RELIABILITY AND VALIDITY OF THE BALANCE EVALUATION SYSTEMS TEST (BESTest) IN PERSONS WITH STROKE

A THESIS

BY

BUTSARA CHINSONGKRAM

Presented in Partial Fulfillment of the Requirements for the

Doctor of Philosophy Degree in Physical Therapy

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The Balance Evaluation Systems Test (BESTest) is new clinical balance assessment tool but it has never been validated in patients with subacute stroke. Therefore, this study aims to examine the reliability, validity, and responsiveness of the BESTest in patients with stroke. Method: Twelve patients participated in the interrater and intrarater reliability study. The convergent validity was studied in seventy patients using the Berg Balance Scale (BBS), Postural Assessment Scale for Stroke Patients (PASS), Community Balance and Mobility Scale (CB&M) and as the references. The Receiver Operating Characteristics (ROC) curve was used to calculate the sensitivity, specificity and accuracy of the scale in classifying patients into low (LFA) and high functional ability level (HFA) based on the Fugl-Meyer Assessment motor subscale. Fifty remaining participants completed all balance measures again after the rehabilitation program for investigate responsiveness. Internal responsiveness was classified using the standardized response mean (SRM), whereas external responsiveness of the BESTest was quantified by the ROC curve approach that used to calculate the sensitivity, specificity and accuracy of the BESTest in identifying patients with no balance change and with balance change based on the BBS score change < 7 and higher. Results: The BESTest showed excellent intrarater reliability and interrater reliability (ICC = 0.99) and was highly correlated with the BBS (Spearman Rank r=0.96), PASS (r=0.96), CB&M (r=0.91) indicating excellent convergent validity. In addition, the BESTest showed high accuracy as the BBS in separating patients into HFA and LFA group. The internal responsiveness of all balance measures was high (SRM from 1.1 -1.2). The BESTest showed high, sensitivity and specificity in identifying patients who have balance change after receiving rehabilitation. The best change scores that indicate balance change was 10 point for the BESTest. The BESTest is a balance measure that is reliable, valid and sensitive to change in persons with subacute stroke throughout different levels of functional ability.

การทดสอบความเที่ยงและความตรงของแบบประเมิน Balance Evaluation Systems Test (BESTest) ในผู้ป่วยโรคหลอดเลือดสมอง

บทคัดย่อ

โดย

บุศรา ชินสงคราม

เสนอต่อบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ เพื่อเป็นส่วนหนึ่งของการศึกษาตาม
หลักสูตรปรัชญาดุษฎีบัณฑิต สาขาวิชากายภาพบำบัด
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แบบประเมิน Balance Evaluation Systems Test (BESTest) เป็นแบบประเมินใหม่ที่ยังไม่เคยมีการศึกษาเกี่ยวกับคุณสมบัติของแบบประเมินในการประเมินการทรงตัวในผู้ป่วยโรคหลอดเลือดสมองมาก่อน ดังนั้นวัตถุประสงค์ของการศึกษานี้คือหาความเที่ยง ความตรง และความไวในการวัดการเปลี่ยนแปลงของแบบประเมิน BESTest ในผู้ป่วยโรคหลอดเลือดสมอง การหาความเที่ยงภายในผู้วัดและระหว่างผู้วัดศึกษาในผู้ป่วยจำนวน 12 ราย การหาความตรงศึกษาในผู้ป่วยจำนวน 70 รายโดยการหาความสัมพันธ์ของคะแนนจากแบบประเมิน BESTest กับแบบประเมินมาตรฐานที่นิยมใช้ในทางคลินิก ประกอบด้วยแบบประเมิน Berg Balance Scale (BBS) แบบประเมิน Postural Assessment Scale for Stroke Patients (PASS) และแบบประเมิน Community Balance and Mobility Scale (CB&M) ใช้สถิติสหสัมพันธ์สเปียแมนแรงค์ (Spearman Rank order correlation) และใช้สถิติ Receiver Operating Characteristics (ROC) curve ในการประเมินความสามารถของแบบประเมิน BESTest ในการจำแนกผู้ป่วยที่มีระดับความสามารถในการทำกิจกรรมต่ำ (คะแนน Fugl-Meyer Assessment motor (FM-motor) $\leq$ 55) และสูง (FM-motor > 55) และการหาความไวในการวัดการเปลี่ยนแปลงศึกษาในผู้ป่วยจำนวน 50 คน หลังได้รับการฟื้นฟูทางกายภาพบำบัด ความไวในการวัดการเปลี่ยนแปลงหาจากค่า standardized response mean (SRM) และหาจากการเปรียบเทียบคะแนนของแบบประเมิน BESTest ที่เปลี่ยนแปลงหลังการฟื้นฟูกับคะแนนของแบบประเมิน BBS เปลี่ยนแปลงหลังการฟื้นฟู โดยใช้สถิติ ROC curve ในการเปรียบเทียบ คะแนนของแบบประเมิน BBS เปลี่ยนแปลงไปมากกว่า 7 คะแนนแปลผลว่ามีการเปลี่ยนแปลงของการทรงตัวเกิดขึ้นจริง ผลดารศึกษาพบว่าแบบประเมิน BESTest มีความเที่ยงทั้งภายในผู้วัดและระหว่างผู้วัดอยู่ในระดับสูง (ICC = 0.99) และคะแนนของแบบประเมิน BESTest มีความสัมพันธ์กับแบบประเมิน BBS (r=0.96) แบบประเมิน PASS (r=0.96) และแบบประเมิน CB&M (r=0.91) อยู่ในระดับสูง แปลผลว่าแบบประเมิน BESTest มีความตรงในการวัดการทรงตัว นอกจากนี้แบบประเมิน BESTest ยังมีความแม่นยำในการจำแนกผู้ป่วยตามระดับความสามารถในการทำกิจกรรมได้แม่นยำกว่าแบบประเมิน BBS ในการวัดการเปลี่ยนแปลงแบบประเมิน BESTest มีความไวในการวัดการเปลี่ยนแปลงสูงเหมือนแบบประเมิน BBS และ PASS (SRM = 1.1 -1.2). และแบบประเมิน BESTest มีความแม่นยำในการวัดการเปลี่ยนแปลงของการทรงตัวได้เหมือนกับแบบประเมิน BBS โดยคะแนนของแบบประเมิน BESTest ที่เปลี่ยนแปลงไป 10 คะแนนบ่งชี้ว่ามีการเปลี่ยนแปลงของการทรงตัวเกิดขึ้นจริง จากผลการศึกษานี้สรุปได้ว่าแบบประเมิน BESTest มีความเที่ยง ความตรง และความไวในการวัดการเปลี่ยนแปลงในผู้ป่วยโรคหลอดเลือดสมอง

The dissertation titled

"Reliability and Validity of the Balance Evaluation Systems Test (BESTest)

in Persons with Stroke"

by

Butsara Chinsongkram

has been approved by the Graduate School as partial fulfillment of the requirements for the Doctor of Philosophy degree in Physical Therapy of Srinakharinwirot University.

…………………………………………… Dean of Graduate School

(Assoc. Prof. Dr. Somchai Santiwatanakul)

January , 2015

Thesis Committee	Oral Defense Committee
.... Major-advisor	....Chair
(Assoc. Prof. Dr. Rumpa Boonsinsukh)	(Asst. Prof. Dr. Nopporn Jongkamonwiwat)
…... Co-advisor	....Committee
(Dr. Nitaya Viriyatharakij)	(Dr. Wanvisa Panichaporn)
	....Committee
	(Dr. Anchalee Foongchomcheay)

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Butsara Chinsongkram

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CHAPTER 1

INTRODUCTION

Background

The number of global burden of stroke continues to grow at a remarkable rate. The global prevalence is expected to reach 77 million by 2030.[1, 2] The prevalence of stroke is increasing with age, especially in adults who are 65 years and older.[3] Annually, stroke results in 43.70 million lost disability-adjusted life-years (DALYs) which represents approximately 3.20% of global lost DALYs.[1] About 15% to 30% of persons with stroke have permanently disabled and another 20% are functional dependent.[4, 5]

Falls are one of the most frequent common complications seen in patients with stroke. Both fall-related injury and fear of falling could lead to long term disability.[6-8] The incidence of falling after stroke has been reported during hospital stay and after discharge which range from 14% to 73%.[9, 10] Consequence of falls in patient with stroke results in hip fracture, soft tissue injuries,[11-14] fear of falling,[14] hospitalization, increased immobility and greater disability.[10, 14] These fall-related injuries result in long term hospitalization and increased health care costs.[15, 16] Even without physical injuries, falls could lead to post-fall syndrome or fear of falling,[17] resulting in reduced physical,[18] and social activities.[13] Evidence from most studies has identified balance impairment as an important fall risk factor in patients with stroke.[9, 19-27] The patients with stroke who have balance deficits especially during walking are at higher risk for falling.[8] Balance control is a complex integration and coordination of multiple systems, including sensory and motor systems, sensorimotor integration and higher level pre-motor processing requires.[28] The central processing of sensory information from the visual, vestibular and somatosensory inputs is required to activate the appropriate muscle groups for two important goals of controlling orientation and equilibrium.[29] Our body is constantly perturbed by internal and external forces, thus anticipatory postural adjustments (APA) and triggered postural responses (TPR) are also necessary for maintaining balance. APA is a compensatory strategy for internal disturbance from voluntary movement,[30] whereas the ability to restore the body's equilibrium during external perturbation is the role of TPR. It has been found that balance deficits in persons with stroke result from multiple systems involved in the balance control.

