of participants in the reliability study were presented in Table 9.

High correlation of S-BESTest total scores from concurrent test with videotape examination (*r*= .97) and subsection *r* ranged from .90 to 1, interpreting excellent correlation was shown in Table 10. This table demonstrated that the result of S-BESTest scoring from concurrent test and from videotape were not different.

The intrarater and interrater reliability of the S-BESTest in people with stroke were demonstrated in Table 11. The intrarater and interrater reliability of the S-BESTest total scores were excellent with ICC of 0.98 and 0.95. Excellent the intrarater and interrater reliability of domain ICCs ranged 0.91 to 0.98 and 0.83 to 0.96, respectively.

The intrarater and interrater reliability of the Brief-BESTest in persons with stroke were presented in Table 12. Excellent intrarater and interrater reliability of the Brief-BESTest total scores with ICC were 0.98 and 0.95. Excellent reliability of the domain (ICC=0.94 to 0.99 and 0.85 to 0.99) were also noted.

TABLE 9 DEMOGRAPHIC DATA OF PARTICIPANTS WITH STROKE IN THE RELIABILITY TEST (N=32).

Characteristics	Participants with stroke (N=32)	
	Mean (SD)	Range
Age (years):	61.87 (9.86)	32-77
Gender: M/F, n	21/11	
Time since stroke (years):	4.81 (4.61)	7 day- 12.96 years
Type of stroke: I/H, n	23/9	

Note: All values are presented as mean ± SD.

TABLE 10 THE CORRELATION COEFFICIENT BETWEEN SCORES FROM CONCURRENT TEST OF THE S-BESTEST AND SCORES FROM VIDEOTAPE TEST OF THE S-BESTEST.

13 items of S-BESTest	Spearman rho's	
	r	P value
Total	0.97	0.01
Section 1 Biomechanical constraints	1	0.01
- Hip/ Trunk Lateral Strength	1	0.01
Section 2 Limits of stability	1	0.01
- Functional Reach- Lateral_Non-paretic side	1	0.01
Section 3 Anticipatory adjustments	Range 0.93- 1	0.01
- Rise to Toes	0.97	0.01
- Standing on Paretic Leg	0.93	0.01
- Standing on Non-Paretic Leg	0.93	0.01
- Standing Arm Raise	1	0.01
Section 4 Postural responses	0.97	0.01
- Compensatory Stepping Correction- Lateral_Paretic side	0.97	0.01
Section 5 Sensory orientation	Range 0.92- 1	0.01
- Eyes Closed, Firm Surface	1	0.01
- Eyes Open, Foam Surface	0.92	0.01
- Incline- Eyes Closed	1	0.01
Section 6 Stability in gait	Range 0.90- 1	0.01
- Change in Gait Speed	0.90	0.01
- Walk head turns, lateral	1	0.01
- TUG with dual task	0.90	0.01

Abbreviation: *r* = correlation coefficient and TUG= Timed "Get Up and Go" test.

TABLE 11 INTRARATER AND INTERRATER RELIABILITY OF THE S-BESTEST IN PEOPLE WITH STROKE (N=32).

13 items S-BESTest	Intrarater Reliability		Interrater Reliability	
	ICC (3,5)	95% CI	ICC (2,5)	95% CI
Total	0.98	0.98- 0.99	0.95	0.93- 0.97
Section 1	0.95	0.92- 0.97	0.85	0.74- 0.92
- Hip/ Trunk Lateral Strength	0.95	0.92- 0.97	0.85	0.74- 0.92
Section 2	0.98	0.97- 0.99	0.96	0.93- 0.98
- Functional Reach- Lateral_Non-paretic side	0.98	0.97- 0.99	0.96	0.93- 0.98
Section 3	0.96	0.94- 0.98	0.87	0.78- 0.93
- Rise to Toes	0.97	0.95- 0.98	0.92	0.87- 0.96
- Standing on Paretic Leg	0.97	0.95- 0.98	0.94	0.91- 0.97
- Standing on Non-Paretic Leg	0.98	0.97- 0.99	0.95	0.92- 0.97
- Standing Arm Raise	0.97	0.95- 0.98	0.91	0.85- 0.95
Section 4	0.97	0.95- 0.98	0.94	0.90- 0.97
- Compensatory Stepping Correction- Lateral_Paretic side	0.97	0.95- 0.98	0.94	0.90- 0.97
Section 5	0.98	0.97- 0.99	0.95	0.91- 0.97
- Eyes Closed, Firm Surface	0.95	0.91- 0.97	0.90	0.83- 0.94
- Eyes Open, Foam Surface	0.98	0.97- 0.99	0.95	0.91- 0.97
- Incline- Eyes Closed	0.97	0.96- 0.99	0.96	0.93- 0.98
Section 6	0.95	0.92- 0.97	0.89	0.82- 0.94
- Change in Gait Speed	0.92	0.88- 0.96	0.83	0.71- 0.91
- Walk with Head Turns	0.91	0.86- 0.95	0.83	0.71- 0.91
- TUG with Dual Task	0.94	0.90- 0.97	0.88	0.80- 0.94

Note: All intraclass correlation coefficient (ICCs) were significant, with p value of < 0.001. CI= confidence interval and TUG= Timed Up and Go.

TABLE 12 INTRARATER AND INTERRATER RELIABILITY OF THE BRIEF-BESTEST IN PEOPLE WITH STROKE (N=32).

Brief-BESTest	Intrarater Reliability		Interrater Reliability	
	ICC (3,5)	95% CI	ICC (2,5)	95% CI
Total	0.98	0.97- 0.99	0.95	0.92- 0.97
Section 1 Hip/Trunk Lateral Strength	0.95	0.92- 0.97	0.85	0.74- 0.92
Section 2 Functional Reach Forward	0.99	0.98- 0.99	0.99	0.98- 0.99
Section 3 Stand on One Leg	0.96	0.94- 0.98	0.90	0.83- 0.94
Section 4 Compensatory, Lateral	0.98	0.97- 0.99	0.96	0.93- 0.98
Section 5 Eyes Closed, Foam Surface	0.99	0.98- 0.99	0.98	0.96- 0.99
Section 6 Timed “Get Up and Go” test	0.94	0.91- 0.97	0.85	0.74- 0.92

Note: All intraclass correlation coefficient (ICCs) were significant, with p value of < 0.001. CI= confidence interval.

Subgroup analysis of the reliability based on the stroke onset; subacute and chronic stages, is also carried out.

2.1 Reliability in people with subacute stroke.

Eight males and four females were included in the reliability study. The age of twelve people with ischemic or hemorrhagic stroke ranged from 32 to 73 years. Onset time since stroke ranged between 7 to 120 days. Demographic data of participants in the reliability study were presented in Table 13.

The intrarater and interrater reliability of the S-BESTest in people with subacute stroke were demonstrated in Table 14. The intrarater and interrater reliability of the S-BESTest total scores were excellent with ICC of 0.98 and 0.95 as well as excellent reliability of the domain ICCs ranged 0.94 to 0.99 and 0.83 to 0.97.

The intrarater and interrater reliability of the Brief-BESTest in persons with subacute stroke were presented in Table 15. Excellent intrarater and interrater reliability of the Brief-BESTest total scores (ICC=0.98 and 0.96) as well as excellent reliability of the domain (ICC=0.96 to 0.99 and 0.91 to 0.99) were also noted.

TABLE 13 DEMOGRAPHIC DATA OF PARTICIPANTS WITH SUBACUTE STROKE IN THE RELIABILITY TEST.

Characteristics	Participants with subacute stroke (N=12)	
	Mean (SD)	Range
Age (years):	58.42 (13.41)	32-73
Gender: M/F, n	8/4	
Time since stroke (days):	40.60 (45.39)	7-120
Type of stroke: I/H, n	8/4	

Note: All values are presented as mean ± SD.

TABLE 14 INTRARATER AND INTERRATER RELIABILITY OF THE S-BESTEST IN PEOPLE WITH SUBACUTE STROKE (N=12).

13 items S-BESTest	Intrarater Reliability		Interrater Reliability	
	ICC (3,5)	95% CI	ICC (2,5)	95% CI
Total	0.98	0.97- 0.99	0.95	0.91- 0.98
Section 1	0.97	0.93- 0.99	0.91	0.78- 0.97
- Hip/ Trunk Lateral Strength	0.97	0.93- 0.99	0.91	0.78- 0.97
Section 2	0.98	0.96- 0.99	0.96	0.90- 0.99
- Functional Reach- Lateral_Non-paretic side	0.98	0.96- 0.99	0.96	0.90- 0.99
Section 3	0.96	0.92- 0.99	0.88	0.75- 0.96
- Rise to Toes	0.94	0.86- 0.98	0.83	0.63- 0.94
- Standing on Paretic Leg	0.96	0.91- 0.99	0.91	0.80- 0.97
- Standing on Non-Paretic Leg	0.96	0.92- 0.99	0.91	0.80- 0.97
- Standing Arm Raise	0.99	0.97- 0.99	0.97	0.92- 0.99
Section 4	0.96	0.92- 0.99	0.90	0.78- 0.97
- Compensatory Stepping Correction- Lateral_Paretic side	0.96	0.92- 0.99	0.90	0.78- 0.97
Section 5	0.97	0.94- 0.99	0.91	0.82- 0.97
- Eyes Closed, Firm Surface	0.94	0.86- 0.98	0.85	0.67- 0.95
- Eyes Open, Foam Surface	0.98	0.96- 0.99	0.96	0.91- 0.99
- Incline- Eyes Closed	0.96	0.92- 0.99	0.92	0.82- 0.97
Section 6	0.96	0.92- 0.99	0.91	0.83- 0.97
- Change in Gait Speed	0.95	0.89- 0.98	0.86	0.68- 0.95
- Walk with Head Turns	0.95	0.89- 0.98	0.87	0.70- 0.96
- TUG with Dual Task	0.95	0.90- 0.98	0.93	0.85- 0.98

Note: All intraclass correlation coefficient (ICCs) were significant, with p value of < 0.001. CI= confidence interval.

TABLE 15 INTRARATER AND INTERRATER RELIABILITY OF THE BRIEF-BESTEST IN PEOPLE WITH SUBACUTE STROKE (N=12).

Brief-BESTest	Intrarater Reliability		Interrater Reliability	
	ICC (3,5)	95% CI	ICC (3,5)	95% CI
Total	0.98	0.97- 0.99	0.98	0.97- 0.99
Section 1 Hip/Trunk Lateral Strength	0.97	0.93- 0.99	0.97	0.93- 0.99
Section 2 Functional Reach Forward	0.99	0.98- 0.99	0.99	0.98- 0.99
Section 3 Stand on One Leg	0.96	0.91- 0.99	0.96	0.91- 0.99
Section 4 Compensatory, Lateral	0.98	0.95- 0.99	0.98	0.95- 0.99
Section 5 Eyes Closed, Foam Surface	0.99	0.98- 0.99	0.99	0.98- 0.99
Section 6 Timed “Get Up and Go” test	0.97	0.94- 0.99	0.97	0.94- 0.99

Note: All intraclass correlation coefficient (ICCs) were significant, with p value of < 0.001. CI= confidence interval.

2.2 Reliability in people with chronic stroke.

Twenty persons with ischemic or hemorrhagic stroke consisted 13 males and 7 females with time since stroke from 19.83 to 155.5 months and age ranged 53 to 77 years in the reliability study. Demographic of participants in this study were presented in Table 16.

The intrarater and interrater reliability of the S-BESTest in people with chronic stroke were demonstrated in Table 17. The intrarater and interrater reliability of the S-BESTest total scores were excellent with ICC of 0.99 and 0.96 and domain ICCs ranged from 0.92 to 0.99 and 0.80 to 0.97, respectively.

The intrarater and interrater reliability of the Brief-BESTest in persons with chronic stroke were presented in Table 18. Excellent intrarater and interrater reliability of the Brief-BESTest total scores (ICC=0.97 and 0.93) were also noted. The intrarater and interrater reliability of the domain on the Brief-BESTest (ICC=0.96 to 0.99 and 0.80 to 0.98) were moderate to excellent.

TABLE 16 DEMOGRAPHIC DATA OF PEOPLE WITH CHRONIC STROKE IN THE RELIABILITY TESTING (N=20).

Characteristics	People with chronic stroke (N=20)	
	Mean (SD)	Range
Age (years):	63.95 (6.51)	53-77
Gender: M/F, n	13/7	
Time since stroke (months):	91.50 (42.31)	19.83-155.5
Type of stroke: I/H, n	15/5	

Abbreviation: I= Ischemic, and H= Hemorrhage.

TABLE 17 INTRARATER AND INTERRATER RELIABILITY OF THE S-BESTEST IN PEOPLE WITH CHRONIC STROKE (N=20).

13 items of S-BESTest	Intrarater Reliability		Interrater Reliability	
	ICC (3,6)	95% CI	ICC (2,6)	95% CI
Total	0.99	0.98- 0.99	0.96	0.94- 0.98
Section 1	0.96	0.92- 0.98	0.84	0.67- 0.93
- Hip/ Trunk Lateral Strength	0.96	0.92- 0.98	0.84	0.67- 0.93
Section 2	0.98	0.96- 0.99	0.96	0.92- 0.98
- Functional Reach- Lateral_Non-paretic side	0.98	0.96- 0.99	0.96	0.92- 0.98
Section 3	0.97	0.95- 0.99	0.89	0.80- 0.95
- Rise to Toes	0.98	0.97- 0.99	0.96	0.92- 0.98
- Standing on Paretic Leg	0.97	0.95- 0.99	0.95	0.90- 0.98
- Standing on Non-Paretic Leg	0.98	0.97- 0.99	0.97	0.95- 0.99
- Standing Arm Raise	0.96	0.93- 0.98	0.88	0.78- 0.95
Section 4	0.98	0.96 -0.99	0.96	0.92 -0.98
- Compensatory Stepping Correction-Lateral_Paretic side	0.98	0.96- 0.99	0.96	0.92 -0.98
Section 5	0.99	0.98- 0.99	0.97	0.94- 0.99
- Eyes Closed, Firm Surface	0.97	0.95- 0.99	0.96	0.92– 0.98
- Eyes Open, Foam Surface	0.97	0.95- 0.99	0.93	0.85- 0.97
- Incline- Eyes Closed	0.99	0.98- 0.99	0.97	0.95 -0.99
Section 6	0.95	0.91 -0.98	0.87	0.77 -0.94
- Change in Gait Speed	0.92	0.86- 0.96	0.84	0.71- 0.93
- Walk with Head Turns	0.92	0.85- 0.96	0.80	0.63- 0.91
- TUG with Dual Task	0.94	0.90- 0.97	0.87	0.75 -0.94

Note: All intraclass correlation coefficient (ICCs) were significant, with p value of < 0.001. CI= confidence interval.

TABLE 18 INTRARATER AND INTERRATER RELIABILITY OF THE BRIEF-BESTEST IN PEOPLE WITH CHRONIC STROKE (N=20).

Brief-BESTest	Intrarater Reliability		Interrater Reliability	
	ICC (3,6)	95% CI	ICC (2,6)	95% CI
Total	0.97	0.95- 0.99	0.93	0.88- 0.97
Section 1 Hip/Trunk Lateral Strength	0.96	0.92- 0.98	0.84	0.67- 0.93
Section 2 Functional Reach Forward	0.99	0.98- 0.99	0.98	0.97- 0.99
Section 3 Stand on One Leg	0.97	0.95- 0.99	0.92	0.84- 0.96
Section 4 Compensatory, lateral	0.98	0.97- 0.99	0.96	0.92- 0.98
Section 5 Eyes Closed, Foam Surface	0.98	0.97- 0.99	0.97	0.95- 0.99
Section 6 Timed “Get Up and Go” test	0.94	0.89- 0.97	0.80	0.60- 0.91

Note: All intraclass correlation coefficient (ICCs) were significant, with p value of < 0.001. CI= confidence interval.

3. Validity and responsiveness test in persons with subacute stroke

Seventy persons with ischemic or hemorrhagic stroke (44 males and 26 females) participated in validity and responsiveness test. Persons with stroke aged between 30 to 77 years with the stroke onset time from 7 to 103 days. Demographic and clinical characteristics of participants with subacute stroke in the validity and the responsiveness test were presented in Table 19.

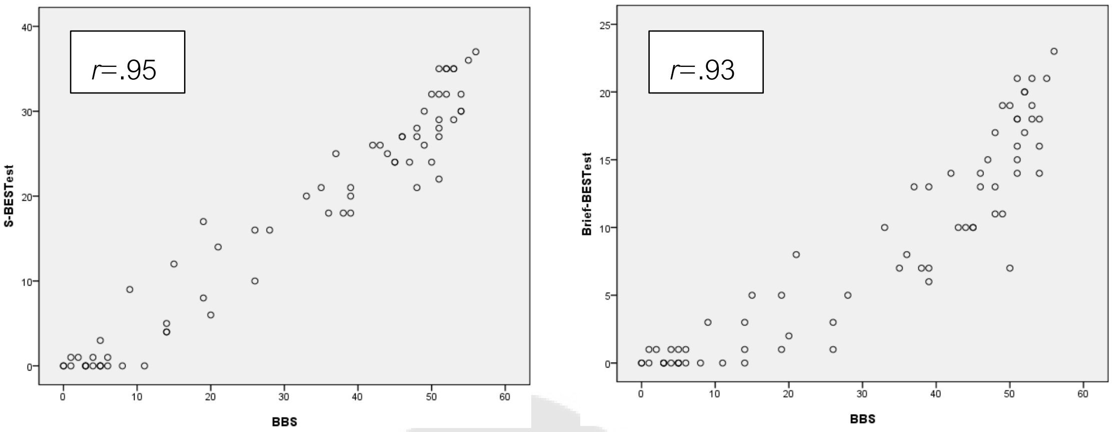
TABLE 19 DEMOGRAPHIC AND CLINICAL CHARACTERISTICS FOR PARTICIPANTS WITH SUBACUTE STROKE IN VALIDITY AND RESPONSIVENESS STUDY.

Characteristics	Participants with subacute stroke (N=70)	
	Mean (SD)	Range
Age (years):	55.24 (12.11)	30-77
Gender: M/F, n	44/26	
Time since stroke (days):	15.81 (15.6)	7-103
Type of stroke: I/H, n	64/6	
Affected side (right/left), n	37/33	
MMSE (/30)	27.33 (1.87)	24-30
FM-LE-motor (/34)	19.39 (10.06)	2-34
STREAM (/70)	40.81 (19.63)	0-67
BBS (/56)	31.24 (19.96)	0-56
BESTest (/108)	55.26 (34.15)	0-104
Brief-BESTest (/24)	8.80 (7.46)	0-23
S-BESTest (/39)	17.41 (12.73)	0-39

Abbreviation: I= Ischemic, H= Hemorrhage, MMSE= Mini-Mental State Examination, FM-LE-motor= Fugl-Meyer Stroke Assessment–lower extremity motor subscale, STREAM= Stroke Rehabilitation Assessment of Movement, BBS= Berg Balance Scale, BESTest= Balance Evaluation Systems Test, Brief-BESTest= Brief-Balance Evaluation Systems Test, and S-BESTest= Stroke- Balance Evaluation Systems Test.

3.1 Concurrent validity

Figure 12A demonstrated that the S-BESTest was highly correlated with the BBS (r=.95). Similarly, correlation of total scores from the Brief-BESTest with the BBS (r=.93) was also excellent (Figure 12B).



A) B)

FIGURE 12 RELATIONSHIPS BETWEEN THE TOTAL SCORES OF A) THE S-BESTEST WITH THE BBS AND B) THE BRIEF-BESTEST WITH THE BBS.

3.2 Predictive validity

The predictive validity of the S-BESTest and the Brief-BESTest was conducted using linear regression analysis (Table 20). The S-BESTest and the Brief-BESTest at admission were the significant predictors of the stroke rehabilitation assessment of movement (STREAM) at 2-week and 4-week post treatment. However, the ability to predict has decreased at 4 weeks as compared to 2 weeks. In addition, The S-BESTest was able to predict motor function outcome (as measured by STREAM) better than the Brief-BESTest.

TABLE 20 LINEAR REGRESSION ANALYSES FOR THE S-BESTEST AND THE BRIEF-BESTEST (N=70).

Predictors	STREAM	
	2 weeks	4 weeks
S-BESTest		
R^2	0.66*,†,‡	0.54*,†
Brief-BESTest		
R^2	0.57*,‡	0.46*

Abbreviation: STREAM= stroke rehabilitation assessment of movement, *= statistical was significant predictor, † = Significant difference between the S-BESTest and the Brief-BESTest with p value of < 0.001, and ‡ = Significant difference between 2 and 4 weeks with p value of < 0.001.

3.3 Floor and ceiling effects

Floor and ceiling effects of the S-BESTest and the Brief-BESTest and the BESTest measurement at baseline, 2 and 4 weeks are shown in Table 21. The number of participants with subacute stroke who received 0 of 24 scores on the Brief-BESTest equal 20% of all participants reflected a floor effect ($n_{Brief\text{-}BESTest}$ = 14/70, 20%) whereas the S-BESTest and the BESTest showed no floor effect. All three balance measurements showed no ceiling effect. Score distribution of the S-BESTest and the Brief-BESTest measurement at baseline, 2 and 4 weeks were demonstrated in Figure 13 and Figure 14, respectively.

TABLE 21 FLOOR AND CEILING EFFECTS OF THE S-BESTEST AND THE BRIEF-BESTEST AND THE BESTEST MEASURED AT BASELINE, 2 AND 4 WEEKS.

Participants with subacute stroke (N=70)	Baseline n (%)	2 weeks n (%)	4 weeks n (%)
S-BESTest			
Floor effect	13 (18.6)	3 (4.3)	0 (0.0)
Ceiling effect	0 (0.0)	3 (4.3)	8 (11.4)
Brief-BESTest			
Floor effect	14 (20)	2 (2.9)	0 (0.0)
Ceiling effect	0 (0.0)	3 (4.3)	11 (15.7)
BESTest			
Floor effect	4 (5.7)	0 (0.0)	0 (0.0)
Ceiling effect	0 (0.0)	0 (0.0)	3 (4.3)

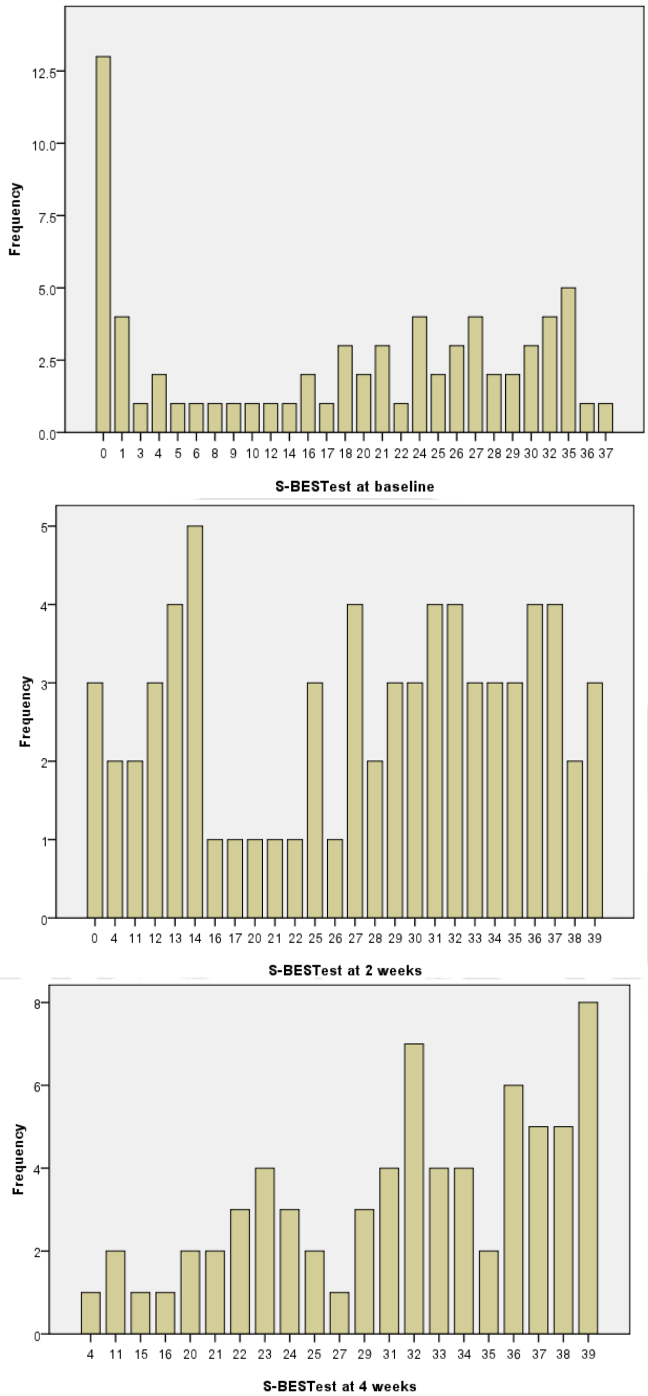


FIGURE 13 SCORE DISTRIBUTION OF THE S-BESTEST MEASURED AT BASELINE, 2 AND 4 WEEKS (N= 70).

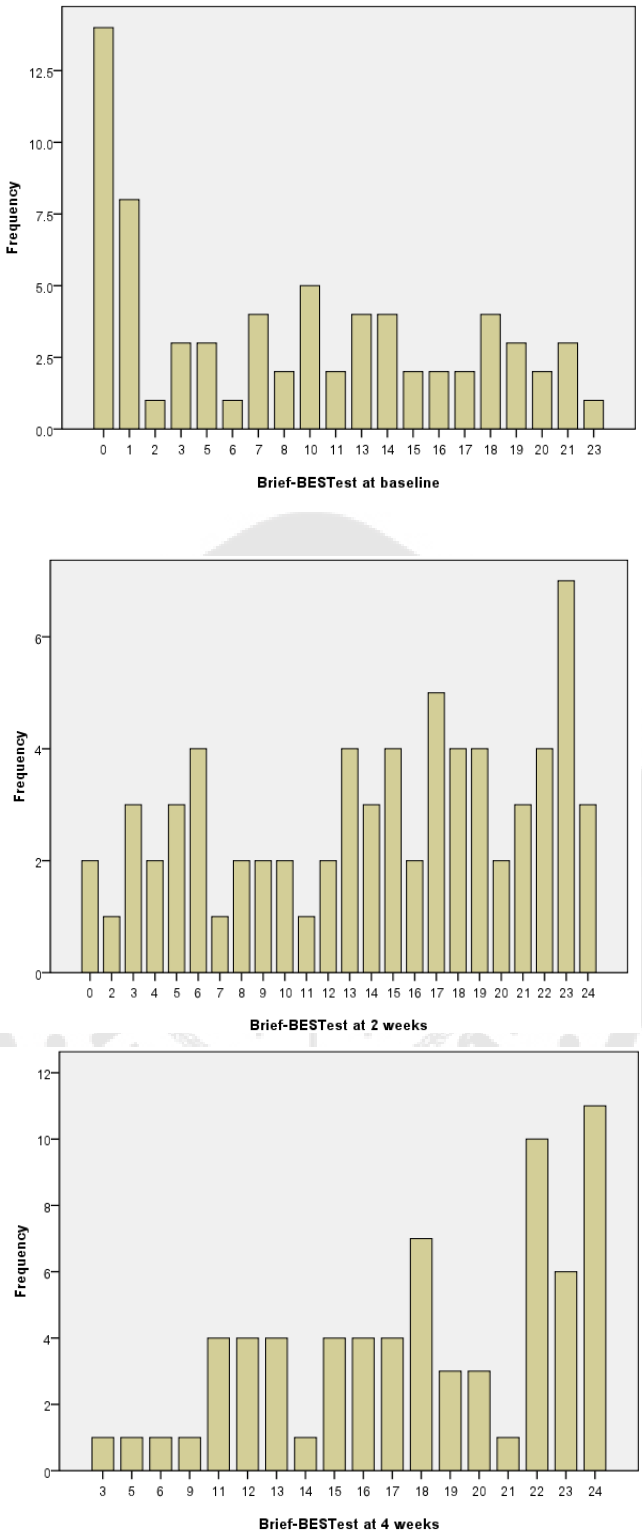


FIGURE 14 SCORE DISTRIBUTION OF THE BRIEF-BESTEST MEASURED AT BASELINE, 2 AND 4 WEEKS (N= 70).

3.4 Responsiveness

3.4.1 Internal responsiveness

After the end at 2 weeks and 2 to 4 weeks of rehabilitation program, all participants showed improvement of balance performance as presented by significant increase in total scores of the S-BESTest, the Brief-BESTest, and the BESTest (Table 22). Values of the minimal detectable change at 95% confidence interval (MDC_{95}) on the S-BESTest, the Brief-BESTest, and the BESTest measure at 0 to 2 weeks were higher than 2 to 4 weeks. The value of MDC_{95} of all three balance measures from small to large were the Brief-BESTest, the S-BESTest, and the BESTest, respectively. The standardized response mean (SRM) of the S-BESTest, the Brief-BESTest, and the BESTest were large, ranged between 1.23 to 1.57. Large SRM indicated sufficient internal responsiveness. These results represented that the S-BESTest, the Brief-BESTest, and the BESTest in participants with subacute stroke were sensitive to detect changed over time. Percentage of no change measure at 0 to 2 weeks and 2 to 4 weeks showed no significant difference among all three balance measures.

TABLE 22 INTERNAL RESPONSIVENESS OF THE S-BESTEST TOTAL SCORE, THE BRIEF-BESTEST TOTAL SCORE, AND THE BESTEST TOTAL SCORE MEASURE AT 0 TO 2 WEEKS AND 2 TO 4 WEEKS AFTER PHYSICAL THERAPY REHABILITATION.

Balance assessment	Before mean (SD)	After mean (SD)	Change mean (SD)	SRM	N (%) No change	MDC_{95}
S-BESTest (/39)						
0 to 2 weeks	17.41 (12.73)	25.27 (10.93)	7.86 (6.14)*	1.28	2 (2.86)	4.99
2 to 4 weeks	25.27 (10.93)	30.31 (7.93)	5.04 (3.91)*	1.29	5 (7.14)	4.28
Brief-BESTest (/24)						
0 to 2 weeks	8.79 (7.46)	14.24 (7.00)	5.46 (3.47)*	1.57	3 (4.28)	2.92
2 to 4 weeks	14.24 (7.00)	17.99 (5.19)	3.74 (2.82)*	1.33	9 (12.86)	2.74
BESTest (/108)						
0 to 2 weeks	55.23 (34.15)	77.29 (26.32)	22.06 (17.90)*	1.23	1 (1.43)	9.47
2 to 4 weeks	77.29 (26.32)	90.66 (16.98)	13.37 (10.85)*	1.23	0	7.29

Abbreviation: SD= standard deviation, SRM= standardized response mean, N (%) no change = number of participants showed no change, MDC_{95}= minimal detectable change at 95% confidence interval, * = Significant difference between before and after rehabilitation ($p<0.001$).