Stroke pathology affects the motor and sensory systems as well as central processing that acts as sensorimotor integration and interpretation. Since different area of the brain may be impaired, patients with stroke demonstrate different characteristic of balance impairments. Motor impairment such as muscle paresis or spasticity are one of the distinctive characteristics of subjects following stroke that often result in decreased range of motion, inappropriate base of support and pain which could lead to poor postural control.[31-34] Most patients with stroke demonstrate decreased ankle proprioception and somatosensation at the feet which are positively correlated with balance impairment.[33, 35, 36] Not only the presence of single motor or sensory system disorders, it has been shown that patients with stroke also have difficulties with multiple sensorimotor processes that require the central processing of vestibular, visual and somatosensory information.[37] It is evidenced that persons with stroke have impaired sensory reweighting. They demonstrated more postural sway in the conditions of altered somatosensory information[38] such as walking on uneven surface and walking in the dark. Excessive reliance on visual inputs is a result of a learned compensatory response of sensory reweighting.[39] Anticipatory postural adjustment and triggered postural response are also affected. Although person with stroke still has some anticipatory postural adjustment, APA is often lower on the paretic side than the age-match controls.[40] Even patients post-stroke with mild motor impairment or high functional level who show better anticipatory postural reaction still have abnormal APA pattern.[41-43] Triggered postural response in person with stroke remained inefficient to restore equilibrium.[44] Therefore, it has been shown that these patients frequently used compensatory strategies such as grasping and stepping.[45] Cognitive impairment, commonly found in patients with stroke,[46-49] leads to disturbance of attention, delayed recall and impaired ability to analyze, interpret, plan, organize and execute complex information.[50-52] Inadequate allocation of attention can lead to increased instability and greater fall risk.[31, 53, 54] From this review, it can be seen that postural control impairments in patients with stroke stem from diverse mechanisms involved in balance control. Therefore, therapists need to be able to identify and manage all of the defect mechanisms in order to effectively retrain balance ability.

The current design of balance training program focuses on regulating body orientation and equilibrium while maintaining or changing positions that are related to functional tasks,[37] such as mobility group exercise, Bobath approach,[37] orthopedic approach[37] and task-oriented training.[37, 55-57] Even though balance ability post-stroke can be improved by these training programs,[37, 57] the benefit of balance exercise for fall prevention in patients with stroke is inconclusive. This is partly due to those exercises could not replicate the situation where most falls occur such as tripping and slipping or they are not specific to patient's causes of balance impairments.

Three main approaches of balance assessment consist of laboratory, functional, and system/physiological assessment. The laboratory instrument provides objective and quantitative measurement without tester's bias but it is expensive and requires extensive training and testing. Functional balance assessment was developed to be used in clinical setting that does not require expensive equipment and easy to use. The functional balance assessment tools could identify balance status and its changes over time. Functional balance scale is an ordinal scale that assesses a set of functional task which requires balance during maintaining posture or changing position.[58] The example of most commonly used functional scale in patients with stroke includes 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).[59] These functional balance scales, however, have a limitation which they cannot provide the information underlying of balance problems. The results simply show whether a person has balance impairments or not. Also, those functional balance scales usually have floor and ceiling effect that might affect the sensitivity in detecting changes across stroke severity. For example, BBS has been shown to have a floor and ceiling effect in individuals with stroke as well as other population.[57, 59-61] Recently, there were two clinical balance tests that are developed to identify the underlying of balance problem. Physiological Balance Profile (PPA) focuses on physiological impairment that leads to fall risk which a simple test of vision, cutaneous sensation on the feet, leg muscle force, reaction time, and postural sway in stance.[62] The PPA is a valid and reliable measure fall risk in older adult and can use to discriminate between faller and non-fallers.[62-64] However, results from PPA do not help guide treatment because it focuses on identifying the pathology such as peripheral neuropathy or visual problem that may contribute to balance problem. Balance Evaluation systems Test (BESTest), on the other hand, focuses on differentiating 6 different underlying balance control system.[65] The novel items include a dual-task, postural response and compensatory stepping items, general alignment in standing, functional strength in the hip and ankle, leaning and returning to vertical, sitting on the ground and returning to standing position and standing on an incline.[65] As a result, scores from the BESTest can be used to identify the balance control system underlying postural impairments and could possibly lead to the design of a balance-specific rehabilitation.

A theoretical construct of the BESTest is based on Bernstein's concept that postural control results from a set of interacting system[66-71] and supported by research evidence of how constraints or deficit in different underlying system can impair balance.[58, 66-68, 70, 72-88] Each of six interacting systems underlying control of balance in the BESTest consists of neurophysiological mechanism that controls a particular aspect of postural control. Content validity of BESTest was studied by thousands of experimental physical therapy clinicians providing feedback about clarify, sensitivity, and practicality of item between 1999 and 2005.[65] The psychometric properties of this scale in normal subject and some neurological patients showed excellent inter-rater reliability (ICC=0.91), moderate validity with individual's self-perceived balance (r=0.64).[65] The psychometric properties of the BESTest in Parkinson's disease reported excellent test-retest reliability (ICC=0.88) and inter-rater reliability (ICC=0.96). The BESTest showed excellent convergent validity with BBS (r=0.87). Cutoff scores to identify fallers in Parkinson's disease were 69% for the BESTest.[89] Considering the construct validity that the BESTest covers all the balance control systems that have been shown to be affected following stroke, this test may be able to capture balance problems in patients with stroke. However, the BESTest has never been validated and used in the population with stroke. Therefore, it is necessary to examine whether the items of the BESTest will be appropriate and adequate to assess balance change overtime in stroke patients across functional ability by compare with the PASS, BBS and CB&M those as a reference standard in stroke patients with low, moderate and high functional ability, respectively.

Research Question

Is the Balance Evaluation System Test (BESTest) reliable, valid and responsiveness in persons with stroke across different level of functional abilities?

Objectives of the Study

1. To examine the intrarater reliability and interrater reliability of the BESTest.
2. To assess the extent of association between BESTest and Berg Balance Scale (BBS), Postural Assessment Scale for Stroke Patients (PASS) and Community Balance and Mobility Scale (CB&M) in each level of functional ability in patients with stroke (convergent validity).
3. To compare the floor, ceiling and responsive ceiling effects of the BESTest with BBS, PASS and CB&M.
4. To determine if the BESTest could be used to identify patients with low and high functional ability, as classified by the Fugl-Meyer Assessment-Motor (FM-Motor) subscale.
5. To determine internal and external responsiveness of the BESTest in patients with stroke.

Research Hypothesis

1. The BESTest would be reliable and well correlated with other balance scales such as the BBS, PASS and CB&M.

2. The BESTest would have less floor, ceiling and responsive ceiling effects than the other clinical balance tests, so that the BESTest will be more feasible for persons with stroke across a wider range of motor disability.
3. The BESTest would reveal high responsiveness in persons with stroke.

Significance of the Study

Balance ability is an important component toward attaining autonomy in performing daily activities. Impairment of balance control is one of the major problems found in patients with stroke and the effective treatments of balance impairments need to be specific to the cause of balance impairments. This study is the initial step aiming to improve the evaluation and treatment of mobility disability in patients with stroke. It is the first study that will provide the clinical evaluating tool that can identify the causes of balance impairments in patients with stroke. The new evaluating scale developed in this study will help guide the clinicians to select and program the effective balance training programs as well as to provide the valid clinical tool to assess the effectiveness of such balance training programs. The effective balance training program could possibly lead to the successful fall prevention programs which will eventually reduce the health care costs and improve the quality of life in persons with stroke.