3.4.2 External responsiveness

The minimal clinically important difference (MCID) of the S-BESTest, the Brief-BESTest, and the BESTest measure at 0 to 2 weeks and 2 to 4 weeks based on the BBS score change and based on the GRC score change are presented in Table 23 and Table 24, respectively. Values of the MCID on the S-BESTest, the Brief-BESTest, and the BESTest based on BBS and GRC evaluation as an external criterion measure at 0 to 2 weeks were higher than 2 to 4 weeks excepted the S-BESTest based on GRC. The area under the curve (AUC) of the S-BESTest measure at 2 to 4 weeks based on the BBS score change was significant difference with the Brief-BESTest while the AUC of the Brief-BESTest measure at 0 to 2 weeks and 2 to 4 weeks based on the BBS score change was significant difference with the BESTest. However, values of the AUC on the

S-BESTest and the BESTest were similarly or equally which expressed confidence to using the recommended cutoff point in categorizing participants into balance change or no balance change measured at 0 to 2 weeks and 2 to 4 weeks, respectively.

The posttest accuracy and the likelihood ratio (LR) of the S-BESTest based on the BBS score change measure at 0 to 2 weeks were higher than the Brief-BESTest but lower than the BESTest. The posttest accuracy and the likelihood ratio (LR) of the S-BESTest based on the BBS score change measure at 2 to 4 weeks were lower than the BESTest while the Brief-BESTest was lowest as compared to the S-BESTest and the BESTest. The S-BESTest, the Brief-BESTest, and the BESTest change scores based on BBS scores measure at 0 to 2 weeks and 2 to 4 weeks for the ROC plot is displayed in Figure 15A and 15B. In brief, the MCID of the S-BESTest and the BESTest measure at 0 to 2 weeks and 2 to 4 weeks based on the BBS score change was better than the Brief-BESTest. In contrast, values of the MCID on the S-BESTest, the Brief-BESTest, and the BESTest based on GRC evaluation as an external criterion measure at 0 to 2 weeks and 2 to 4 weeks had low posttest accuracy and LR, indicating low probability to correctly distinguish participants who have balance improvement, excepted the S-BESTest at 0 to 2 weeks and the BESTest at 2 to 4 weeks.

TABLE 23 CUTOFF SCORES RELATED AREA UNDER THE CURVE (AUC), SENSITIVITY, SPECIFICITY, AND LIKELIHOOD RATIOS (LR) OF THE RECEIVER OPERATING CHARACTERISTIC (ROC) CURVES FOR THE S-BESTEST, THE BRIEF-BESTEST, AND THE BESTEST WITH IDENTIFY BALANCE PERFORMANCE CHANGING BASED ON THE BERG BALANCE SCALE (BBS) USED AS AN ANCHOR CRITERIA.

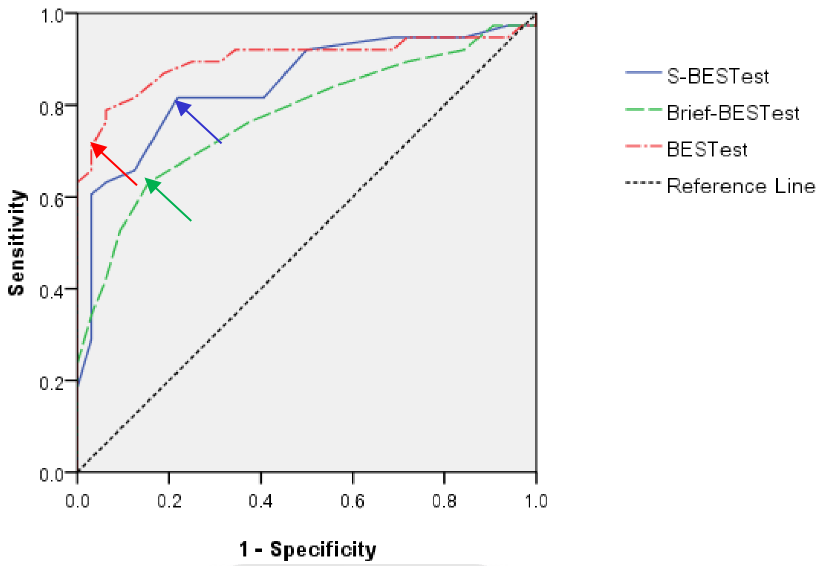
Characteristics	S-BESTest		Brief-BESTest		BESTest	
	Anchor: BBS	95% CI	Anchor: BBS	95% CI	Anchor: BBS	95% CI
0 to 2 weeks						
Optimal cutoff point: MCID	6.5		5.5		18.5	
Posttest accuracy	0.80		0.70		0.83	
AUC	0.84	0.75 - 0.94	0.77†	0.66- 0.88	0.89	0.82- 0.98
Sensitivity	0.78	0.60 - 0.91	0.63	0.46- 0.78	0.79	0.63- 0.90
Specificity	0.82	0.66 - 0.92	0.84	0.67- 0.95	0.94	0.79- 0.99
LR+	4.24		4.04		12.63	
LR-	0.27		0.44		0.22	
2 to 4 weeks						
Optimal cutoff point: MCID	5.5		4.5		13.5	
Posttest accuracy	0.80		0.66		0.87	
AUC	0.89*	0.82 - 0.97	0.79†	0.68- 0.91	0.89	0.81- 0.98
Sensitivity	0.78	0.65 - 0.89	0.74	0.49- 0.91	0.89	0.67- 0.99
Specificity	0.84	0.60 - 0.97	0.72	0.58- 0.84	0.86	0.74- 0.94
LR+	4.97		2.68		6.52	
LR-	0.26		0.36		0.12	

Abbreviation: CI= confidence interval, MCID= minimal clinically important difference, LR+= positive likelihood ratio, LR-= negative likelihood ratio, * = ROC curve area comparison of the S-BESTest and the Brief-BESTest were significant difference with p value of < 0.01, and † = ROC curve area comparison of the Brief-BESTest and the BESTest were significant difference with p value of < 0.01.

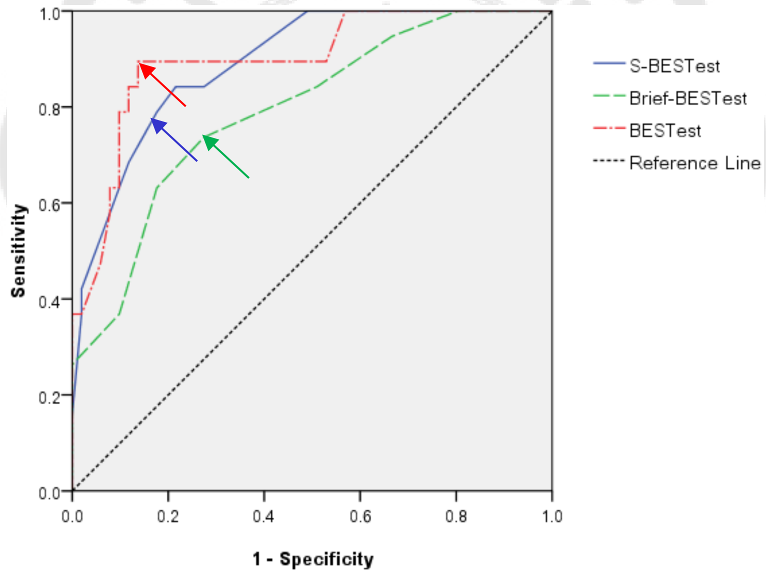
TABLE 24 CUTOFF SCORES RELATED AREA UNDER THE CURVE (AUC), SENSITIVITY, SPECIFICITY, AND LIKELIHOOD RATIOS (LR) OF THE RECEIVER OPERATING CHARACTERISTIC (ROC) CURVES FOR THE S-BESTEST, THE BRIEF-BESTEST, AND THE BESTEST WITH IDENTIFY BALANCE PERFORMANCE CHANGING BASED ON THE GLOBAL RATING OF CHANGE (GRC) USED AS AN ANCHOR CRITERIA.

Characteristics	S-BESTest		Brief-BESTest		BESTest	
	Anchor: GRC	95% CI	Anchor: GRC	95% CI	Anchor: GRC	95% CI
0 to 2 weeks						
Optimal cutoff point: MCID	2.5		4.5		8.5	
Posttest accuracy	0.83		0.74		0.77	
AUC	0.73	0.55 – 0.91	0.73	0.56- 0.90	0.71	0.53- 0.88
Sensitivity	0.50	0.23 – 0.77	0.66	0.52- 0.78	0.86	0.74- 0.94
Specificity	0.91	0.80 – 0.97	0.71	0.42- 0.92	0.57	0.29- 0.82
LR+	5.60		2.31		2.00	
LR-	0.55		0.47		0.25	
2 to 4 weeks						
Optimal cutoff point: MCID	4.5		3.5		2.5	
Posttest accuracy	0.56		0.41		0.05	
AUC	0.69	0.38 - 1	0.68	0.42- 0.93	0.50	-0.35- 1
Sensitivity	1	0.16 - 1	1	0.16- 1.00	0.50	0.01- 0.99
Specificity	0.44	0.32 – 0.57	0.51	0.39- 0.64	0.91	0.82- 0.97
LR+	1.79		2.06		5.67	
LR-	0		0		0.55	

Abbreviation: CI= confidence interval, MCID= minimal clinically important difference, LR+= positive likelihood ratio, and LR-= negative likelihood ratio.



A) 0 TO 2 WEEKS



B) 2 TO 4 WEEKS

FIGURE 15 RECEIVER OPERATING CHARACTERISTIC (ROC) PLOT OF THE S-BESTEST, THE BRIEF-BESTEST, AND THE BESTEST SCORE CHANGE BASED ON BBS SCORE CHANGE <7 AND >7 MEASURE AT A) 0 TO 2 WEEKS B) 2 TO 4 WEEKS IN PEOPLE WITH SUBACUTE STROKE FOR DETERMINING REAL BALANCE PERFORMANCE CHANGE. ARROW DEPICTS THE CUTOFF SCORE FOR REPRESENTED BALANCE PERFORMANCE CHANGE.

CHAPTER 5
CONCLUSION AND DISCUSSION

Discussion

This study aimed to create the shorter version of the BESTest that was appropriate to be used in persons with subacute and chronic stroke. The S-BESTest was developed using "both approaches combined" method of shortening the existing scale; Rasch analysis merged with expert agreement. The final S-BESTest contained thirteen items that preserved all domains and scoring system of the BESTest. Therefore, the S-BESTest can assess six domains in postural control system, including biomechanical constraints, stability limit, anticipatory postural adjustments, reactive postural responses, sensory orientation and stability in gait, similar to the BESTest[25] and the Brief-BESTest.[29] In contrast, the Mini-BESTest was developed to evaluate a unidimensionality of the dynamic balance construct.[27] Unlike the BESTest that assesses postural control in both sitting and standing postures, the S-BESTest consists of only the test items that assess postural control in standing posture. In addition, the S-BESTest demonstrated unidimensionality to evaluate balance construct similar to the Mini-BESTest that its unidimensionality was related to dynamic balance construct.[27] Similar to the Mini-BESTest[183] and the Brief-BESTest,[192] the S-BESTest demonstrated no item bias (no significant DIF) among persons with stroke based on affected side and age groups, except item 8 "eyes closed, firm surface" that showed item bias.

In this study, although all 13 items of the S-BESTest were approved from the expert in the field (CVR > 0.5), three items of the S-BESTest received lower agreement than the others. Those items were item 6 "standing arm raise" (CVR= 0.6), item 7 "compensatory stepping correction-lateral paretic side" (CVR= 0.7), and item 13 "Timed Up and Go (TUG) with dual task" (CVR= 0.6). Some experts felt that inability to perform "standing arm raise" item may be due to inability to lift the paretic arm up, rather than poor postural control. Some of them felt that "compensatory stepping correction-lateral paretic side" and "TUG with dual task" was too difficult and unsafe for patients with stroke. These feedbacks from the experts suggested that the training of how to use the scale and techniques to ensure safety of the patients during testing should be provided to the clinician prior to the implementation of the S-BESTest in real clinical settings.

This study employed the hypothesis testing on the known group (based on the FM-LE score) to confirm construct validity of the S-BESTest. The S-BESTest is more likely to represent the impairments and activity limitations of the patients with stroke better than the other short-forms of the BESTest. For example, it has been found that patients with stroke exhibited larger mediolateral postural sway than healthy subjects while antero-posterior sway showed no difference between groups.[193] Item "functional reach lateral on non-paretic side" has been included in the S-BESTest to represent the impairment of the paretic trunk muscles to maintain posture when reaching toward non-paretic side, whereas the Brief-BESTest contains the item "functional reach forward". Another example on 2 additional items "rise to toes" and "standing arm raise" in the S-BESTest, as compared to those in the Brief-BESTest and Mini-BESTest. In the "rise to toes" situation, although the prime mover was soleus muscle but tibialis anterior muscle worked in the anticipatory fashion before the activation of soleus muscle to move CoM forward and encourage weight shifting from heel to toes.[194] Paralyzed tibialis anterior muscles commonly found in patients with stroke would limit the ability to perform rise to toes. Similarly, in "standing arm raising situation", people with stroke lacked or delayed activation of hamstrings muscle on paretic side prior to anterior deltoid muscle contraction, resulting in reduced speed of arm raise or limit ability to raise the full range of motion.[74]

The Rasch analysis method was selected in this study to shorten the BESTest scale, similar to the development of Mini-BESTest, therefore, we used the same infit/ outfit MnSq criteria (0.6-1.4) as that of the Mini-BESTest.[27] With this infit/outfit MnSq criteria, 23 items were deleted from the BESTest to form the S-BESTest. Our results showed that the deleted items were not appropriate for patients with stroke because they were either too difficult or too easy for the patients. For example, some deleted items did not sufficiently challenge balance ability of the persons with stroke. Those items were “base of support” (86 %), “sitting verticality and lateral lean” (87 %), “sit to stand” (74 %), and “eyes open, firm surface” (74 %), of which the majority of persons with stroke received full score. On the other hand, items such as “alternate stair touching” (50 %), “eyes closed, foam surface” (61 %), and “step over obstacle” (50 %) were too hard as can be seen from more than half of patients were scored “0” in those items.

Results of the Rasch analysis also demonstrated the level of item difficulty which can be seen from the map of person balance ability and item difficulty response (Figure 11) and mean difficulty value (Table 5). From the map, items that were located in the same linear continuum of the map implied the same level of item difficulty.[140] For example, item 1 (“hip/trunk lateral strength”) and item 13 (“Timed Up and Go with dual task”)/ item 5 (“standing on non-paretic leg”) and item 12 (“walking with head turns”) were on the same linear continuum of the map and demonstrated a similar level of difficulty. The most difficult item or the highest mean difficulty score of the S-BESTest for persons with stroke was “standing on paretic leg” where paretic lower extremity were required to maintain balance on the narrow base of support with less compensation from the non-paretic side.[195] The easiest item or the lowest mean difficulty score of the S-BESTest was “eyes closed, firm surface”, which only visual input is absent but somatosensory and vestibular inputs are still present for postural control.[196]

The category outfit MnSq is used to represent the consistency of the item rating score with the total score such that a person with the high total score is expected to do well in most items and those with the low total score are expected to score low in most items. The category outfit MnSq was set at lower than 2.0 to represent the consistency of category rating scale. We found the category outfit MnSq higher than 2 which indicates inconsistency for the item “functional reach lateral-non-paretic side” and “standing on paretic leg”. Our individual data showed inconsistency in these two items, for example, a patient received 3 points in item of “functional reach lateral-non-paretic side” but his total score was low (7/39) or another person received 2 points in the “standing on paretic leg" item but his total score was high (36/39). The inconsistency may be due to compensation of the patients during the assessment such as the trunk rotation and arm abduction level found in the "functional reach lateral-non-paretic side" item where the control of movement compensation may help improve the consistency of the item rating score.