Keywords

Cerebrovascular accident, Postural control, Balance assessment, Psychometric property, Clinical scale

Conceptual Framework

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

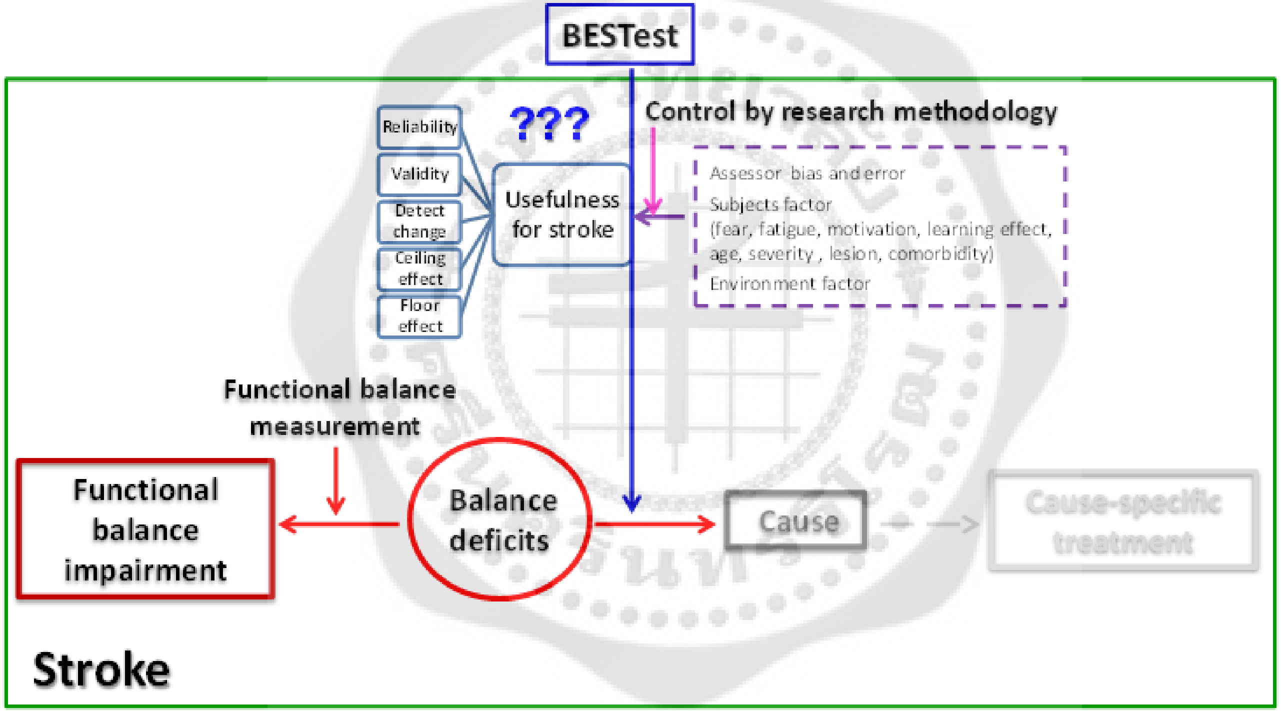

FIGURE 1 CONCEPTUAL FRAMEWORK

CHAPTER 2

THE LITERATURES REVIEW

The review of literatures is divided into 6 parts as follows.

1. Stroke and long term disability
2. Cause of fall in stroke
3. Postural control impairment in stroke
4. Balance rehabilitation
5. Balance measurement
6. Psychometric properties of measurement

1. Stroke and long term disability

Stroke or cerebrovascular accident (CVA) has been defined as an acute onset neurological deficit lasting more than 24 hours or culminating in death caused by sudden impairment of cerebral circulation.[90] The number of global burden of stroke continues to rise every year. The global prevalence is expected to reach 77 million by 2030[1, 2] and increasing with age, especially in adult who have aged 65 years and older.[3] Annually, stroke results in 43.70 million lost disability-adjusted life-years (DALYs) around the world that represents approximately 3.20% of global lost DALYs.[1] The stroke recovery time depends on its severity. About 50% to 70% of stroke survivors regain functional independence, but 15% to 30% are permanently disabled and another 20% are functional dependent.[4, 5] Of these survivor strokes, 45% are discharged directly to their home and other 40% need a nursing home care or rehabilitation.[20]

Falls are one of most frequent common complication seen in patients with stroke. Both fall-related injury and fear of falling could lead to long term disability in patients with stroke.[6-8] The incidence of falling after stroke has been reported during hospital stay and after discharge which range from 14% to 73%.[9, 10] Fall incidence following in acute stage in hospital setting ranges from 14% to 65%[11, 19, 20] and increases to 73% of survivors stroke who living in community.[13, 18] These rates are higher than in the elderly, where fall rate has been reported as 34% and up to 45% for those over 80 to 89 years of age.[18, 91]

Consequence of falls in patient with stroke results in hip fracture, soft tissue injuries,[11-14] fear of falling,[14] hospitalization, increased immobility and greater disability.[9, 13] Falls resulted in injury range from 8 percent to as much as possible 69%.[8] These fall-related injuries result in long term hospitalization and increased healthcare costs.[15, 16] Even Falls that do not cause in physical injuries could result in post fall syndrome or fear of falling[17] and lead to reduced physical[18] and social activity.[13]

2. Cause of fall in stroke

Several factors such as gait and balance impairment, sedative and hypotonic medication, difficult in performance in activities of daily living (ADL), inactivity, incontinence, visual impairment and reduced lower limb strength have been reported as a fall risk factors in the elderly population.[24] However, risk factors for fall are varies with time after stroke and places which patients live. In acute stroke setting, risks of fall consist of heart disease, urinary incontinence, a previous history of fall, and mental decline.[92] While male gender, poor performance in ADL, urinary incontinence, disturbed balance, left-sided or bilateral motor deficit, neglect, aphasia, current medication with hypotensive, diuretics, antidepressants, sedatives, or taking many medication at the same time, previous history falls, and cognitive disorders[11, 19, 20, 93] have been identified as fall risk factor in patient with stroke during inpatients rehabilitation setting. In community dwellings, an higher risk of falls in patients with stroke was associated with age over 60 years, visual or sensory deficits, neglects, residual lower limb paresis, disturbed balance, depression, epilepsy, poor performance in activities of daily living, restricted participation and use of sedative medications.[13, 24, 94, 95]

However, most studies (ten form twelve studies) have identified balance impairment particularly in a more challenge task such walking while talking or dressing as the important fall risk factors in patient with stroke.[9, 19-27] Moreover, evidence has been suggested that patients with stroke who have gait deficits are at the higher risk for falling[8] and more likely to fall when walking that requires substantial cognitive control.[26, 96]

3. Postural control impairment in stroke

Postural control is required when performing daily activities for three purposes; maintaining stability in each posture, generating postural adjustment with movement and reacting quickly and appropriately to external perturbation.[97] Therefore, postural control involves controlling the body position in space to achieve goal of postural orientation and postural stability or equilibrium.[29] This requires a complex interaction between the musculoskeletal and neural system to control the body orientation and equilibrium according to environmental constraints.[29, 97]

Postural orientation is defined as the ability to maintain an appropriate relationship between the body segments, and between the body and environment.[98] This term involves both biomechanical alignment of the body and the orientation of the body to the environment that established from multiple sensory references.[29] There are several frames of reference for postural orientation, it can be visual which based on visual information of the surrounding environment; somatosensory which based on information from contact with external objects; or vestibular which based on gravitoinertial forces; and sometime from internal representation of the body orientation or environment that estimated referent position from memory.[98]

Postural stability or balance is ability to control the center of mass (CoM) in relation to the base of support.[29, 97] The center of mass (CoM) is a one key variable that is controlled by the postural control system. CoM defined as a point that is at the center of the total body mass. [29] The base of support (BoS) is defined as the area of the body that is in contact with the support surface.[29] The stability to control the CoM relative to the BoS is considered from controlling the vertical projection of the CoM that is called the center of gravity (CoG).[29] Control of balance, can be reactive, that is in response to external forces displacing the CoM, or proactive, as occurs in anticipation of internally generated destabilizing forces imposed by the body's own movement.[74]

3.1 Components of postural control

The postural control is a complex integration and coordination of musculoskeletal and neural systems. Evidence from many research found the postural control is not regulated by a single system, but emerge from the interaction of many systems,[29, 32, 99] as shown in figure 2. Musculoskeletal component consists of joint range of motion, spinal flexibility, muscle properties, and biomechanical relationship among linked body segments. Neural components are including sensory system, motor and higher level pre-motor systems.(28) Sensory or perception processes involve the organization and integration of individual sensory information from visual, vestibular and somatosensory system. Motor processes include organizing muscle throughout the body into neuromuscular synergies. Higher-level processes are essential for mapping sensation to action or internal representation, and ensuring anticipatory and adaptive aspects to postural control.(29)

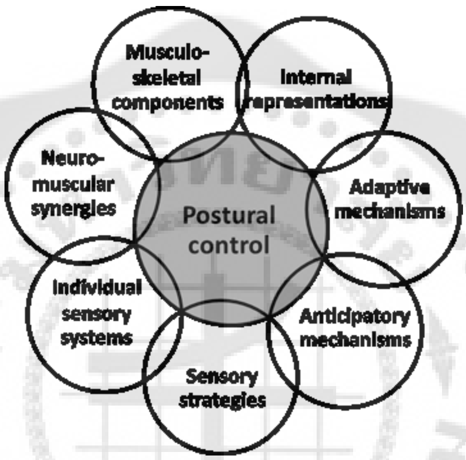

FIGURE 2 PHYSIOLOGICAL SYSTEMS UNDERLYING POSTURAL CONTROL.(29)

In addition, cognitive processing(32, 99) and control of dynamics during gait and while changing position(32) are also required in postural control.

3.1.1 Musculoskeletal components

Body alignment, size and quality of base of support are important factors that influence the ability to keep the projected CoM within the limits of base of support or stability limits.(29, 32, 99) Body alignment is necessary for minimizing the internal energy used for keeping the vertical line of gravity within base of support. (29) Any abnormality in range of motion of joints, muscle tone, muscle strength and flexibility, muscle control and pain will affect the postural control.(32, 99-101)

3.1.2 Individual sensory system and sensory strategies

The sensory inputs that provided primarily from visual, vestibular, and somatosensory systems about information concerning of the body and its surroundings are critical to maintain adequate postural control. The central nervous system needs to extract and interpret the relevant sensory information to determine whether the body or the environment is still or in motion and orient the body with respect to relevant surface, gravitoinertial forces and visual cues. The effect of each sensory system on posture depends on the task and context.

Vision provides information about the position and movement of the head respect to surrounding objects as well as reference for verticality[29] Visual information is also important in identifying environmental cues and distinguishing the environmental hazards and upcoming perturbation.[97, 102] The visual cues are delivered from the retina to the central nervous system (CNS). Vision seems to influence balance by reacting to motion as a relative image shift on the retina, and it also triggers the muscle activation required for postural corrections. The efficiency of vision in postural control depends on individual's visual acuity, visual contrast, room illumination and object distances.[102] The proportion of sensory weighting on vision input depends on whether the visual input acts alone or in combination with perturbation of the support surface. In general, visual information dominates at the low frequency of body sway or when there is a conflict between vision and the other sensory information.[98] When people stand with their eyes closed, postural sway increases between 20% and 70%.[103, 104] It has also been shown that moving visual fields can induce a powerful sense of self-motion and mislead visual cues resulting in increased sway.[105] Visual input plays an important role in response to unexpected disturbances of balance and in the anticipatory postural adjustments that accompany voluntary movements. Visual also becomes more important when vestibular and/or somatosensory input are compromised or during learning of a new skill.[98] However, only information from the visual system cannot differentiate between object (Exocentric) and self (egocentric) motions. This deficit can be solved by the vestibular system that provides information about head motion which helps the nervous system to distinguish between exocentric and egocentric motions.[106]

The vestibular system provides the CNS with information on head movement and position by using gravity reference. There are two types of sensors to orient the head in space, semicircular canals and otolith organs. Three semicircular canals are located in each inner ear providing information on head rotation or angular acceleration. The canals are oriented along the x, y, z axes, and define motion on each of three dimensions of space. When the head moves, hair cells detect the motion of the fluids in each canal.[107] The CNS uses this information to calculate changes in inertia.[102] The otolith organs perceive information of head position and head linear acceleration. The otolith organs use a pendulum-like appendage, the utricle, to orient the sense to the vertical force of gravity. The semicircular canals are sensitive to higher frequencies of head motions than are the otoliths.[107] The vestibular system plays an important role in stabilizing the head in space and linking the head movement with the responses needed to maintain balance. Vestibular afferents are responsible for triggering the response to sudden, unexpected falling while they do not required for the triggering the responses to movement of a stable and large support surface.[98] Although vestibular information is not necessary for the triggering of a postural response to surface perturbation, such inputs may be necessary for the selection and use of movement strategies in which the head must be stabilized in space.[98] Although, the vestibular system can be used to distinguish between exocentric and egocentric motions, it has some limitation in differentiating only head or whole body movement.[106]

The somatosensory system provides information of the body in relation to the supporting surface and the relationship of body segment to one another by the exteroceptive and proprioceptive receptors.[29] Exteroceptive receptors are specific receptors for each sensation such as pain, temperature and touch which located in cutaneous and subcutaneous tissues. The proprioceptors are located in the muscles, tendons, and joints giving information about the limbs and body position and the tension of respective muscles. The proprioceptive receptors include muscle spindles giving information about the change in muscle length and tension, while the golgi tendon organs provide the information about tendon's tension, and joint receptors giving information about the movements and body position parts relative to each other.[98] Somatosensory receptors in the feet, legs, and trunk may be critically important for controlling the trunk, particularly when the subject maintains contact with a large, rigid, and stable support.[102] Proprioceptive information from the neck is used in combination with vestibular information in order to control the trunk position and velocity.[102] The information from the neck muscles gives an important reference concerning head movement in relation to the trunk. Moreover, the proprioceptive information from the eye muscles reflects the eye position in relation to the head.[102]

Sensory information is regulated dynamically and modified by changes in environment condition.[86] All multiple sensory information requires an integrative action of the CNS to choose and weigh priority to one system that is more accurate and useful over another.[102] These dynamic reweighting of sensory input depends upon the task, the availability of sensory information within particular environment, and the movement strategies used in the task.[98] Healthy subjects when standing on a firm base of support tend to prefer information from somatosensory (70%) while relying less on the vestibular (20%) and vision (10%) for postural control.[86] However, when one is standing on an unstable surface, the CNS increases sensory weight to vestibular and visual information and decrease the dependence on somatosensory input for control equilibrium.[86] In the same way, in darkness, CNS relies more on somatosensory and vestibular inputs. Sensory reweighting is also important in the situation of sensory conflict that frequently occurs in daily activities such when standing next to a bus in movement. In this situation, the visual system report relative movement of person in relation to an object, which conflict with information from somatosensory and vestibular input. The CNS must reject visual information and use vestibular and somatosensory inputs to control stability.[99] In addition, redundancy in the sensory system allows for compensatory when one system is dysfunction.[97]

3.1.3 Internal representation of the body

Internal representation or body schema provides a postural frame of reference.[29] Body schema is a type of internal representation of the body which is largely unconscious representation of the body.[108] Body schema defined as a dynamic representation of relative position of body parts derived from multiple sensory (figure 3) and motor inputs (e.g., proprioceptive, vestibular, tactile, visual, efferent copy) that interacts with motor systems in genesis action.[109] This is like a body map which is used as a reference for perceiving orientation of the body in relative to earth vertical and as a representation of how body can move within stability limits.[32] The body schema plays a central role in interrelating concurrent perceptual inputs allowing for the reconstruction of missing information, enabling the detection and resolution of conflicts, and ensuring an integrated, globally consistent, multimodal representation of body configuration (figure 3).[29, 110, 111] These maps would build up from development of sensory and motor aspects of postural control[29, 110] and remains stored in the brain.[112] In microgravity, the body schema was stable, although there were extensive changes in the sensory input such as labyrinthine and proprioceptive inputs which were influenced by gravity but the level of implementation or muscle force also has highly adaptation.[112]

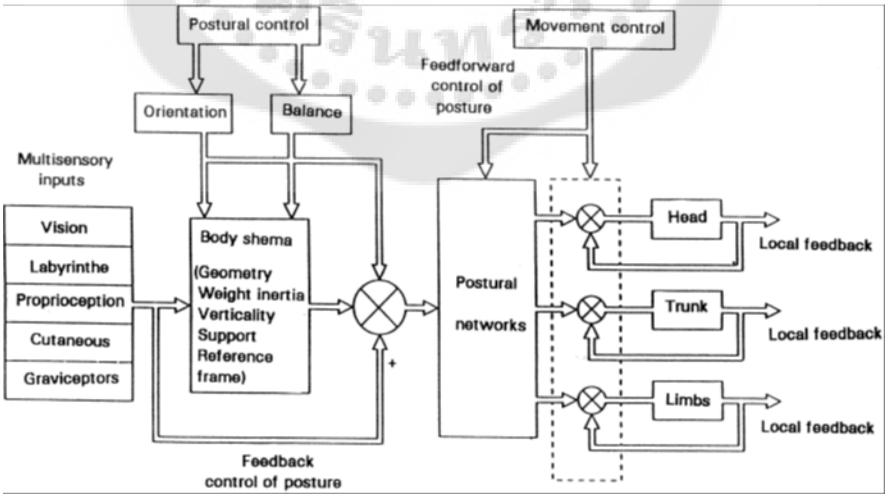

FIGURE 3 THE MODEL OF MOVEMENT AND POSTURAL CONTROL.