We suggested the total score of the S-BESTest to indicate the severity of balance impairment in patients with stroke into 4 categories; mild (31–39), moderate (19–30), severe (10–18), and very severe (0-9). Previous study on the Mini-BESTest suggested five levels of balance impairment using the total score of the Mini-BESTest; mild deficit to normal (24-28), moderate deficit (18-23), moderately severe deficit (12-17), severe deficit (6-11), and very severe deficit (0-5).[183] The main difference in the classification of balance performance using the S-BESTest and the Mini-BESTest is that the S-BESTest is specifically used for persons with stroke, but the Mini-BESTest can be used to classify people with a variety of neurological disorders. This information is useful for clinicians to help them plan the intervention appropriate to the level of balance impairment and to predict the prognosis and outcome of their intervention.

Excellent intrarater and interrater reliability of the S-BESTest and the Brief-BESTest in patients with subacute stroke and chronic stroke were consistent with previous study in people with balance disorders including persons with subacute stroke[26] and chronic stroke.[197] Intrarater reliability and interrater reliability of the BESTest in patients with subacute stroke was 0.99 (ICC) with domain score ICCs ranging from 0.87 to 0.99. Similarly, the Brief-BESTest in chronic stroke demonstrated excellent intrarater and interrater reliability of the total score (ICC= 0.97). Excellent concurrent validity of the S-BESTest and the Brief-BESTest with BSS in persons with subacute stroke confirmed that the S-BESTest and the Brief-BESTest assessed the same balance constructs as BBS which was the clinical gold standard of balance tests. Our results were in the same line with previous findings of strong correlation between the BESTest and BBS (r=.96),[26] between the Brief-BESTest and the BBS (r =.87) in persons with chronic stroke.[197]

For predictive validity study, the S-BESTest at admission was able to predict motor function outcome using by the stroke rehabilitation assessment of movement (STREAM) at 2-week and 4-week post treatment better than the Brief-BESTest. The S-BESTest was able to predict 60% and 54% of motor function outcome at 2-week and 4-week post treatment, while the Brief-BESTest was able to predict 57% and 46% of motor function outcome at 2-week and 4-week post treatment. The S-BESTest contains items that could reflect the movements required in the STREAM. Those related items are hip and trunk lateral strength, rise to toes, standing arm raise and change in gait speed that could be used to estimate similar movements such as abduct affected hip with knee extended, dorsiflex affected ankle with knee extended, raise arm overhead to fullest elevation, and walks 10 meters indoors in the STREAM. The ability of the S-BESTest to predict the movements has decreased at 4 weeks when compared at 2 weeks because the decrease in the recovery of paretic leg at the later time post stroke.[(198) (199)]

Our results demonstrated that all 3 balance tools had no floor and ceiling effect, except the Brief-BESTest showed a floor effect for participants with subacute stroke at the first assessment. Therefore, the Brief-BESTest may be suitable for persons with chronic stroke because the Brief-BESTest showed no floor effect in these subject group.[(197)] The S-BESTest and the Brief-BESTest demonstrated good internal responsiveness (large SRM) similar to the BESTest in the previous study,[(26)] suggesting all three balance measures were sensitive to detect the effectiveness of the rehabilitation or the recovery of the participants with subacute stroke.[(125, 127)] However, internal responsiveness decreased at 4 weeks as compared to 2 weeks, which was in the same line as previous studies.[(118) (200)] We found that the minimal clinically important difference (MCID) of the S-BESTest, the Brief-BESTest, and the BESTest calculated using the BBS score change was more accurate than those calculated using the GRC score change. The GRC was obtained from patient's perception that may underestimate or overestimate from recall bias and ability to understand the context of improvement.[(161)] The MCID of the S-BESTest, the Brief-BESTest, and the BESTest based on BBS and GRC evaluation as an external criterion measure at 0 to 2 weeks were higher than 2 to 4 weeks, consistent with decrease in recovery rate of stroke while increasing time since stroke.[198] [199] Previous evidence demonstrated high recovery rate of stroke at 2 and 4 weeks post stroke and a plateau phase of recovery after 6 months.[198] [199] Our recommended cutoff point in differentiation patients into balance change or no balance change measured at 0 to 2 weeks and 2 to 4 weeks using the S-BESTest, the Brief-BESTest, and the BESTest in persons with subacute stroke measure at 2 to 4 weeks was 6, 5, and 16 points, respectively. However, the S-BESTest demonstrated high probability to correctly distinguish participants who have balance improvement than the Brief-BESTest (LR+). With similar AUC, the S-BESTest can be used to decrease assessment time when comparing with the BESTest.

The S-BESTest was appropriate to use in people with subacute stroke for identifying causes of balance deficits and planning treatment. This scale can be completed within 15-20 minutes. Assessors should be comprehended in the testing procedures and reduced compensatory movement of patients when using the S-BESTest. For example, patients may lack ability to lift the paretic arm up in “standing arm raise” item but they will be allowed to lift the non-paretic arm for evaluating anticipatory responses. The S-BESTest had good psychometric properties and responsiveness to detect balance improvement.

Limitation and further study

This study has its limitation regarding generalization to different groups and settings. The results of our study were carried out in persons with subacute and chronic stroke who had high lower limb ability, as seen by the mean score of FM-LE (22/34), and able to stand independently for at least 3 seconds. Therefore, the findings may not be appropriate for persons with stroke who cannot stand independently. Further studies should include persons with subacute stroke with different level of balance impairment for extensive generalization in clinical practice. Other information can be further explored such as relationships between lower extremity muscle strength, walking and fear of falling in people with subacute stroke who have different level of balance impairment.

Clinical implications

The S-BESTest has several advantages. The S-BESTest reduced the administration time in clinical practice and score on the S-BESTest can assist clinicians to plan the interventions suitable for level of balance impairment. The S-BESTest can be used to evaluate balance deficits covered all domain of postural control and assessed the effectiveness of balance training program improvement among persons with subacute stroke. Score on the S-BESTest can be used to differentiate persons with subacute stroke into 4 groups of balance impairment; mild (31–39), moderate (19–30), severe (10–18), and very severe (0-9). The S-BESTest did not have a floor and ceiling effects in persons with subacute stroke but the Brief-BESTest had a floor effect in these group, suggesting that the S-BESTest can be used in persons with subacute stroke better than the Brief-BESTest. Moreover, the S-BESTest can predict motor function outcome at 2-week and 4-week post physical therapy rehabilitation better than the Brief-BESTest. The S-BESTest showed high probability to precisely discriminate participants who have balance improvement than the Brief-BESTest. Therefore, we recommended the S-BESTest to be used in people with subacute stroke.

Conclusion

The S-BESTest is the shorten version of the BESTest specifically to be used in persons with subacute and chronic stroke. This scale was developed using Rasch analysis merged with expert agreement, resulting in thirteen items that preserved all domains and scoring system of the BESTest. This scale demonstrated unidimensionality and construct validity using hypothesis testing on the known group. The S-BESTest and the Brief-BESTest had excellent reliability, high concurrent validity with BBS. The S-BESTest can predict motor outcome at discharge as measured by the STREAM and had high internal responsiveness in person with subacute stroke. The S-BESTest had no floor and ceiling effects but the Brief-BESTest had a floor effects in persons with subacute stroke. The MCID for the S-BESTest, the Brief-BESTest, and the BESTest in people with subacute stroke measure at 2 to 4 weeks was 6, 5, and 16 points, respectively.

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APPENDICES

APPENDIX A DEMOGRAPHIC AND CLINICAL CHARACTERISTICS FORM

Name of subject …………………………… Study number………………………………..

Date of test …………………………………… Level of education ………………………….

Age ………………………………………….. Gender ……………..………………………....

Weight ………………………………………… Height …………..……………………………...

Stroke type …………………………………… Lesion location ..…………………………….

Time since stroke …………………………….. Onset …………………………………………

Underlying disease …………………………… Medication……………………………………

Tel …………………………………………….. Occupation…………………………………..

Address……………………………..…………………………………………….……………

BP ……………………mmHg HR ………..beats/min. RR …………….beats/min.

MMSE score ………………………………….. FM score ……………… ☐ HFA ☐ LFA

BBS score …………………………...…….. STREAM score ……………………………

BESTest score ………….. S-BESTest score ………….. Brief-BESTest score ………

Study: ☐ Scale development ☐ Reliability ☐ Validity and responsiveness

Evaluation: ☐ Baseline ☐ 2 weeks ☐ 4 weeks

History……………………………………………………………………………………………

……………………………………………………………………………………………………

APPENDIX B MINI-MENTAL STATE EXAMINATION

THAI VERSION

1. Orientation for time (5 คะแนน) บันทึกคำตอบไว้ทุกครั้งทั้งคำตอบที่ถูกและผิด

ตอบถูก ☑ ข้อละ 1 คะแนน

1.1 วันนี้วันที่เท่าไร………………………....☐

1.2 วันนี้วันอะไร…………………………..☐

1.3 เดือนนี้เดือนอะไร……………………..☐

1.4 ปีนี้ปีอะไร………………………….....☐

1.5 ฤดูนี้ฤดูอะไร…………………………..☐

2. Orientation for place (5 คะแนน) (เลือกข้อใดข้อหนึ่งจาก 2.1 และ 2.2)

2.1 กรณีอยู่ที่สถานพยาบาล

2.1.1 สถานที่ตรงนี้เรียกว่า อะไร และ.....ชื่อว่าอะไร………… ☐

2.1.2 ขณะนี้ท่านอยู่ที่ชั้นที่เท่าไรของตัวอาคาร………. ☐

2.1.3 ที่อยู่ในอำเภอ - เขตอะไร……………………….. ☐

2.1.4 ที่นี่จังหวัดอะไร………………………………….. ☐

2.1.5 ที่นี่ภาคอะไร……………………………………… ☐

2.2 กรณีที่อยู่ที่บ้านของผู้ถูกทดสอบ

2.2.1 สถานที่ตรงนี้เรียกว่าอะไรและบ้านเลขที่อะไร……………. ☐

2.2.2 ที่นี่หมู่บ้าน หรือละแวก/คุ้ม/ย่าน/ถนนอะไร………………... ☐

2.2.3 ที่นี่อำเภอเขต / อะไร……………………………. ☐

2.2.4 ที่นี่จังหวัดอะไร…………………………………... ☐

2.2.5 ที่นี่ภาคอะไร……………………………………... ☐

3. Registration (3 คะแนน)

ต่อไปนี้เป็นการทดสอบความจำ ดิฉันจะบอกชื่อของ 3 อย่าง คุณ (ตา, ยาย...) ตั้งใจฟังให้ดีนะ เพราะจะบอกเพียงครั้งเดียว ไม่มีการบอกซ้ำอีก เมื่อผม (ดิฉัน) พูดจบ ให้คุณ (ตา,ยาย...)

พูดทบทวนตามที่ได้ยินให้ครบ ทั้ง 3 ชื่อ แล้วพยายามจำไว้ให้ดี เดี๋ยวดิฉันจะถามซ้ำ

∗ การบอกชื่อแต่ละคำให้ห่างกันประมาณหนึ่งวินาที ต้องไม่ช้าหรือเร็วเกินไป (ตอบถูก 1 คำได้ 1 คะแนน)

○ดอกไม้ ○แม่น้ำ ○รถไฟ.....................☐

ในกรณีที่ทำแบบทดสอบซ้ำภายใน 2 เดือน ให้ใช้คำว่า

○ต้นไม้ ○ทะเล ○รถยนต์.................☐

4. Attention/Calculation (5 คะแนน) (ให้เลือกข้อใดข้อหนึ่ง)

ข้อนี้เป็นการคิดเลขในใจเพื่อทดสอบสมาธิ คุณ (ตา,ยาย...) คิดเลขในใจเป็นไหม ? ถ้าตอบคิดเป็นทำข้อ 4.1 ถ้าตอบคิดไม่เป็นหรือไม่ตอบให้ทำข้อ 4.2

4.1 "ข้อนี้คิดในใจเอา 100 ตั้ง ลบออกทีละ 7 ไปเรื่อยๆ"

ได้ผลเท่าไรบอกมา .... ☐

บันทึกคำตอบตัวเลขไว้ทุกครั้ง (ทั้งคำตอบที่ถูกและผิด) ทำทั้งหมด 5 ครั้ง ถ้าลบได้ 1, 2, หรือ 3 แล้วตอบไม่ได้ ก็คิดคะแนนเท่าที่ทำได้ ไม่ต้องย้ายไปทำข้อ 4.2

4.2 "ผม (ดิฉัน) จะสะกดคำว่า มะนาว ให้คุณ (ตา, ยาย...) ฟังแล้วให้คุณ (ตา, ยาย...) **สะกดถอยหลังจากพยัญชนะตัวหลังไปตัวแรก คำว่ามะนาวสะกดว่า**

มอม้า-สระอะ-นอหนู-สระอา-วอแหวน ไหนคุณ (ตา, ยาย...) สะกดถอยหลัง ให้ฟังซิ"

.... ว า น ะ ม

5. Recall (3 คะแนน)

"เมื่อสักครู่ที่ให้จำของ 3 อย่างจำได้ไหมมีอะไรบ้าง" (ตอบถูก 1 คำได้ 1 คะแนน)

○ดอกไม้ ○แม่น้ำ ○รถไฟ ....☐

ในกรณีที่ทำแบบทดสอบซ้ำภายใน 2 เดือน ให้ใช้คำว่า

○ต้นไม้ ○ทะเล ○รถยนต์..........................☐

6. Naming (2 คะแนน)

6.1 ยื่นดินสอให้ผู้ถูกทดสอบดูแล้วถามว่า "ของสิ่งนี้เรียกว่าอะไร"..................... ☐

6.2 ชี้นาฬิกาข้อมือให้ผู้ถูกทดสอบดูแล้วถามว่า "ของสิ่งนี้เรียกว่าอะไร"...............☐

7. Repetition (1 คะแนน) (พูดตามได้ถูกต้องได้ 1 คะแนน)

ตั้งใจฟังผม (ดิฉัน) เมื่อผม (ดิฉัน) พูดข้อความนี้แล้วให้คุณ (ตา, ยาย) พูดตาม จะบอกเพียงครั้งเดียว "ใครใคร่ขายไก่ไข่"............................☐

8. Verbal command (3 คะแนน)

ข้อนี้ฟังคำสั่ง "ฟังดีๆ นะ เดี๋ยวผม (ดิฉัน) จะส่งกระดาษให้คุณ แล้วให้คุณ (ตา, ยาย...) รับด้วยมือขวา พับครึ่งกระดาษ แล้ววางไว้ที่........." (พื้น, โต๊ะ, เตียง) ผู้ทดสอบแสดงกระดาษเปล่าขนาดประมาณ เอ-4 ไม่มีรอยพับ

ให้ผู้ถูกทดสอบ ○ รับด้วยมือขวา ○ พับครึ่ง ○ วางไว้ที่......(พื้น, โต๊ะ, เตียง) □

9. Written command (1 คะแนน)

ต่อไปเป็นคำสั่งที่เขียนเป็นตัวหนังสือ ต้องการให้คุณ (ตา, ยาย...) อ่านแล้วทำตาม (ตา, ยาย...) จะอ่านออกเสียงหรืออ่านในใจ ผู้ทดสอบแสดงกระดาษที่เขียนว่า “หลับตาได้”

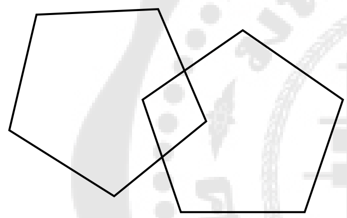
○ หลับตาได้.................... □

10. Writing (1 คะแนน)

ข้อนี้จะเป็นคำสั่งให้ “คุณ (ตา, ยาย...) เขียนข้อความอะไรก็ก็ที่อ่านแล้วรู้เรื่อง หรือมีความหมายมา 1 ประโยค”...○ ประโยคมีความหมาย □

11. Visuoconstruction (1 คะแนน)

ข้อนี้เป็นคำสั่ง “จงวาดภาพให้เหมือนภาพตัวอย่าง” (ในช่องว่างด้านขวาของภาพตัวอย่าง) □



คะแนนเต็ม........................

CHINESE VERSION

賽馬會耆智園 Jockey Club Centre for Positive Ageing

簡短智能測驗

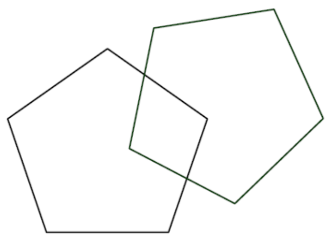
Mini Mental State Examination

園友姓名：_______________ 年齡/性別：________ 個案編號：JCCPA-_______________

評估日期：_____________________

Items	Responses and Mark(s)	
依家係乜嘢日子?	年份 / 月份 / 幾號 / 星期幾 / 季節	___
我地依家係邊度?	新界 / 沙田 或 馬鞍山 / 亞公角街 27 號 / 賽馬會耆智園 / ___ 樓	___
依家我會講三樣嘢嘅名，講完之後，請你重複一次。 蘋果 → 報紙 → 火車	蘋果 / 報紙 / 火車	___
提示 ： 請記住佢地，因為幾分鐘後，我會叫你再講番俾我聽。		
請你用一百減七，然後再減七，一路減落去， 直至我叫你停為止。 (或：依家我讀個數目俾你聽，請你倒轉頭講番出來：4－2－7－3－1)	___ ___ ___ ___ ___	___
我頭先叫你記住嘅三樣嘢係乜嘢呀?	蘋果 / 報紙 / 火車	___
依樣係乜嘢？	鉛筆 / 手錶	___
請你跟我講句說話：姨丈買魚腸		___
依家檯上面有一張紙。用你既右手拿起張紙；用兩隻手一齊將紙摺成一半；然後放番張紙係檯上面。		___
請你講任何一句完整嘅句子俾我聽。 例如：今日天氣好好		___
請讀出哩張上面嘅字，然後照住去做。		__
拍手		
依處有幅圖，請你照住嚟畫啦。		___

MMSE Total = /30



職員簽署：___________________ （職級：_________________）

JCCPA-SA-006

APPENDIX C INFORMATION SHEET AND CONSENT FORM

แบบคำชี้แจงอาสาสมัคร

1. ชื่อโครงการวิจัย

(ภาษาไทย) การพัฒนาแบบประเมินทางคลินิกฉบับย่อสำหรับทดสอบสาเหตุความบกพร่องในการทรงตัวสำหรับผู้ป่วยโรคหลอดเลือดสมองระยะหลังเฉียบพลัน

(ภาษาอังกฤษ) The development of short form clinical test for assessing causes of balance deficits in patients with subacute stroke

2. ชื่อผู้รับผิดชอบโครงการ

นางสาวธิติมาศ วินัยรักษ์

นิสิตปริญญาเอก สาขากายภาพบำบัด คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ

โทรศัพท์ 097-023-8118 E-mail: ttmwnr@hotmail.com

3. เหตุที่ต้องทำวิจัยและเหตุผลที่ต้องการศึกษาในคน รวมทั้งเหตุผลที่อาสาสมัครที่ได้รับเชิญเข้าร่วมโครงการ

ผู้ป่วยโรคหลอดเลือดสมองมีความบกพร่องในการทรงตัว ซึ่งเป็นปัญหาสำคัญที่ส่งผลต่อคุณภาพชีวิตและความสามารถในการดำรงชีวิตประจำวัน การประเมินความสามารถในการทรงตัวของผู้ป่วย เพื่อให้ได้ข้อมูลเกี่ยวกับสาเหตุของความบกพร่องนั้นเป็นสิ่งจำเป็นต่อการแก้ปัญหาความบกพร่องของการทรงตัวอย่างมีประสิทธิภาพ เนื่องจากความสามารถในการทรงตัวเกิดจากการทำงานร่วมกันของระบบต่าง ๆ ภายในร่างกาย แบบประเมินการทรงตัวที่ดีต้องสามารถประเมินได้ครอบคลุมทุกระบบจึงจะสามารถตรวจสอบแยกแยะความผิดปกติของแต่ละระบบเพื่อนำไปแก้ปัญหาได้อย่างเฉพาะเจาะจง ซึ่งแบบประเมินการทรงตัวถูกพัฒนาให้สามารถประเมินแยกแยะระบบต่าง ๆ ที่ควบคุมการทรงตัวได้ แต่การนำไปใช้ยังไม่เป็นที่นิยม เพราะใช้ระยะเวลาในการตรวจนาน จึงจำเป็นต้องพัฒนาแบบประเมินการทรงตัวฉบับย่อที่ยังคงความสามารถในการระบุปัญหาของระบบการทรงตัวได้ครบถ้วนทุกระบบเช่นเดียวกับแบบประเมินเดิม แต่ใช้ระยะเวลาในการตรวจประเมินที่สั้นลง เพื่อนำไปใช้ในการตรวจประเมินความสามารถในการทรงตัวของอาสาสมัครในโครงการวิจัยนี้ และวิเคราะห์สาเหตุที่ทำให้เกิดความบกพร่องในการทรงตัว ซึ่งจะนำไปสู่การออกแบบการฟื้นฟูความสามารถในการทรงตัวที่มีประสิทธิภาพสอดคล้องกับปัญหาการทรงตัวของอาสาสมัครอย่างแท้จริง

4. วัตถุประสงค์

พัฒนาแบบประเมินฉบับย่อ เพื่อทดสอบสาเหตุของความบกพร่องในการทรงตัวของผู้ป่วยโรคหลอดเลือดสมองระยะหลังเฉียบพลัน

5. ขั้นตอนและกระบวนการทำวิจัย

อาสาสมัครได้รับการตรวจประเมินสาเหตุของความบกพร่องของการทรงตัว โดยใช้แบบประเมินฉบับสั้นที่พัฒนาขึ้นมา ขณะทำการประเมินผู้วิจัยจะทำการบันทึกเป็นภาพวิดีโอเพื่อใช้ในการตรวจสอบความถูกต้องในการแปลผล เมื่อได้ผลการประเมินจากนักกายภาพบำบัดอื่นเรียบร้อยแล้ว ผู้วิจัยคนเดิมจะทำการรักษาทางกายภาพบำบัดตามปัญหาที่เฉพาะเจาะจงของอาสาสมัครแต่ละบุคคล โดยที่ผู้วิจัยจะไม่ทราบผลคะแนนการทรงตัวของผู้ป่วยมาก่อน จากนั้นจะมีการติดตามผลการรักษาในสัปดาห์ที่ 2 และสัปดาห์ที่ 4 หลังจากได้รับการประเมินในครั้งแรก เพื่อประเมินความก้าวหน้าและให้โปรแกรมการรักษาที่ตรงกับปัญหาที่เกิดขึ้น โดยอาสาสมัครจะเป็นผู้ระบุผลของการเปลี่ยนแปลงที่เกิดขึ้นในสัปดาห์ที่ 2 และสัปดาห์ที่ 4

6. ประโยชน์ที่คาดว่าจะเกิดขึ้นจากการทำวิจัย

แบบประเมินฉบับย่อที่พัฒนาขึ้นมา สามารถตรวจประเมินและวิเคราะห์สาเหตุของความบกพร่องในการทรงตัวของอาสาสมัครโดยใช้ระยะเวลาในการตรวจประเมินที่สั้น แต่ได้ข้อมูลที่ละเอียดและครอบคลุมปัญหาการทรงตัว ทำให้สามารถนำไปใช้เป็นแนวทางในการวางแผนการฟื้นฟูความสามารถในการทรงตัวได้อย่างมีประสิทธิภาพและมีความจำเพาะเจาะจงกับปัญหาของอาสาสมัครแต่ละบุคคล ซึ่งก่อให้เกิดประโยชน์สูงสุดต่อการรักษากายภาพบำบัดในผู้ป่วยโรคหลอดเลือดสมองต่อไป

7. สิ่งที่อาสาสมัครจะต้องปฏิบัติและไม่ปฏิบัติระหว่างการศึกษา และระยะเวลาของการวิจัย

อาสาสมัครสามารถปฏิบัติตนได้ตามปกติ

8. ความเสี่ยงหรืออันตรายที่จะเกิดขึ้นและหรือความไม่สะดวกสบายของอาสาสมัครที่อาจได้รับและมาตรการที่ผู้วิจัยเตรียมไว้ป้องกัน

การศึกษาในครั้งนี้ อาจมีความเสี่ยงเกิดขึ้นต่ออาสาสมัคร คือ การล้ม อย่างไรก็ตาม ทางคณะผู้วิจัย ได้มีมาตรการในการป้องกันการล้มที่จะเกิดขึ้น โดยระหว่างการวิจัยจะมีนักกายภาพบำบัดอยู่กับอาสาสมัครทุกครั้ง มีการใส่เข็มขัด เพื่อป้องกันการล้ม รวมทั้งหากอาสาสมัครรู้สึกไม่สบาย มีอาการวิงเวียน หรือมีอาการผิดปกติใด ๆ เกิดขึ้น สามารถขอยุติการวิจัยได้ทันที

9. กรณีเกิดภาวะแทรกซ้อนที่เกี่ยวข้องกับการวิจัยผู้วิจัยจะให้การดูแลรักษาพยาบาลหรือชดเชยอาสาสมัครอย่างไร

หากมีอันตรายใด ๆ เกิดขึ้นกับอาสาสมัคร คณะผู้วิจัยจะดูแลและประสานงานให้อาสาสมัครได้รับการรักษาพยาบาลตามสิทธิของอาสาสมัคร โดยคณะผู้วิจัยจะเป็นผู้รับผิดชอบค่าใช้จ่ายส่วนเกินที่เกิดขึ้นตามสมควร

10. การให้ค่าตอบแทนเป็นเงิน ควรระบุจำนวนและจำนวนครั้งที่ให้อาสาสมัคร

ไม่เกิน 200 บาทต่อการวัด 1 ครั้ง วัดทั้งหมด 2 ครั้ง ที่สัปดาห์ที่ 2 และสัปดาห์ที่ 4

11. การรักษาความลับเกี่ยวกับอาสาสมัคร

ในการวิจัยครั้งนี้ ผู้วิจัยขอสัญญาว่าจะเก็บข้อมูลส่วนตัวของอาสาสมัครเป็นความลับ จะไม่เปิดเผยข้อมูลหรือผลการวิจัยของอาสาสมัครเป็นรายบุคคลต่อสาธารณชน จะเปิดเผยเฉพาะผลสรุปการวิจัยเท่านั้น

12. สิทธิของอาสาสมัครในการถอนตัวออกจากโครงการเมื่อไรก็ได้ โดยไม่กระทบต่อการรักษาพยาบาลของอาสาสมัครที่เป็นผู้ป่วย

ในระหว่างทำการศึกษา อาสาสมัครมีสิทธิที่จะขอยุติการวิจัยได้ในขณะทำการเก็บข้อมูลโดยไม่มีผลกระทบใดๆ ทั้งสิ้นต่อการรักษาพยาบาลของอาสาสมัคร รวมทั้งหากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยจะแจ้งให้อาสาสมัครทราบอย่างรวดเร็วโดยไม่ปิดบัง

13. โครงการวิจัยได้รับความเห็นชอบจากคณะกรรมการจริยธรรมการวิจัยในมนุษย์

จากคณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ โรงพยาบาลนครนายก โรงพยาบาลเลิดสิน และสถาบันประสาทวิทยา

หนังสือให้ความยินยอมเข้าร่วมในโครงการวิจัย

วันที่ ………………………

ข้าพเจ้า…………………………………… อายุ………ปี อยู่บ้านเลขที่ ………..

ถนน………...หมู่ที่………. แขวง/ตำบล……………….เขต/อำเภอ…...………………...................

จังหวัด………................................ โทรศัพท์...

ขอทำหนังสือนี้ให้ไว้ต่อหัวหน้าโครงการวิจัยเพื่อเป็นหลักฐานแสดงว่า

ข้อ 1. ข้าพเจ้า ได้รับทราบโครงการวิจัยของ นางสาวธิติมาศ วินัยรักษ์ เรื่อง "การพัฒนาแบบประเมินทางคลินิกฉบับย่อสำหรับทดสอบสาเหตุความบกพร่องในการทรงตัวสำหรับผู้ป่วยโรคหลอดเลือดสมองระยะหลังเฉียบพลัน"

ข้อ 2. **ข้าพเจ้า ยินยอมเข้าร่วมโครงการวิจัยนี้ ด้วยความสมัครใจ โดยมิได้มีการบังคับขู่เข็ญ หลอกลวงแต่ประการใด และจะให้ความร่วมมือในการวิจัยทุกประการ**

ข้อ 3. ข้าพเจ้า ได้รับการอธิบายจากผู้วิจัยเกี่ยวกับวัตถุประสงค์ของการวิจัย วิธีการวิจัย ประสิทธิภาพ ความปลอดภัย อาการหรืออันตรายที่อาจเกิดขึ้น รวมทั้งแนวทางป้องกันและแก้ไขหากเกิดอันตราย ค่าตอบแทนที่จะได้รับ ค่าใช้จ่ายที่ข้าพเจ้าจะต้องรับผิดชอบจ่ายเอง โดยได้อ่านข้อความที่มีรายละเอียดอยู่ในเอกสารชี้แจงผู้เข้าร่วมโครงการวิจัยโดยตลอด อีกทั้งยังได้รับคำอธิบายและตอบข้อสงสัยจากหัวหน้าโครงการวิจัยเป็นที่เรียบร้อยแล้ว และตกลงรับผิดชอบตามคำรับรองในข้อ 5 ทุกประการ

ข้อ 4. ข้าพเจ้า ได้รับการรับรองจากผู้วิจัยว่าจะเก็บข้อมูลส่วนตัวของข้าพเจ้าเป็นความลับ จะเปิดเผยเฉพาะผลสรุปการวิจัยเท่านั้น

ข้อ 5. ข้าพเจ้า ได้รับทราบจากผู้วิจัยแล้วว่า หากมีอันตรายใด ๆ **อันเกิดขึ้นจากการวิจัยดังกล่าว** ข้าพเจ้าจะได้รับการดูแลและประสานงานให้ได้รับการรักษาพยาบาลตามสิทธิของข้าพเจ้า โดยคณะผู้วิจัยจะเป็นผู้รับผิดชอบค่าใช้จ่ายส่วนเกินที่เกิดขึ้นตามสมควร

ข้อ 6. ข้าพเจ้า ได้รับทราบแล้วว่าข้าพเจ้ามีสิทธิ์จะบอกเลิกการร่วมโครงการวิจัยนี้ และการบอกเลิกการร่วมโครงการวิจัยจะไม่มีผลกระทบต่อการดูแลรักษาโรคที่ข้าพเจ้าจะพึงได้รับต่อไป

ข้อ 7. หากข้าพเจ้ามีข้อข้องใจเกี่ยวกับขั้นตอนของการวิจัย หรือหากเกิดผลข้างเคียงที่ไม่พึงประสงค์จากการวิจัยสามารถติดต่อกับนางสาวธิติมาศ วินัยรักษ์

ที่อยู่ 23/16 ซอยพึ่งมี 50 ถนนสุขุมวิท 93 แขวงบางจาก เขตพระโขนง กทม. 10260

โทรศัพท์ 02-331-5767 โทรศัพท์มือถือ 097-023-8118

ข้อ 8. หากข้าพเจ้า ได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าจะสามารถติดต่อกับประธานคณะกรรมการจริยธรรมสำหรับการพิจารณาโครงการวิจัยที่