Note: Represent a two level of postural control, the body scheme and the postural network.[76]

A basic level of internal representation is the representation of the verticality or ability to align the body with respect to gravity, so called perception of verticality.[113] The representation of verticality is intimately linked to the available cues from the personal and extrapersonal spaces.[114] For the representation of verticality to be built, the integration of visual, somatosensory, and vestibular cues is required.[114] Verticality can be perceived though different modalities: the visual verticality (VV) is a perception of the vertical that relies on visual estimation of gravitational direction, the postural verticality (PV) is the estimation of body tilt with respect to gravitational line, and the haptic vertical (HV) is the perception of verticality that is estimated by haptic or touch sensation.[115] The perception of verticality based on only one modality should not be appropriate for postural orientation. In healthy subjects, detection of body tilt seems to be heavily dependent on proprioceptive-contact cues and vestibular input is required for normal sensitivity in the perception of body verticality.[79] The parieto-insular vestibular cortex is a brain area that integrates vestibular, proprioceptive and visual information to produce the internal representation of verticality.[116]

3.1.4 Movement strategies and automatic postural responses

Postural control is challenged constantly by disturbing forces that arise from either internal disturbances resulted from voluntary movements or external disturbances from outside environment such as gravity. Both types of disturbing forces may be expected (i.e., visible obstacles) or unexpected (i.e., sudden change of the support surface). The strategy to restore the body's equilibrium during external perturbation is the role of triggered postural response. These triggered postural responses are controlled through the feedback control in response to external perturbation trigger stimuli.[117]

Three basic of movement strategies can be used to restore the body equilibrium in a stance position. Two strategies keep the feet in place and the other strategy change the base of support by stepping or reaching (figure 4).[32] The first strategy is an ankle strategy that is used for relatively small disturbance of the base of support which body moves as a relatively rigid mass about the ankle joint, like an inverted pendulum, to bring the center of gravity back over the base of support. For more forceful perturbations or for perturbations that occur while standing on a narrow or unstable base of support, a hip strategy is typically seen. In hip strategy, the primary movement occurs at the hip as the center of gravity moves rapidly back and forth over a relatively short distance.[29, 32, 118] The third major classification is the stepping strategy that occurs while the center of gravity is displaced beyond the limits of the base of support. Stepping or stumbling strategy is necessary to regain postural stability when neither the ankle nor hip strategy is sufficient to move the center of gravity back over the base of support.[29, 32, 118] Stepping strategy is usually seen during walking[32] or when individuals perceive a risk of falling as a mean ensuring stability.[45] Stepping initiated vary rapidly, and inability to step accurately and quickly enough may be a major cause of loss balance confidence and high risk to falls.[97]

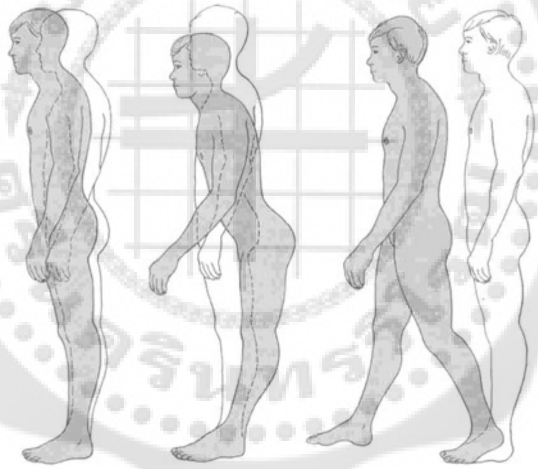

FIGURE 4 MOVEMENT STRATEGIES TO EXTERNAL PERTURBATION: FEET IN PLACE AND STEPPING RESPONSE.[29]

There is evidence that the triggered postural response was not a common stretch reflex, although its response occurred more quickly than the fastest voluntary movements. The onset of postural response occurs at longer latencies than those of spinal stretch reflexes, suggesting greater potential for modification by the cortex.[82] In addition, in-place strategies can be changed to stepping strategy if those in-place strategies are not adequate. Furthermore, the cortex is involved in changing postural response with alteration in cognitive state, initial sensorimotor condition, prior experience, and prior warning of a perturbation; all represent change in central set or plan of action (figure. 5).[82]

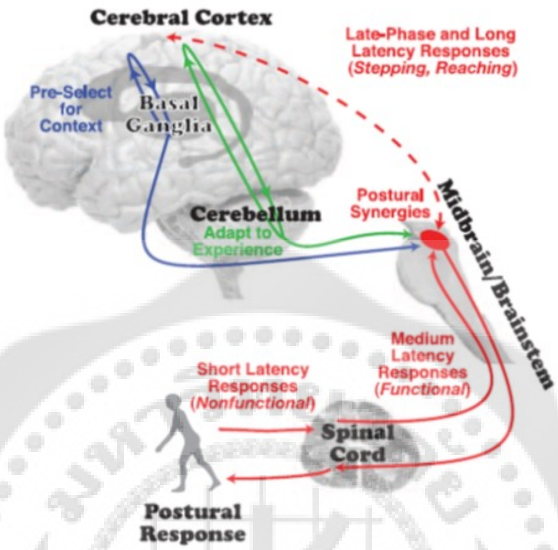

FIGURE 5 A SIMPLE MODEL OF PROPOSED NEURAL PATHWAY INVOLVED IN CORTICAL CONTROL OF SHORT, MEDIUM AND LONG LATENCY AUTONOMIC POSTURAL RESPONSE TO EXTERNAL PERTURBATION.[82]

Movement strategies are continuum of strategy and could gradually be learned with experience in new environmental context (figure 6). At first, these strategies were conceived as consisting of distinct, centrally programmed patterns that were combined to provide a continuum of "mixed" strategies. More recently, the continuum of postural strategies from ankle to hip is considered to be similar to the continuum of locomotor strategies in which there are transitions from walking to galloping and trotting.[74] However, the stepping strategy could represent a truly independent strategy that is usually preferred to the hip strategy when there is no surface or instructional constraints. Thus, the strategy concept has been gradually changing to allow for the functional flexibility, specificity which varied with context of the task such as direction and speed of perturbation and type of base of support, and motor learning apparent in postural behavior.[74]

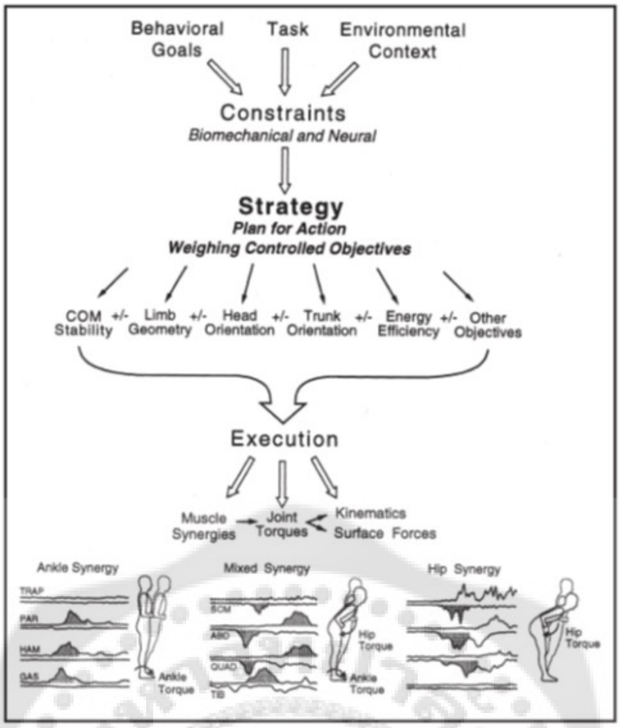

FIGURE 6 A CONCEPTUAL FRAMEWORK FOR EMERGENCE OF STRATEGIES THAT ARE PLAN OF ACTION (CENTRAL PROGRAMMING).[74]

3.1.5 Anticipatory postural response

Postural adjustment occurs not only as a result of sensory feedback in response to external perturbation, but also as a result of feedforward in anticipatory of expected, self-generated perturbation such as voluntary movement.[73] Anticipatory postural adjustment is the compensatory strategy for internal disturbance from voluntary movement.[30] With the onset occurs shortly prior voluntary movement,[117] the anticipatory postural adjustment stabilizes the position of body segments with respects to each other and environment during movement performance.[119] Anticipatory adjustment also directly provides additional force for performing the movement.[120]

A postural response synergy for anticipatory adjustment is flexible depends on the initial body position or the support condition.[121] This strategy can be adaptive as a result of instruction and predication[80] prior experience, cognitive information and intrinsic information about the body and environment.[122]

3.1.6 Cognitive processing

Although normal postural control occurs automatically, without conscious effort but in more challenge postural task such dual-task interference has suggested that there are significant more cognitive process requirement for postural control.[29, 32] Since balance control and other cognitive processing share cognitive resources, reaction times and performance in a cognitive task impair as the difficulty of the postural task increases.[32, 123] Individuals who have cognitive impairment are at risks to fall while performing a secondary task.[32] The evidence suggested the attention demands for postural control are very dynamic and depend on many factor such as age that healthy young adult requires low attention demand than older adult.[29]

3.2 Postural control deficits in stroke

Multiple systems underlying balance control are impaired following stroke. Stroke pathological can affect the motor and sensory systems as well as central processing that acts as sensorimotor integration and interpretation. Motor impairment such as muscle paresis or spasticity are one of the distinctive characteristics of subjects following stroke[29] that often lead to decreased range of motion, inappropriate base of support and pain.[31-34] Most of the patients with stroke show decreased ankle proprioception and somatosensation at the feet which is positive correlated with balance impairment.[33, 35, 36]

Not only the presence of single motor or sensory system disorders, it has been shown that patients with stroke also have difficulties with multiple sensorimotor processes that require the central processing of vestibular, visual and somatosensory information to activate the musculoskeletal system for postural control.[38] It is evidenced that the persons with stroke have impaired sensory reweighting such that they demonstrated more postural sway in the conditions of altered somatosensory information,[38] such as walking on uneven surface and walking in the dark. Measurement of sensory organization demonstrated that patients with stroke were mostly unstable in conditions of visual deprivation or inaccurate visual inputs, indicating the excessive reliance on visual input even when it provides inaccurate information.[39] It has been suggested that excessive reliance on visual inputs is a result of a learned compensatory response of sensory reweighting that occurs over time in patients with stroke. This previous study even showed that relying on a single sensory system can lead to inappropriate adaptations which could increase fall risks in subjects with stroke.[39]

Visual neglect (i.e., ignoring one side of the body) and pusher syndrome (i.e., constantly pushing the body away from the unaffected side) are common inaccurate representation of vertical that causes balance and postural problems following stroke. Contraversive pushing is defined as active pushing of nonparetic extremities to the side contralateral to the brain lesion (figure 7).[124] The incidence of pusher syndrome is 10.4 percent in persons with stroke.[125] The "pusher" stroke showed the alteration in perception of body orientation in relation to gravity but had normal visual perception in space. Karnath et al found "pusher" patients with occluded eyes corrected their body as oriented "upright" when actually tilted 18 degrees to the side of the brain lesion. While given the visual input, the same patients could align their longitudinal body axis to earth vertical (figure. 8).[126]

FIGURE 7 THE CHARACTERISTIC FEATURE OF THE PATIENTS WITH PUSHER SYNDROME.

Note: These right-side brain damage patients spread the nonparetic extremities from the body to push away actively the nonparetic side while sitting (left) of standing (right) [124]

The lesions of posterolateral thalamus and its projection into the posterior limb of the internal capsule suggest that these areas were likely to be involved in the neural representation of the graviceptive system in human to control upright were found in patients with “pusher stroke”.[126]

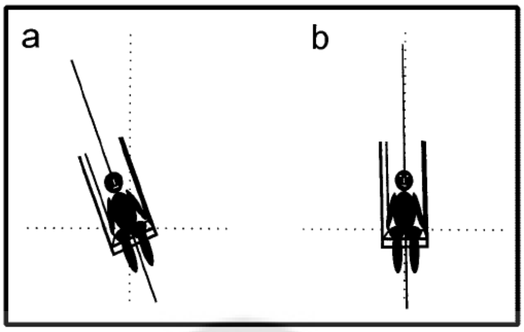

FIGURE 8 SITTING ON TILTING CHAIRS FOR TEST PERCEPTION OF VERTICALITY.

Note: The patient was required to indicate when they reached upright body orientation after a randome tilt the left or right of at least 35 degrees. (A) Occluded eyes (B) Viewing the laboratory structure surround.[126]

Visual neglect is a common neurological sign following stroke, characterized by a deficit in attention and appreciation of stimuli on the contralesional side of the body.[127] The prevalence rate of visual neglect is 43% and 20% following right and left hemispheric stroke, respectively.[127] It is generally agreed that left neglect associated with a right hemisphere stroke is both more frequent and severe than right neglect associated with a left hemisphere stroke[128, 129] demonstrated that patients with unilateral neglect stroke perceived the visual target as “straight ahead” when the target was actually deviated approximately 15 degrees toward the nonparetic side. Misperception of visual verticality in patients with hemineglect stroke is due to a disturbance of cortical structures that transform sensory inputs from the periphery into the non-retinal spatial reference frame.[129]

Anticipatory postural adjustment and triggered postural response are also impaired in persons with stroke. Although person with stroke still has some anticipatory postural adjustment, the responses are often less or abnormal than age-match control.[40-43] Inadequate anticipatory mechanism that found in stroke was reduced anticipatory muscular activity in limb muscles especially on the paretic side and superficial trunk muscle.[130] In addition, patient with stroke exhibited more compensatory strategies such as holding onto object or stepping strategies than healthy subjects.[45] For in-place strategy, patients with stroke trend to use the hip strategy more than ankle strategy,[131] but this strategy remained inefficient to restore equilibrium.[29]

Stroke is a commonest cause of cognitive impairment.[46-49] Cognitive impairment in patients with stroke leads to disturbance of attention, delayed recall and impaired ability to analyze, interpreted, plan, organize and execute complex information.[50-52] Normally, postural control skill is an automatic process that requires less attention, but patients with stroke showed greater attention demands for static postural control which increases with task difficulty.[53] This inadequate allocation of attention can lead to increased instability and greater fall risk.[31, 53, 54]

From this review, it can be seen that postural control impairments in patients with stroke stem from diverse mechanisms involved in balance control. Therefore, therapists need to be able to identify and manage all of the defect mechanisms in order to effectively retrain balance ability.

4. Balance rehabilitation

Balance training has been found to improve balance performance in person with stroke. Balance ability post-stroke can plausibly be improved by a variety of physiotherapy intervention performed without the use of intensive technical equipment such as mobility group exercise, Bobath approach,[37] orthopedic approach[37] and task-oriented training.[37, 55-57] These programs are more effective when it is directed to a functional task with sufficient balance challenge and intensively.[55] In acute phase, Bobath approach and motor relearning program (MRP) demonstrated larger balance improvement.[37, 57] Appropriate exercise dosage was 2 to 3 sessions per week for 40 to 120 minutes per sessions or 5 sessions per week for 45 to 60 minutes per sessions.[57] In subacute phase, therapist-supervised, moderately intense home program was recommended. Moreover, problem-oriented willed movement therapy is appropriate for stroke patients who have cognitive and perception impairment.[37] And, for chronic phase, patient with stroke can regain balance ability by exercise including activity targeting balance in an active manner.[37, 57] The training program could be one-on-one, short and intense (10 days), or in a group format, for longer period of time (from 8 weeks up to 6 months) at a lower intensity.[57] Furthermore, intense programs were feasible, demonstrated excellent adherence and remained partially effective after 3 months.[57]

Despite the benefit of exercise and balance training on balance improvement, they cannot prevent fall in patients with stroke. Batchelor and coworker has reported that the effective intervention in reducing falls in their systematic review and meta-analysis was vitamin D supplementation. The intervention such as balance training exercise, strength training did not have significant effect on fall prevention.[10] The possible reasons for the lack of significant result in fall prevention could be that the exercise may not have been specifically designed for cause of balance impairment or fall risk factor and their not have sufficient intensity and duration.[10] Unable to design balance-specific exercise is partly due to the lack of the measurement tool that identifies the cause of balance impairment and falls in person with stroke. The design of current balance training program based on the data from functional balance measurement tools that provided only patient have or have not balance impairment in which functional activity such as sitting, standing or during gait. The characteristics of this balance training program, therefore, focused on maintaining or changing position that related with functional more than direct specific to cause of balance impairment of fall risk factor.[37] It is possible that the patients with stroke who fall have some underlying of balance, such as compensatory postural response or sensory organization, that have not been recognized by these training programs. Therefore, it is necessary to have a clinical measurement tool that can identify the specific system underlying balance impairment in patients with stroke, so that the effective balance training for fall prevention could be designed.

5. Balance measurement

The purpose for balance evaluation include the identification of whether or not balance problem exists, the identification of underlying of balance problem, and the assessment of fall risk and effectiveness of treatment program.(28) To reach these goals, balance measurement tool should reflect the functional capacities and quality of postural strategies, sensitive and selective for postural control abnormalities, reliable, valid and practical use.(28) At present, however, there is no balance measurement tool that has all of these features. The commonly used balance measurement can be divided into three main approaches that consist of laboratory assessment, functional assessment, and system/physiological assessment.(28)

First, the laboratory instrument is providing objective, quantitative measurement which free from tester bias. These tools, such as somatosensory evoked potential, electromyography (EMG) or magnetic resonance imaging (MRI), can be used for the cause diagnosis or identify the pathophysiology of postural disturbance.(132) Posturography is the most popular and represents gold standard for assessing postural control. Static posturography aims to assess postural sway during quiet stance in several manipulations for challenging balance task, such as reduced size the base of support, decreased sensory feedback or applying a secondary task. Dynamic posturography is used to assess postural response during external balance perturbation and identify how each sensory system contributes to balance control and ability in organize sensory information by assess postural sway during changing surface and/or visual condition.(133) However, posturography have limited assess during gait and postural transition such as turning or sit to stand.(28) Recently, wearable motion sensors developed for used to measure balance in these situations. These sensors use wireless data transfer that small, inexpensive and robust sensor with long life battery and local data storage to enable ambulatory systems for all-day monitoring.(134, 135) Nevertheless, laboratory instrument remained expensive and required time for training and testing.