ทำในมนุษย์หรือผู้แทน ได้ที่ ดร. ชัชฎา ชินกุลประเสริฐ คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ องครักษ์ จ.นครนายก โทรศัพท์ 085-010-7495, 086-364-7666

ข้าพเจ้าได้อ่านและเข้าใจข้อความตามหนังสือนี้โดยตลอดแล้ว เห็นว่าถูกต้องตามเจตนาของข้าพเจ้า จึงได้ลงลายมือชื่อไว้เป็นสำคัญพร้อมกับหัวหน้าโครงการวิจัยและต่อหน้าพยาน

ลงชื่อ ………………………………….. (…………………………………....) ผู้ยินยอม

ลงชื่อ…………………………………… (นางสาวธิติมาศ วินัยรักษ์) ผู้ให้ข้อมูลและขอความยินยอม/หัวหน้าโครงการวิจัย

ลงชื่อ ……………………………………พยาน (……………………………………)

ลงชื่อ ……………………………พยาน (……………………………………)

ในกรณีที่ผู้เข้าร่วมการวิจัย อ่านหนังสือไม่ออก ผู้ที่อ่านข้อความทั้งหมดแทนผู้เข้าร่วมการวิจัยคือ นางสาวธิติมาศ วินัยรักษ์

จึงได้ลงลายมือชื่อไว้เป็นพยาน

ลงชื่อ …………………………………พยาน (……………………………………)

หมายเหตุ

1. กรณีผู้ยินยอมตนให้ทำวิจัย ไม่สามารถอ่านหนังสือได้ ให้ผู้วิจัยอ่านข้อความในหนังสือให้ความยินยอมนี้ให้แก่ผู้ยินยอมตนให้ทำวิจัยฟังจนเข้าใจแล้ว และให้ผู้ยินยอมตนให้ทำวิจัยลงนามหรือพิมพ์ลายนิ้วหัวแม่มือรับทราบในการให้ความยินยอมดังกล่าวด้วย

APPENDIX D FUGL-MEYER ASSESSMENT: LOWER EXTREMITY MOTOR FUNCTION

Test	Instruction	Score	Scoring criteria
Motor Function- Lower Extremity			
I. Reflex Activity	Achilles Patellar		0-No reflex activity can be elicited 2-Reflex activity can be elicited
II. A. Flexor Synergy (in supine)	Hip flexion Knee flexion Ankle dorsiflexion		0-Cannot be performed at all 1-Partial motion 2-Full motion
II. B. Extensor Synergy (in sidelying)	Hip extension Adduction Knee extension Ankle plantar flexion		0-Cannot be performed at all 1-Partial motion 2-Full motion
III. Movement combining synergies (sitting: knees free of chair)	A. Knee flexion beyond 90° B. Ankle dorsiflexion		0-No active motion 1-From slightly extended position, knee can be flexed, but not beyond 90° 2- Knee flexion beyond 90°
IV. Movement out of synergy (Standing, hip at 0°)	A. Knee flexion		0-Knee cannot flex without hip flexion 1-Knee begins flexion without hip flexion, but does not reach to 90°, or hip flexes during motion 2-Full motion as described
	B. Ankle dorsiflexion		0-No active motion 1-Partial motion 2-Full motion

Fugl-Meyer assessment: lower extremity motor function (continued)

Test	Instruction	Score	Scoring criteria
Motor Function- Lower Extremity			
V. Normal Reflexes (sitting)	Knee flexors, Patellar, Achilles (This item is only tested if the patient achieves a maximum score on all previous LE items. If the person has not achieved a full score to this point, enter 0)		0-At least 2 of the 3 phasic reflexes are markedly hyperactive 1-One reflex is markedly hyperactive, or at least 2 reflexes are lively 2-No more than one reflex is lively and none are hyperactive
VI. Coordination/speed - Sitting: Heel to opposite knee (5 repetitions in rapid succession)	A. Tremor		0-Marked tremor 1-Slight tremor 2-No tremor
	B. Dysmetria		0-Pronounced or unsystematic dysmetria 1-Slight or systematic dysmetria 2- No dysmetria
	C. Speed		0-Activity is more than 6 seconds longer than unaffected side 1-(2-5.9) seconds longer than unaffected side 2-Less than 2 seconds difference
Lower Extremity		Total Maximum = 34	

APPENDIX E THE SCOPE OF DISCUSSION AND RATER EXPLANATION

Scope of discussion

Discussion เฉพาะในประเด็นที่มีความเข้าใจไม่ตรงกัน หรือเกณฑ์การแปลผลการให้คะแนนที่ไม่ตรงกันระหว่าง rater หรือเข้าใจความหมายคลาดเคลื่อนจากสิ่งที่แบบประเมินจะสื่อออกมาจากการแปลเพื่อให้เกิดความเข้าใจที่ตรงกันกับเกณฑ์ที่แท้จริง

Rater explanation for reliability study

1. ผู้ประเมินแต่ละคนจะได้รับ DVD ที่บันทึกการตรวจประเมินด้วยแบบประเมิน BESTest ในผู้ป่วยโรค
หลอดเลือดสมองระยะกึ่งฉับพลันและระยะเรื้อรัง จำนวน 10 และ 20 คน ตามลำดับ
2. ผู้ประเมินจะต้องทำการประเมินความสามารถการทรงตัวในแต่ละ items โดยให้คะแนนตามเกณฑ์การให้คะแนนของแบบประเมิน BESTest โดยผู้ประเมินสามารถดูเกณฑ์การให้คะแนนได้ในขณะที่ทำการประเมิน
3. ในผู้ป่วย 1 คนผู้ประเมินต้องทำการประเมินทั้งหมด 2 รอบโดยรอบที่สองประเมินห่างจากรอบแรกแรก 7 วัน
4. ให้ผู้ประเมินทำการประเมินโดยใช้โปรแกรม windows media player
5. ในการประเมินแต่ละรอบให้ผู้ประเมิน ดู DVD เพียงครั้งเดียวห้ามเล่นซ้ำ แต่สามารถหยุดภาพในระหว่าง item เพื่อให้คะแนนได้
6. ให้ผู้ประเมินใช้นาฬิกาจับเวลาใน item ที่ต้องจับเวลาเพื่อใช้ประกอบการให้คะแนนไม่ควรดูเวลาจากในวีดีโอเพราะอาจมีการคลาดเคลื่อนของเวลาได้
7. กรณีที่มีการทดสอบหลายๆ ครั้งใน 1 item ให้เลือกคะแนนในครั้งที่ดีที่สุดมาให้คะแนน ยกเว้น item 19 ให้เอาเวลาในแต่ละครั้งมาเฉลี่ยเพื่อให้คะแนน
8. ถ้าผู้ป่วยมีเครื่องช่วยเดิน หรือจำเป็นต้องได้รับการช่วยเหลือจากนักกายภาพบำบัด ให้ลดคะแนนใน item นั้นๆ ลง 1 คะแนน
9. หากไม่มีการตรวจใน item ที่ผู้ป่วยน่าจะทำได้ หรือเกิดจากข้อจำกัดอื่นที่ไม่เกี่ยวข้องกับการทรงตัว เช่น ไม่สามารถประเมิน lateral functional reach test ได้เนื่องจาก spastic ของแขน ให้ใส่

NA (not assess) แต่หากไม่มีการประเมินเนื่องจากผู้ทดสอบเห็นว่าไม่ปลอดภัยกับผู้ป่วย จะต้องให้คะแนน item นั้นเท่ากับศูนย์

10. ให้ผู้ประเมินกรอกคะแนนการประเมินลงในแบบฟอร์มที่กำหนดให้ (file excel) 1 sheet ต่อการประเมิน 1 รอบ

11. เมื่อทำการประเมินเรียบร้อยทั้ง 2 รอบให้ส่งแบบกรอกคะแนนมาที่อีเมล์ ttmwnr@hotmail.com

APPENDIX F BALANCE EVALUATION SYSTEM TEST (BESTEST)

Domains/ Items	Score	Scoring criteria
I. Biomechanical constraints		
1. Base of support		(3) Normal: Both feet have normal base of support with no deformities or pain
		(2) One foot has deformities and/or pain
		(1) Both feet has deformities or pain
		(0) Both feet have deformities and pain
2. CoM alignment		(3) Normal AP and ML CoM alignment and normal segmental postural alignment
		(2) Abnormal AP or ML CoM alignment or abnormal segmental postural alignment
		(1) Abnormal AP or ML CoM alignment and abnormal segmental postural alignment
		(0) Abnormal AP and ML CoM alignment
3. Ankle strength &range		(3) Normal: able to stand on toes with maximal height and to stand on heels with front of feet up
		(2) Impairment in either foot of either ankle flexors or extensors (i.e. less than maximum height)
		(1) Impairment in two ankle groups (eg; bilateral flexors or both ankle flexors and extensors in 1 foot)
		(0) Both flexors and extensors in both left and right ankles impaired (i.e. less than maximum height)
4. Hip/trunk lateral strength		(3) Normal: abducts both hips to lift the foot off the floor for 10 s while keeping trunk vertical
		(2) Mild: abducts both hips to lift the foot off the floor for 10 s but without keeping trunk vertical
		(1) Moderate: Abducts only one hip off the floor for 10 s with vertical trunk
		(0) Severe: cannot abduct either hip to lift a foot off the floor for 10 s with trunk vertical or without vertical
5. Sit on floor and stand up		(3) Normal: independently sits on the floor and stands up
		(2) Mild: uses a chair to sit on floor or to stand up
		(1) Moderate: uses a chair to sit on floor and to stand up
		(0) Severe: cannot sit on floor or stand up, even with a chair, or refuses

Balance evaluation system test (continued)

Domains/ Items	Score	Scoring criteria
II. Stability limits		
6. Lateral lean (Lt./Rt.)		(3) Maximum lean, subject moves upper shoulders beyond body midline, very stable
		(2) Moderate lean, subject's upper shoulder approaches body midline or some instability
		(1) Very little lean, or significant instability
		(0) No lean or falls (exceeds limits)
Verticality (Lt./Rt.)		(3) Realigns to vertical with very small or no overshoot
		(2) Significantly over- or undershoots but eventually realigns to vertical
		(1) Failure to realign to vertical
		(0) Falls with the eyes closed
7. Functional reach forward		(3) Maximum to limits: >32 cm (12.5 in)
		(2) Moderate: 16.5 cm - 32 cm (6.5 – 12.5 in)
		(1) Poor: < 16.5 cm (6.5 in)
		(0) No measurable lean – or must be caught
8. Functional reach lateral		(3) Maximum to limit: > 25.5 cm (10 in)
		(2) Moderate: 10-25.5 cm (4-10 in)
		(1) Poor: < 10 cm (4 in)
		(0) No measurable lean, or must be caught
III. Transitions-anticipatory postural adjustment		
9. Sit to stand		(3) Normal: comes to stand without the use of hands and stabilizes independently
		(2) Comes to stand on the first attempt with the use of hands
		(1) Comes to stand after several attempts or requires minimal assist to stand or stabilize or requires touch of back of leg or chair
		(0) Requires moderate or maximal assist to stand
10. Rise to toes		(3) Normal: stable for 3 sec with good height
		(2) Heels up, but not full range (smaller than when holding hands so no balance requirement) -or- slight instability & holds for 3 sec
		(1) Holds for less than 3 sec
		(0) Unable
11. Stand on one leg		(3) Normal: Stable for > 20s
		(2) Trunk motion, or 10-20 s
		(1) Stands 2-10s
		(0) Unable

Balance evaluation system test (continued)

Domains/ Items	Score	Scoring criteria
III. Transitions-anticipatory postural adjustment		
12. Alternate stair touching		(3) Normal: stands independently and safely and completes 8 steps in < 10 seconds
		(2) Completes 8 steps (10-20 seconds) and/or show instability such as inconsistent foot placement, excessive trunk motion, hesitation or arhythmical
		(1) Completes < 8 steps – without minimal assistance (i.e. assistive device) OR > 20 sec for 8 steps
		(0) Completes < 8 steps, even with assistive devise
13. Standing arm raise		(3) Normal: Remains stable
		(2) Visible sway
		(1) Steps to regain equilibrium/unable to move quickly w/o losing balance
		(0) Unable, or needs assistance for stability
IV. Reactive postural response		
14. In place response-forward		(3) Recovers stability with ankles, no added arms or hips motion
		(2) Recovers stability with arm or hip motion
		(1) Takes a step to recover stability
		(0) Would fall if not caught or requires assist or will not attempt
15. In place response-backward		(3) Recovers stability at ankles, no added arm / hip motion
		(2) Recovers stability with some arm or hip motion
		(1) Takes a step to recover stability
		(0) Would fall if not caught -or- requires assistance -or- will not attempt
16. Compensatory stepping correction-forward		(3) Recovers independently a single, large step (second realignment step is allowed)
		(2) More than one step used to recover equilibrium, but recovers stability independently or 1 step with imbalance
		(1) Takes multiple steps to recover equilibrium, or needs minimum assistance to prevent a fall
		(0) No step, or would fall if not caught, or falls spontaneously
17. Compensatory stepping correction-backward		(3) Recovers independently a single, large step
		(2) More than one step used, but stable and recovers independently or 1 step with imbalance
		(1) Takes several steps to recover equilibrium, or needs minimum assistance
		(0) No step, or would fall if not caught, or falls spontaneously

Balance evaluation system test (continued)

Domains/ Items	Score	Scoring criteria
IV. Reactive postural response		
18. Compensatory stepping correction-lateral		(3) Recovers independently with 1 step of normal length/width (crossover or lateral is okay) (2) Several steps used, but recovers independently (1) Steps, but needs to be assisted to prevent a fall (0) Falls, or cannot step
V. Sensory orientation		
19. Sensory integration for balance (modified CTSIB)		
Eye open/firm surface Eye close/firm surface Eye open/foam surface Eye close/foam surface		(3) 30s stable (2) 30s unstable (1) < 30s (0) Unable
20. Incline eyes closed		(3) Stands independently, steady without excessive sway, holds 30 sec, and aligns with gravity (2) Stands independently 30 sec. with greater sway than in item 19B -or- aligns with surface (1) Requires touch assist -or- stands without assist for 10-20 sec. (0) Unable to stand >10 sec. -or- will not attempt independent stance
VI. Stability on gait		
21. Gait-level surface		(3) Normal: walks 20 ft., good speed ($\leq$ 5.5 sec), no evidence of imbalance. (2) Mild: 20 ft., slower speed (>5.5 sec), no evidence of imbalance. (1) Moderate: walks 20 ft., evidence of imbalance (wide-base, lateral trunk motion, inconsistent step path) – at any preferred speed. (0) Severe: cannot walk 20 ft. without assistance, or severe gait deviations OR severe imbalance
22. Change in speed		(3) Normal: significantly changes walking speed without imbalance (2) Mild: unable to change walking speed without imbalance (1) Moderate: changes walking speed but with signs of imbalance, (0) Severe: unable to achieve significant change in speed and signs of imbalance

Balance evaluation system test (continued)

Domains/ Items	Score	Scoring criteria
VI. Stability on gait		
23. Walk with head turns-horizontal		(3) Normal: performs head turns with no change in gait speed and good balance (2) Mild: performs head turns smoothly with reduction in gait speed, (1) Moderate: performs head turns with imbalance (0) Severe: performs head turns with reduced speed and imbalance and/or will not move head within available range while walking.
24. Walk with pivot turns		(3) Normal: turns with feet close, FAST (< 3 steps) with good balance. (2) Mild: turns with feet close SLOW (>4 steps) with good balance (1) Moderate: turns with feet close at any speed with mild signs of imbalance (0) Severe: cannot turn with feet close at any speed and significant imbalance.
25. Step over obstacle		(3) Normal: able to step over 2 stacked shoe boxes without changing speed and with good balance (2) Mild: steps over 2 stacked shoe boxes but slows down, with good balance (1) Moderate: steps over shoe boxes with imbalance or touches box. (0) Severe: cannot step over shoe boxes and slows down with imbalance or cannot perform with assistance.
26. Timed “Get Up & Go”		(3) Normal: fast (<11 sec) with good balance (2) Mild: slow (>11 sec with good balance) (1) Moderate: fast (<11 sec) with imbalance. (0) Severe: slow (>11 sec) and imbalance.
27. Timed “Get Up & Go” with dual task		(3) Normal: no noticeable change between sitting and standing in the rate or accuracy of backwards counting and no change in gait speed. (2) Mild: noticeable slowing, hesitation or errors in counting backwards or slow walking (10%) in dual task (1) Moderate: affects on both the cognitive task and slow walking (>10%) in dual task. (0) Severe: cannot count backward while walking or stops walking while talking
Total scores		Maximum 108 points

APPENDIX G BRIEF-BESTEST

General Note: "instability" is defined as using more than an ankle strategy to maintain balance (e.g., a hip strategy is employed).