Second, functional balance assessment was developed to use in clinical setting that does not require expensive equipment. The functional balance assessment tools identify balance status and it change over time. Functional balance scale is a set of functional tasks that require balance during maintaining posture or changing position. The rating of balance performance is using an ordinal scale or use of a stop-watch to time how long the subject can maintain balance in a particular posture.[58] The common use of functional balance measurement in stroke patients consists of Berg Balance Scale (BBS), Postural Assessment Scale for Stroke Patients (PASS), Community Balance and Mobility Scale (CB&M) and Dynamic Gait Index (DGI). These measurements are suitable for use in some stroke population group. With the floor and ceiling effect, these scales may have problems in detecting changes across stroke severity. BBS has been shown to have a floor and ceiling effect in individuals with stroke as well as other population. BBS has significant floor effect at 14 days post stroke and large ceiling effect in high functioning such as community-dwelling stroke.[57, 59-61] PASS was specifically developed to measure balance function in patient with stroke, including those with very poor performance,[136] but it still has notable ceiling effects found as early as 3 months after stroke limiting the ability of PASS to discriminate between individual patients.[137] The CB&M and DGI have floor effect in patients who cannot walk independently because it was developed for assessing balance and mobility in moderate to high functioning person after stroke who are in the process of returning to community living.[138, 139] More importantly, these functional balances previously mentioned cannot provide information about the underlying of balance problem.

Third, two clinical balance tests that are developed recently can identify the underlying of balance problem. Physiological Balance Profile (PPA) focuses on physiological impairment that leads to fall risk which a simple test of vision, coetaneous sensation on the feet, leg muscle force, reaction time, and postural sway in stance.[62] The PPA is a valid and reliable measure of fall risk in older adult and can use to discriminate between faller and non-fallers.[62-64] However, PPA scores do not help guide treatment because its purposes are to identify the pathology such as peripheral neuropathy or visual problem that may contribute to balance problem. Balance Evaluation Systems Test (BESTest) focuses on differentiating 6 different underlying balance control system. Many tasks of BESTest have been borrowed from the following previously validated balance assessment and the novel items are added to assess the remaining subsystems of postural control including biomechanical constraints, autonomic postural response, cognitive processing (dual-task), perception of verticality, and dynamic control during walking.[65] Therefore, results from the BESTest can be used to design a specific rehabilitation approaches for managing different balance deficits. However, the BESTest has not been used in patients with stroke, so the psychometric properties in stroke are still unknown.

5.1 Berg Balance Scale (BBS)

The BBS is a widely used objective measure for functional balance in the clinic and in research and is considered as a reference standard for assessing balance in patients with stroke. The BBS assesses the functional balance in three dimensions: maintenance of a position, postural adjustment to voluntary movements.[140, 141] The BBS consists of 14 functional tasks common in everyday life. The score for each task ranges from 0 to 4, where 0 means unable to perform and 4 means able to complete the task. A total possible score of the BBS is 56 points.

This test has excellent internal consistency in patients with stroke, Cronbach alphas ranging from 0.92 to 0.98.[59] The BBS has been accepted that it has a very good reliability. It showed excellent interrater reliability (intraclass correlation coefficient ICC=0.95 in 123 patients studied at 14 days post-stroke and ICC=0.98 in patient with acute and chronic stroke).[60, 142, 143] Intrarater reliability which examined in 6 patients with stroke with 1 week apart was excellent (ICC=0.97).[142]

Validity of BBS has been established in patients with stroke. The convergent construct validity was excellent correlated with Barthel Index (r=0.8-0.94), with Fugl-Meyer Assessment (FM) (r=0.71), with FIM (r=0.76), with PASS (r=0.92-0.95), and adequate correlation with FM balance score (r=0.62-0.92) and Balance Master (r=0.48-0.67).[59] The previous studies of the known group analysis demonstrated that BBS can be discriminative between groups based on the location at follow up evaluation (home, rehabilitation program, acute care hospital),[140] between functional subgroups at the time of study enrollment[144] and between patient who walk with aid, walk independently and healthy subjects.[34] The

BBS has predictive validity in predicted length of stay (r = -0.39 to -0.53),[145, 146] predicted score on the motor assessment scale at 180 days post-stroke (Spearman correlations ranging from 0.82-0.91)[60] and strangely predicted disability level as measured by the Barthel Index.[61, 137] There was strongly evidence reported moderate to excellent sensitive to change in the early post-stroke period. The responsiveness of the BBS are varied with different times for individuals with different levels of stroke severity (ES=0.21-1.28)[59] which greatest ES found in the interval between 14 to 30 days and decreased when time after stroke increases.[60] A different of 5.8 and 6.9 point on the BBS was required to conclude with 90% and 95% certainty real clinical balance change.[144]

However, this functional balance test has some limitations. The important limitation is that it cannot assess the underlying cause of balance. The other limitations are the floor and ceiling effect that might affect sensitivity in detecting changes across stroke severity. BBS has been showed to have a floor and ceiling effect in individuals with stroke as well as other population.[59, 99] BBS has significant floor effect at 14 days post stroke[60] and large ceiling effect in high functioning such as community-dwelling stroke.[61, 147]

5.2 Postural Assessment Scale for Stroke Patients (PASS)

PASS was specifically developed from the FM to measure balance function in patients with stroke, including those with very poor balance. This scale consists of 12 items of varying difficulty that assess a person’s performance to maintain or change from a lying, sitting, or standing posture.[136] The score for each task ranges from 0 to 3, where 0 means unable to perform and 3 means able to complete the task. Its total score range from 0 to 36. The psychometric properties of the PASS were found to be satisfactory in patients with stroke during the first 6 month after stroke. This scale has high internal consistency (Cronbach alpha coefficient =0.95) and high interrater and test-retest reliability (average k=0.88 and 0.72). The validity was high correlation with FIM score (r=0.73), with lower-limb motricity score (r=0.78) and adequate correlation with balance master (r=0.48).[136]

Even though PASS is designed for very poor performance, it still have notable ceiling effects found as early as 3 months after stroke, limiting its ability to discriminate between individual patients.[136]

5.3 Community Balance and Mobility Scale (CB&M)

The Community Balance and Mobility Scale (CB&M) was developed because of BBS and PASS has ceiling effect to detect patient's improvement after 3 months post-stroke. CB&M was developed for assessing balance and mobility in moderate to high functioning person after stroke in the process of returning to community living.[138] This scale incorporates the demanding tasks commonly performed in community such as walking and looking at target, to assess a wide range of mobility and balance abilities in ambulatory patients.[138] CB&M consists of 19 tasks including advanced functional balance and mobility activities such as hopping on 1-leg, running etc. Items are scored on ordinal scale 0 to 5, where 0 means unable to perform and 5 means able to perform independently, with and extra point given for carrying a basket while descending stairs. The maximum score is 96 points with higher scores indicate better balance and mobility.[138] This scale has moderate to high convergent validities with BBS and TUG (p=0.70-0.83) and moderate correlation with Chodoke McMaster stroke assessment (CMSA) leg and foot score (p=0.61-0.63) and the paretic limb strength (p=0.67). The CB&M provide sufficient challenge to discriminate among those with no know balance impairment and demonstrated the greatest ability to detect change (SRM=0.83).[139]

5.4 Dynamic Gait Index (DGI)

Dynamic Gait Index (DGI) is developed to assess balance during gait. The DGI has 8 items: walking, walking while changing speed, walking while turning the head horizontally and vertically, walking with pivot turn, walking over and around obstacles, and stair climbing. The scoring of the DGI is based on a 4-point scale ranging from 0 to 3, with 0 indicating severe impairment and 3 indicating normal ability.[148] The best performance total score is 24. A low composite DGI score thus indicates greater impairment in functional mobility.[148] These functional balance tools have good reliability in patients with stroke, moderate validity with computerized posturography and good validity with other functional balance assessment tools or disability assessment tools.[148]

5.5 Physiological Balance Profile (PPA)

Physiological Balance Profile (PPA) is focused on physiological impairment that leads to fall risk which a simple test of vision, coetaneous sensation on the feet, leg muscle force, reaction time, and postural sway in stance.[62] Time to complete of a short form PPA is 15 minutes. The PPA is a valid and reliable measure fall risk in older adult and can be used to discriminate between faller and non-fallers.[62-64] However, PPA results do not help guide treatment because it focused on identifying the pathology such as peripheral neuropathy or visual problem that may contribute to balance problem.