Domains/ Items	Score	Scoring criteria
I. Biomechanical constraints		
1. Hip/trunk lateral strength "Rest fingertips in my hands while you lift your leg to the side & hold, keep trunk vertical. You will hold for 10 sec" Count 10 sec, watch for straight knee, if they use moderate force on your hands score as "w/o keeping trunk vertical"		(3) Normal: abducts both hips to lift the foot off the floor for 10 s while keeping trunk vertical (2) Mild: abducts both hips to lift the foot off the floor for 10 s but without keeping trunk vertical (1) Moderate: Abducts only one hip off the floor for 10 s with vertical trunk (0) Severe: cannot abduct either hip to lift a foot off the floor for 10 s with trunk vertical or without vertical
II. Stability limits		
2. Functional reach forward "Stand normally; lift both arms straight in front of you; reach as far forward as you can with arms parallel to the ruler w/o lifting your heels." 2 attempts Observe that subject does not lift heels, rotate trunk, or protract scapula. Watch for vertical initial alignment. Record best reach.		(3) Maximum to limits: >32 cm (12.5 in) (2) Moderate: 16.5 cm - 32 cm (6.5 – 12.5 in) (1) Poor: < 16.5 cm (6.5 in) (0) No measurable lean – or must be caught trial 1 (cm or in) trial 2 (cm or in)

Brief-BESTest (continued)

Domains/ Items	Score	Scoring criteria
III. Transitions-anticipatory postural adjustment		
3. Stand on one leg "Look ahead; hands must stay on hips; bend one leg behind you; stand on one leg as long as you can up to 30 sec. Don't let your lifted leg touch the other leg." Allow 2 attempts, record best; rec time up to 30 sec(stop time if hands off hips or leg on floor or leg touches supporting leg)		(3) Normal: Stable for > 20s (2) Trunk motion, or 10-20 s (1) Stands 2-10s (0) Unable Left (sec) Right (sec)
IV. Reactive postural response		
4. Compensatory stepping correction-lateral "Stand w/feet nearly together; lean into my hands, I will remove my hands, do whatever necessary to keep balance, trying to take 1 step." Note: Stand next to and behind participant. Place hand on greater trochanter and brace yourself to hold the person's weight shifted to supported leg.		(3) Recovers independently with 1 step of normal length/width (crossover or lateral is okay) (2) Several steps used, but recovers independently (1) Steps, but needs to be assisted to prevent a fall (0) Falls, or cannot step Left Right

Brief-BESTest (continued)

Domains/ Items	Score	Scoring criteria
V. Sensory orientation		
5. Sensory integration for balance (modified CTSIB) - Eye close/foam surface "stand on foam with your eyes closed, your hands on your hips, & your feet close but not touching. Start by looking straight ahead & I will start timing when you close your eyes. Stay as stable as possible and try to keep your eyes closed for the entire time. The goal is 30 sec." Two trials, if necessary. Subject must step off foam between trials.		(3) 30s stable (2) 30s unstable (1) < 30s (0) Unable trial 1 (sec) trial 2 (sec)
VI. Stability on gait		
6. Timed "Get Up & Go" "When I say "go" stand up & walk quickly but safely to the tape, turn, walk back & sit in chair." Start w/back against chair, stop timing when buttocks hit the chair; chair should have arms to push from if necessary. Imbalance might include trips or lateral/backward stumbles or cross-overs.		(3) Normal: fast (<11 sec) with good balance (2) Mild: slow (>11 sec with good balance) (1) Moderate: fast (<11 sec) with imbalance. (0) Severe: slow (>11 sec) and imbalance.
Total scores		Maximum 24 points

APPENDIX H BERG BALANCE SCALE (BBS)

Test	Instruction	Score	Scoring criteria
1. Sitting to standing	Please stand up. Try not to use your hand for support.		(4) able to stand without using hands and stabilize independently (3) able to stand independently using hands (2) able to stand using hands after several tries (1) needs minimal aid to stand or stabilize (0) needs moderate or maximal assist
2. Standing unsupported	Please stand for two minutes without holding on.		(4) able to stand safely for 2 minutes (3) able to stand 2 minutes with supervision (2) able to stand 30 seconds unsupported (1) needs several tries to stand 30 seconds unsupported (0) unable to stand 30 seconds unsupported to stand
3. Sitting unsupported	Please sit with arms folded for 2 minutes.		(4) able to sit safely and securely for 2 minutes (3) able to sit 2 minutes under supervision (2) able to able to sit 30 seconds (1) able to sit 10 seconds (0) unable to sit without support 10 seconds
4. Standing to sitting	Please sit down.		(4) sits safely with minimal use of hands (3) controls descent by using hands (2) uses back of legs against chair to control descent (1) sits independently but has uncontrolled descent (0) needs assist to sit
5. Transfers	You may use two chairs (one with and one without armrests) or a bed and a chair.		(4) able to transfer safely with minor use of hands (3) able to transfer safely definite need of hands (2) able to transfer with verbal cuing and/or supervision (1) needs one person to assist (0) needs two people to assist or supervise to be safe

Berg balance scale (continued)

Test	Instruction	Score	Scoring criteria
6. Standing with eyes closed	Please close your eyes and stand still for 10 seconds.		(4) able to stand 10 seconds safely (3) able to stand 10 seconds with supervision (2) able to stand 3 seconds (1) unable to keep eyes closed 3 seconds but stays safely (0) needs help to keep from falling
7. Standing with feet together	Place your feet together and stand without holding on.		(4) able to place feet together independently and stand 1 minute safely (3) able to place feet together independently and stand 1 minute with supervision (2) able to place feet together independently but unable to hold for 30 seconds (1) needs help to attain position but able to stand 15 seconds feet together (0) needs help to attain position and unable to hold for 15 seconds
8. Reaching forward with outstretched arm	Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position.		(4) can reach forward confidently 25 cm (10 inches) (3) can reach forward 12 cm (5 inches) (2) can reach forward 5 cm (2 inches) (1) reaches forward but needs supervision (0) loses balance while trying/requires external support

Berg balance scale (continued)

Test	Instruction	Score	Scoring criteria
9. Retrieving object from floor	Pick up the shoe/slipper, which is place in front of your feet		(4) able to pick up slipper safely and easily (3) able to pick up slipper but needs supervision (2) unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently (1) unable to pick up and needs supervision while trying (0) unable to try/needs assist to keep from losing balance or falling
10. Turning to look behind	Turn to look directly behind you over toward the left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.		(4) looks behind from both sides and weight shifts well (3) looks behind one side only other side shows less weight shift (2) turns sideways only but maintains balance (1) needs supervision when turning (0) needs assist to keep from losing balance or falling
11. Turning 360 degrees	Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.		(4) able to turn 360 degrees safely in 4 seconds or less (3) able to turn 360 degrees safely one side only 4 seconds or less (2) able to turn 360 degrees safely but slowly (1) needs close supervision or verbal cuing (0) needs assistance while turning
12. Placing alternate foot on stool	Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.		(4) able to stand independently and safely and complete 8 steps in 20 seconds (3) able to stand independently and complete 8 steps in > 20 seconds (2) able to complete 4 steps without aid with supervision (1) able to complete > 2 steps needs minimal assist (0) needs assistance to keep from falling/unable to try

Berg balance scale (continued)

Test	Instruction	Score	Scoring criteria
13. Standing with one foot in front	An examiner demonstrates to a subject. Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot.		(4) able to place foot tandem independently and hold 30 seconds (3) able to place foot ahead independently and hold 30 seconds (2) able to take small step independently and hold 30 seconds (1) needs help to step but can hold 15 seconds (0) loses balance while stepping or standing
14. Standing on one foot	Stand on one leg as long as you can without holding on.		(4) able to lift leg independently and hold > 10 seconds (3) able to lift leg independently and hold 5-10 seconds (2) able to lift leg independently and hold ≥ 3 seconds (1) tries to lift leg unable to hold 3 seconds but remains standing independently. (0) unable to try of needs assist to prevent fall
Total score	Maximum score = 56		

APPENDIX I STROKE REHABILITATION ASSESSMENT OF MOVEMENT (STREAM)[171]

STREAM SCORING

I. VOLUNTARY MOVEMENT OF THE LIMBS

0 **unable** to perform the test movement through any appreciable range (includes flicker or slight movement)
1 **a.** able to perform only **part** of the movement, and with **marked deviation** from normal pattern
b. able to perform only **part** of the movement, but in a manner that is **comparable to the unaffected side**
c. able to **complete** the movement, but only with **marked deviation** from normal pattern
2 able to **complete** the movement in a manner that is **comparable to the unaffected side**
X *activity not tested (specify why:* **ROM**, Pain, Other **(reason)***)*

II. BASIC MOBILITY

0 **unable** to perform the test activity through any appreciable range (ie, minimal active participation)
1 **a.** able to perform only **part** of the activity independently (requires partial assistance or stabilization to complete), with or without an aid, and with **marked deviation** from normal pattern
b. able to perform only **part** of the activity independently (requires partial assistance or stabilization to complete), with or without an aid, but with a grossly **normal** movement pattern
c. able to **complete** the activity independently, with or without an aid, but only with **marked deviation** from normal pattern
2 able to **complete** the activity independently with a grossly **normal** movement pattern, but **requires an aid**
3 able to **complete** the activity independently with a grossly **normal** movement pattern, **without an aid**
X *activity not tested (specify why:* **ROM**, Pain, Other **(reason)***)*

		AMPLITUDE OF ACTIVE MOVEMENT		
		None	**Partial**	**Complete**
MOVEMENT QUALITY	**Marked Deviation**	**0**	**1 a**	**1 c**
	Grossly Normal	**0**	**1 b**	**2 (3)**

Stroke rehabilitation assessment of movement (continued)

4	3	2	1		SCORE
				/2	**SUPINE** 1. PROTRACTS SCAPULA IN SUPINE *"Lift your shoulder blade so that your hand moves towards the ceiling"* **Note:** therapist stabilizes arm with shoulder 90° flexed and elbow extended.
				/2	2. EXTENDS ELBOW IN SUPINE (starting with elbow fully flexed) *"Lift your hand towards the ceiling, straightening your elbow as much as you can"* **Note:** therapist stabilizes arm with shoulder 90° flexed; strong associated shoulder extension and/or abduction=marked deviation (score 1a or 1c).
				/2	3. FLEXES HIP AND KNEE IN SUPINE (attains half crook lying) *"Bend your hip and knee so that your foot rests flat on the bed"*
				/3	4. ROLLS ONTO SIDE (starting from supine) *"Roll onto your side"* **Note:** may roll onto <u>either</u> side; pulling with arms to turn over=aid (score 2).
				/3	5. RAISES HIPS OFF BED IN CROOK LYING (BRIDGING) *"Lift your hips as high as you can"* **Note:** therapist may stabilize foot, but if knee pushes strongly into extension with bridging=marked deviation (score 1a or 1c); if requires aid (external or from therapist) to maintain knees in midline=aid (score 2).
				/3	6. MOVES FROM LYING SUPINE TO SITTING (with feet on the floor) *"Sit up and place your feet on the floor"* **Note:** may sit up to <u>either</u> side using any functional and safe method; longer than 20 seconds=marked deviation (score 1a or 1c); pulling up using bedrail or edge of plinth=aid (score 2).
				/2	**SITTING** **(feet supported; hands resting on pillow on lap for items 7-14)** 7. SHRUGS SHOULDERS (SCAPULAR ELEVATION) *"Shrug your shoulders as high as you can"* **Note:** both shoulders are shrugged simultaneously.
				/2	8. RAISES HAND TO TOUCH TOP OF HEAD *"Raise your hand to touch the top of your head"*
				/2	9. PLACES HAND ON SACRUM *"Reach behind your back and as far across toward the other side as you can"*
				/2	10. RAISES ARM OVERHEAD TO FULLEST ELEVATION *"Reach your hand as high as you can towards the ceiling"*

Stroke rehabilitation assessment of movement (continued)

SCORE 4	3	2	1		
				/2	11. SUPINATES AND PRONATES FOREARM (elbow flexed at 90°) *"Keeping your elbow bent and close to your side, turn your forearm over so that your palm faces up, then turn your forearm over so that your palm faces down"* **Note:** movement in one direction only=partial movement (score 1a or 1b).
				/2	12. CLOSES HAND FROM FULLY OPENED POSITION *"Make a fist, keeping your thumb on the outside"* **Note:** must extend wrist slightly (ie, wrist cocked) to obtain full marks; full fist with lack of wrist extention=partial movement (score 1a or 1b).
				/2	13. OPENS HAND FROM FULLY CLOSED POSITION *"Now open your hand all the way"*
				/2	14. OPPOSES THUMB TO INDEX FINGER (tip to tip) *"Make a circle with your thumb and index finger"*
				/2	15. FLEXES HIP IN SITTING *"Lift your knee as high as you can"*
				/2	16. EXTENDS KNEE IN SITTING *"Straighten your knee by lifting your foot up"*
				/2	17. FLEXES KNEE IN SITTING *"Slide your foot back under you as far as you can"* **Note:** start with affected foot forward (heel in line with toes of other foot).
				/2	18. DORSIFLEXES ANKLE IN SITTING *"Keep your heel on the ground and lift your toes off the floor as far as you can"* **Note:** affected foot is placed slightly forward (heel in line with toes of other foot).
				/2	19. PLANTAR FLEXES ANKLE IN SITTING *"Keep your toes on the ground and lift your heel off the floor as far as you can"*
				/2	20. EXTENDS KNEE AND DORSIFLEXES ANKLE IN SITTING *"Straighten your knee and bring your toes towards you"* **Note:** extension of knee without dorsiflexion of ankle=partial movement (score 1a or 1b).
				/3	21. RISES TO STANDING FROM SITTING *"Stand up; try to take equal weight on both legs"* **Note:** pushing up with hand(s) to stand=aid (score 2); asymmetry such as trunk lean, Trendelenburg position, hip retraction, or excessive flexion or extension of the affected knee=marked deviation (score 1a or 1c).

Stroke rehabilitation assessment of movement (continued)

SCORE 4	3	2	1		
					STANDING
				/3	22. MAINTAINS STANDING FOR 20 COUNTS *"Stand on the spot while I count to twenty"*
					STANDING (holding onto a stable support to assist balance for items 23-25)
				/2	23. ABDUCTS AFFECTED HIP WITH KNEE EXTENDED *"Keep your knee straight and your hips level, and raise your leg to the side"*
				/2	24. FLEXES AFFECTED KNEE WITH HIP EXTENDED *"Keep your hip straight, bend your knee back and bring your heel towards your bottom"*
				/2	25. DORSIFLEXES AFFECTED ANKLE WITH KNEE EXTENDED *"Keep your heel on the ground and lift your toes off the floor as far as you can"* **Note:** affected foot is placed slightly forward in position of a small step (heel in line with toes of other foot).
					STANDING AND WALKING ACTIVITIES
				/3	26. PLACES AFFECTED FOOT ONTO FIRST STEP (or stool 18=cm high) *"Lift your foot and place it onto the first step (or stool) in front of you"* **Note:** returning the foot to the ground is not scored; use of handrail =aid (score 2).
				/3	27. TAKES 3 STEPS BACKWARDS (one and a half gait cycles) *"Take three average sized steps backwards, placing one foot behind the other"*
				/3	28. TAKES 3 STEPS SIDEWAYS TO AFFECTED SIDE *"Take three average sized steps sideways towards your weak side"*
				/3	29. WALKS 10 METERS INDOORS (on smooth, obstacle-free surface) *"Walk in a straight line over to ... (a specified point 10 meters away)"* **Note:** orthotic=aid (score 2); longer than 20 seconds=marked deviation (score 1c).
				/3	30. WALKS DOWN 3 STAIRS ALTERNATING FEET *"Walk down three stairs; place only one foot at a time on each step if you can"* **Note:** handrail=aid (score 2); non-alternating feet=marked deviation (score 1a or 1c).

[a]The STREAM scoring form and criteria are presented verbatim. CVA=cerebrovascular accident, ROM=range of motion.

APPENDIX J 15-POINT GLOBAL RATING OF CHANGE (GRC) SCALE

แบบประเมินระดับการเปลี่ยนแปลงนี้ช่วยให้สามารถตรวจสอบผลโดยรวมของการรักษาทางกายภาพบำบัด ซึ่งแบบประเมินนี้มีความน่าเชื่อถือและใช้อย่างกว้างขวางในการวิจัย ใช้เป็นผลตัวชี้วัดเพื่อเปรียบเทียบผลของก่อนและหลังการรักษาทางกายภาพบำบัด

โปรดประเมินสภาพโดยรวมของร่างกายที่ได้รับการรักษาทางกายภาพบำบัดจากเวลาที่คุณเริ่มการรักษาจนถึงขณะนี้ โดยทำเครื่องหมาย ☑ ให้ตรงกับระดับการเปลี่ยนแปลงที่คุณรู้สึกเพียงช่องเดียว

☐ ดีขึ้นมากที่สุด	(7) A very great deal better
☐ ดีขึ้นมากๆ	(6) A great deal better
☐ ดีขึ้นมาก	(5) A good deal better
☐ ดีขึ้นในระดับปานกลาง	(4) Moderately better
☐ ค่อนข้างดีขึ้น	(3) Somewhat better
☐ ดีขึ้นเล็กน้อย	(2) A little better
☐เกือบจะไม่มีการเปลี่ยนแปลงแทบจะไม่ได้แย่ลง	(1)Almost the same,hardly any better at all
☐ ไม่มีการเปลี่ยนแปลง	(0) No change
☐ เกือบจะไม่มีการเปลี่ยนแปลง แทบจะไม่ได้ดีขึ้น	(-1) Almost the same, hardly any worse
☐ แย่ลงเล็กน้อย	(-2) A little worse
☐ ค่อนข้างแย่ลง	(-3) Somewhat worse
☐ แย่ลงในระดับปานกลาง	(-4) Moderately worse
☐ แย่ลงมาก	(-5) A good deal worse
☐ แย่ลงมาก ๆ	(-6) A great deal worse
☐ แย่ลงมากที่สุด	(-7) A very great deal worse

APPENDIX K BALANCE ASSESSMENT FORM FOR VALIDITY AND RESPONSIVENESS STUDY

Balance test in sitting position				
Item	Test	Score		Scoring criteria
		Pre	Post	
Sitting without support (sitting on the edge of an 50-cm-high examination table [a Bobath plane, for instance] with the feet touching the floor)	BBS			4-able to sit safely and securely for 2 minutes 3-able to sit 2 minutes under supervision 2-able to able to sit 30 seconds 1-able to sit 10 seconds 0-unable to sit without support 10 seconds
Verticality left	BEST			(3) Maximum lean, subject moves upper shoulders beyond body midline, very stable (2) Moderate lean, subject's upper shoulder approaches body midline or some instability (1) Very little lean, or significant instability (0) No lean or falls (exceeds limits)
Verticality right				
Lateral lean left	BEST			(3) Realigns to vertical with very SMALL or no OVERSHOOT (2) Significantly Over- or undershoots but eventually realigns to vertical (1) Failure to realign to vertical (0) Falls with the eyes closed
Lateral lean right				
Transfers You may use two chairs (one with and one without armrests) or a bed and a chair.	BBS			4-able to transfer safely with minor use of hands 3-able to transfer safely definite need of hands 2-able to transfer with verbal cuing and/or supervision 1-needs one person to assist 0-needs two people to assist or supervise to be safe

Balance assessment form for validity and responsiveness study (continued)

Balance test in sitting position				
Item	Test	Score		Scoring criteria
		Pre	Post	
Sitting to standing up	BBS			4- able to stand without using hands and stabilize independently 3-able to stand independently using hands 2-able to stand using hands after several tries 1-needs minimal aid to stand or stabilize 0-needs moderate or maximal assist to stand
	BEST			(3) Normal: Comes to stand without the use of hands and stabilizes independently (2) Comes to stand on the first attempt with the use of hands (1) Comes to stand after several attempts or requires minimal assist to stand or stabilize or requires touch of back of leg or chair (0) Requires moderate or maximal assist to stand
Balance test in standing				
Standing without support (feet position free, no other constraints) < 30 s	BBS			4-able to stand safely for 2 minutes 3-able to stand 2 minutes with supervision 2-able to stand 30 seconds unsupported 1-needs several tries to stand 30 seconds unsupported 0-unable to stand 30 seconds unsupported
	BEST			(3) 30s stable (2) 30s unstable (1) < 30s (0) Unable
Base of support	BEST			(3) Normal: Both feet have normal base of support with no deformities or pain (2) One foot has deformities and/or pain (1) Both feet has deformities OR pain (0) Both feet have deformities AND pain

Balance assessment form for validity and responsiveness study (continued)

Balance test in standing				
Item	Test	Score		Scoring criteria
		Pre	Post	
CoM alignment	BEST			(3) Normal AP and ML CoM alignment and normal segmental postural alignment (2) Abnormal AP OR ML CoM alignment OR abnormal segmental postural alignment (1) Abnormal AP OR ML CoM alignment AND abnormal segmental postural alignment (0) Abnormal AP AND ML CoM alignment
Ankle strength &range	BEST			(3) Normal: Able to stand on toes with maximal height and to stand on heels with front of feet up (2) Impairment in either foot of either ankle flexors or extensors (i.e. less than maximum height) (1) Impairment in two ankle groups (eg; bilateral flexors or both ankle flexors and extensors in 1 foot) (0) Both flexors and extensors in both left and right ankles impaired (i.e. less than maximum height)
Hip/trunk lateral strength	BEST			(3) Normal: Abducts both hips to lift the foot off the floor for 10 s while keeping trunk vertical (2) Mild: Abducts both hips to lift the foot off the floor for 10 s but without keeping trunk vertical (1) Moderate: Abducts only one hip off the floor for 10 s with vertical trunk (0) Severe: Cannot abduct either hip to lift a foot off the floor for 10 s with trunk vertical or without vertical
Standing to sitting	BBS			4-sit safely with minimal use of hand 3-controls decent by using hands 2-use back of legs againts chair to control descent 1-sits independently but has uncontrolled descent 0-needs assist to sit

Balance assessment form for validity and responsiveness study (continued)

Balance test in standing				
Item	Test	Score		Scoring criteria
		Pre	Post	
Sit on floor and stand up	BEST			(3) Normal: Independently sits on the floor and stands up (2) Mild: Uses a chair to sit on floor OR to stand up (1) Moderate: Uses a chair to sit on floor AND to stand up (0) Severe: Cannot sit on floor or stand up, even with a chair, or refuses
Standing with eyes closed < 30s	BBS			4-able to stand 10 seconds safely 3-able to stand 10 seconds with supervision 2-able to stand 3 seconds 1-unable to keep eyes closed 3 seconds but stays safely 0-needs help to keep from falling
	BEST			(3) 30s stable (2) 30s unstable (1) < 30s (0) Unable
Standing with feet together	BBS			4-able to place feet together independently and stand 1 minute safely 3-able to place feet together independently and stand 1 minute with supervision 2-able to place feet together independently but unable to hold for 30 seconds 1-needs help to attain position but able to stand 15 seconds feet together 0-needs help to attain position and unable to hold for 15 seconds

Balance assessment form for validity and responsiveness study (continued)

Balance test in standing				
Item	Test	Score		Scoring criteria
		Pre	Post	
Eye open/foam surface Trial 1 ______sec, 2______sec	BEST			(3) 30s stable (2) 30s unstable (1) < 30s (0) Unable
Eye close/foam surface Trial 1______sec, 2______sec	BEST			
Incline eyes closed	BEST			(3) Stands independently, steady without excessive sway, holds 30 sec, and aligns with gravity (2) Stands independently 30 SEC with greater sway than in item 19B -OR- aligns with surface (1) Requires touch assist -OR- stands without assist for 10-20 sec (0) Unable to stand >10 sec -OR- will not attempt independent stance
Reaching forward with outstretched arm	BBS			4-can reach forward confidently 25 cm (10 inches) 3-can reach forward 12 cm (5 inches) 2-can reach forward 5 cm (2 inches) 1-reaches forward but needs supervision 0-loses balance while trying/requires external support
Reaching forward with outstretched arm	BEST			(3) Maximum to limits: >32 cm (12.5 in) (2) Moderate: 16.5 cm - 32 cm (6.5 – 12.5 in) (1) Poor: < 16.5 cm (6.5 in) (0) No measurable lean – or must be caught
Functional reach lateral left	BEST			(3) Maximum to limit: > 25.5 cm (10 in) (2) Moderate: 10-25.5 cm (4-10 in) (1) Poor: < 10 cm (4 in) (0) No measurable lean, or must be caught
Functional reach lateral right				

Balance assessment form for validity and responsiveness study (continued)

Balance test in standing				
Item	Test	Score		Scoring criteria
		Pre	Post	
Standing arm raise	BEST			(3) Normal: Remains stable (2) Visible sway (1) Steps to regain equilibrium/unable to move quickly w/o losing balance (0) Unable, or needs assistance for stability
Rise to toes	BEST			(3) Normal: Stable for 3 sec with good height (2) Heels up, but not full range (smaller than when holding hands so no balance requirement) -OR- slight instability & holds for 3 sec (1) Holds for less than 3 sec (0) Unable
Standing, picking up a pencil from the floor Acknowledgments	BBS			4-able to pick up slipper safely and easily 3-able to pick up slipper but needs supervision 2-unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently 1-unable to pick up and needs supervision while trying 0-unable to try/needs assist to keep from losing balance or falling
Turning to look behind	BBS			4-looks behind from both sides and weight shifts well 3-looks behind one side only other side shows less weight shift 2-turns sideways only but maintains balance 1-needs supervision when turning 0-needs assist to keep from losing balance or falling
Turning 360 degrees	BBS			4-able to turn 360 degrees safely in 4 seconds or less 3-able to turn 360 degrees safely one side only 4 seconds or less 2-able to turn 360 degrees safely but slowly 1-needs close supervision or verbal cuing 0-needs assistance while turning

Balance assessment form for validity and responsiveness study (continued)

Balance test in standing				
Item	Test	Score		Scoring criteria
		Pre	Post	
Placing alternate foot on stool	BBS			4-able to stand independently and safely and complete 8 steps in 20 seconds 3-able to stand independently and complete 8 steps in > 20 seconds 2-able to complete 4 steps without aid with supervision 1-able to complete > 2 steps needs minimal assist 0-needs assistance to keep from falling/unable to try
	BEST			(3) Normal: Stands independently and safely and completes 8 steps in < 10 seconds (2) Completes 8 steps (10-20 seconds) AND/OR show instability such as inconsistent foot placement, excessive trunk motion, hesitation or arhythmical (1) Completes < 8 steps – without minimal assistance (i.e. assistive device) OR > 20 sec for 8 steps (0) Completes < 8 steps, even with assistive devise
Standing with one foot in front	BBS			4-able to place foot tandem independently and hold 30 seconds 3-able to place foot ahead independently and hold 30 seconds 2-able to take small step independently and hold 30 seconds 1-needs help to step but can hold 15 seconds 0-loses balance while stepping or standing
Standing on nonparetic leg (no other constraints)	BBS			4-able to lift leg independently and hold > 10 seconds 3-able to lift leg independently and hold 5-10 seconds 2-able to lift leg independently and hold ≥ 3 seconds 1-tries to lift leg unable to hold 3 seconds but remains standing independently. 0-unable to try of needs assist to prevent fall
	BEST			(3) Normal: Stable for > 20s (2) Trunk motion, OR 10-20 s (1) Stands 2-10s (0) Unable

Balance assessment form for validity and responsiveness study (continued)

Balance test in walking				
Item	Test	Score		Scoring criteria
		Pre	Post	
Standing on paretic leg (no other constraints)	BEST			(3) Normal: Stable for > 20s (2) Trunk motion, OR 10-20 s (1) Stands 2-10s (0) Unable
Gait-level surface *Time______secs*	BEST			(3) Normal: walks 20 ft., good speed (≤ 5.5 sec), no evidence of imbalance. (2) Mild: 20 ft., slower speed (>5.5 sec), no evidence of imbalance. (1) Moderate: walks 20 ft., evidence of imbalance (wide-base, lateral trunk motion, inconsistent step path) – at any preferred speed. (0) Severe: cannot walk 20 ft. without assistance, or severe gait deviations OR severe imbalance
Change in speed	BEST			(3) Normal: Significantly changes walking speed without imbalance (2) Mild: Unable to change walking speed without imbalance (1) Moderate: Changes walking speed but with signs of imbalance, (0) Severe: Unable to achieve significant change in speed AND signs of imbalance
Walk with head turns-horizontal	BEST			(3) Normal: performs head turns with no change in gait speed and good balance (2) Mild: performs head turns smoothly with reduction in gait speed, (1) Moderate: performs head turns with imbalance (0) Severe: performs head turns with reduced speed AND imbalance AND/OR will not move head within available range while walking.

Balance test in walking				
Item	Test	Score		Scoring criteria
		Pre	Post	
Walk with pivot turns	BEST			(3) Normal: Turns with feet close, FAST (< 3 steps) with good balance. (2) Mild: Turns with feet close SLOW (>4 steps) with good balance (1) Moderate: Turns with feet close at any speed with mild signs of imbalance (0) Severe: Cannot turn with feet close at any speed and significant imbalance.
Step over obstacle *Time______sec.*	BEST			(3) Normal: able to step over 2 stacked shoe boxes without changing speed and with good balance (2) Mild: steps over 2 stacked shoe boxes but slows down, with good balance (1) Moderate: steps over shoe boxes with imbalance or touches box. (0) Severe: cannot step over shoe boxes AND slows down with imbalance or cannot perform with assistance.
Timed "Get Up & Go" *Time______sec*	BBEST			(3) Normal: Fast (<11 sec) with good balance (2) Mild: Slow (>11 sec with good balance) (1) Moderate: Fast (<11 sec) with imbalance. (0) Severe: Slow (>11 sec) AND imbalance.
Timed "Get Up & Go" with dual task	BBEST			(3) Normal: No noticeable change between sitting and standing in the rate or accuracy of backwards counting and no change in gait speed. (2) Mild: Noticeable slowing, hesitation or errors in counting backwards OR slow walking (10%) in dual task (1) Moderate: Affects on BOTH the cognitive task AND slow walking (>10%) in dual task. (0) Severe: Can't count backward while walking or stops walking while talking

APPENDIX L PUBLICATION

VITA

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