5.6 Balance Evaluation Systems Test (BESTest)

The Balance Evaluation Systems Test (BESTest) focuses on differentiating 6 different underlying balance control system. A theoretical construct of the BESTest is based on Bernstein's concept that postural control results from a set of interacting system (figure 9)[66-71] and supported by research evidence of how constraints or deficit in different underlying system can impair balance.[58, 66-68, 70, 72-87] There are six interacting systems underlying the control of balance in the BESTest theoretical construct where each system consists of neurophysiological mechanism that controls a particular aspect of postural control.[65] Most of these systems are independent from each other, so that different pathologies involved damage different system result in different characteristic of balance impairment. Therefore, the BESTest is design to differentiate the underlying system contribution to balance problems (table 1) and fall risk in neurological patients in order to appropriately direct intervention.[65]

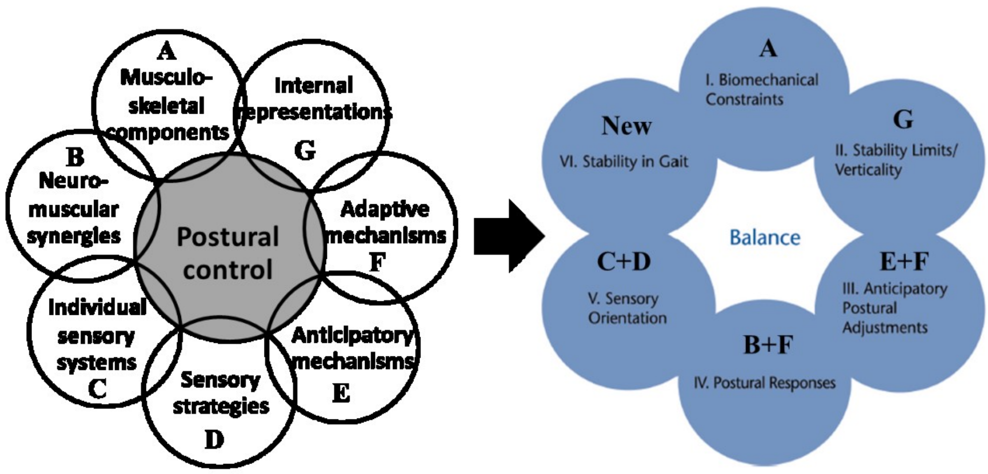

FIGURE 9 A THEORETICAL CONSTRUCT OF THE BESTEST BASED ON CONCEPTUAL MODEL OF POSTURAL CONTROL AND PREVIOUS RESEARCH.(29, 65)

TABLE 1 A COMPREHENSIVE OF EACH CLINICAL BALANCE ASSESSMENT TOOL IN MEASURE VARIOUS ASPECTS OF POSTURAL CONTROL SUCH AS SUBSYSTEM OF POSTURAL CONTROL AND BALANCE PERFORMANCE IN EACH FUNCTIONAL TASK.

Tools	Postural control subcomponent							Functional balance			
	Musculo-skeletal components	Neuro-muscular synergies	Individual sensory systems	Sensory strategies	Anticipatory mechanism	Adaptive mechanisms	Internal representations	Maintain of posture	Position change	Walking	Advance tasks
BESTest	/ Sect I	/ Sect IV	/ Sect V	/ Sect V	/ Sect III	/ Sect IV	/ Sect II	/ Sect II	/ Sect III	/ Sect VI	/ Sect VI
BBS	-	-	-	-	/	-	-	/	/	-	-
PASS	-	-	-	-	/	-	-	/	/	-	-
CB&M	-	-	-	-	/	-	-	/	/	/	/
DGI	-	-	/	/	/	-	-	-	/	/	/
TUG	-	-	-	-	/	-	-	/	/	/	-
FM-B	-	/	-	-	/	/	-	-	/	/	-

Note: Advance tasks are tasks that more challenge to postural control such as dual task, running, hoping. Sect = section

The BESTest consists of 6 performance tasks that are grouped under each postural system (Table 2). Many tasks of the BESTest have been borrowed from the following previously validated balance assessment: BBS, DGI, single limb stand test, Time Up go Test (TUG), Functional Reach Test (FRT) and modified Clinical Test of Sensory Integration and Balance test (mCTSIB) (Table 3). The novel items include a dual-task, postural response and compensatory stepping items, general alignment in standing, functional strength in the hip and ankle, leaning and returning to vertical, sitting on the ground and returning to standing position and standing on an incline.[65]

The section I, biomechanical constraints examine biomechanical component of standing balance by the observation and scaling of the quality of the base of foot support (item 1), geometric postural alignment (item 2), functional ankle and hip strength for standing (item 3 and 4), and ability to rise from the floor to a standing position (item 5).[65]

The section II, stability limits and verticality include items for evaluating perceived limits of stability and perception of verticality that represent internal representation. The ability to lean as far as possible in a sitting position with eyes closed (item 6) provides a measure of lateral limits of stability in a sitting posture, and the ability to realign the trunk and head back to perceived vertical (item 6) provides a measure of internal representation of gravity. The ability to reach maximally forward and laterally while standing (items 7 and 8) represents the functional limits of stability, although this may not necessarily be correlated with how far a person can lean the body’s center of mass when not reaching.[65]

The section III is for testing anticipatory postural adjustments. This section includes tasks that require an active movement of the CoM prior to voluntary commands to active muscle. This system includes tasks that require an active movement of the body’s center of mass in anticipation of a postural transition from one body position to another. The tasks include the transitions from a sitting to a standing position (item 9), from normal stance to stance on toes (item 10), and from 2-legged- to 1-legged stance (item 11).[65]

TABLE 2 SUMMARY OF THE BESTEST ITEMS UNDER EACH SYSTEM CATEGORY.[65]

I. Biomechanical Constraints	II. Stability Limits/Verticality	III. Anticipatory Postural Adjustments	IV. Postural Responses	V. Sensory Orientation	VI. Stability in Gait
1. Base of support	6. Sitting verticality and lateral lean in both side	9. Sit to stand	14. In-place response, forward	19. Sensory integration for balance (modified CTSIB) --	21. Gait, level surface 22. Change in gait speed
2. CoM alignment		10. Rise to toes	15. In-place response, backward	Stance on firm surface, EO Stance on firm surface, EC	23. Walk with head turns, horizontal
3. Ankle strength and ROM	7. Functional reach forward	11. Stand on one leg (left & right)	16. Compensatory stepping correction, forward	Stance on foam, EO Stance on foam, EC	24. Walk with pivot turns 25. Step over obstacles
4. Hip/trunk lateral strength	8. Functional reach lateral (left & right)	12. Alternate stair touching	17. Compensatory stepping correction, backward	20. Incline, EC	26. Timed “Get Up & Go” Test
5. Sit on floor and stand up		13. Standing arm raise	18. Compensatory stepping correction, lateral (left & right)		27. Timed “Get Up & Go” Test with dual task

Note: EO = eyes open and EC = eyes close.

TABLE 3 THE BORROWED TASKS FROM EXISTING CLINICAL TEST IN THE BESTEST.[65]

	Clinical Test					
	Functional Reach Test	Fregly Single-Limb Stance Test	Berg Balance Scale	CTSIB	Dynamic Gait Index	Timed “Up & Go” Test
BESTest Item	7. Functional reach forward	11. Stand on one leg, right	12. Alternate stair touching	19. Sensory integration for balance, stance on firm surface, EO	21. Gait, level surface	26. Timed “Get Up & Go” Test
	8. Functional reach lateral, right	11. Stand on one leg, left		19. Sensory integration for balance, stance on firm surface, EC	22. Change in gait speed	
	8. Functional reach lateral, left			19. Sensory integration for balance, stance on foam, EO	23. Walk with head turns, horizontal	
				19. Sensory integration for balance, stance on foam, EC	24. Walk with pivot turns	
					25. Step over obstacles	

Note: EO = eyes open and EC = eyes close.

In addition, consist task that involves repetitive weight shifting from leg to leg in anticipation of tapping a forefoot on a stool (item 12), and involves anticipatory postural adjustments prior to rapid, bilateral arm raises with a weight (item 13) .[65]

The section IV, Reactive postural responses include both in-place and compensatory stepping responses to an external perturbation induced by the examiner's hands using the unique "push and release" technique. To induce an automatic postural response with the patient's feet in-place (ankle or hip strategy), the tester pushes isometrically against either the front (item 14) or back (item 15) of the patient's shoulders until either the toes or the heels just begin to raise without changing the initial position of the body's center of mass over the feet before suddenly letting go of the push. To induce compensatory stepping responses, the tester requires a forward (item 16) or backward (item 17) or lateral (item 18) lean of the patient's center of mass over the base of foot support prior to release of pressure, requiring a fast, automatic step to recover equilibrium.[65]

The section V is for testing the CNS's ability to appropriately organize and choose sensory information under situation that altering visual or surface somatosensory information for control of standing (sensory organization test). For scoring were based on identifies any increase in body sway during stance associated with altering visual or surface somatosensory information for control of standing balance. Item 19 is the modified Clinical Test of Sensory Integration for Balance (CITSIB),[70] and item 20 involves standing on a 10-degree, toes-up incline with eyes closed for determine whether the CNS can shift from relying on a surface-based to a gravity-based for postural orientation. The patient cannot learn to align the body posture to gravity-based reference frame which directly respect to earth vertical and prefers a surface-based reference frame to keep body alignment perpendicular to supporting surface if a patient sway backward during standing on incline (toe up) surface.[65]

The section VI includes tasks for testing dynamic balance during gait. The body's CoM is controlled over a rhythmic changing base of foot support during walking (item 21). More challenged balance can be tested by changing gait speed (item 22), by head rotation (item 23), by pivot turn (item 24) by stepping over obstacles (item 25). In addition with dual task that assess by the Timed Up and Go test (item 26) Timed Up and Go test with secondary task (item 27).[65]

Content validity of the BESTest were studied by thousands of experimental physical therapy clinicians providing feedback about clarify and sensitivity, and practicality of item for contributed to continued development of the BESTest across 38 continuing education workshops delivered by Horak between 1999 to 2005.[65]

The psychometric properties of this scale in normal subject and neurological patient showed excellent interrater reliability (ICC=0.91), moderate validity with individual's self-perceived balance (r=0.64) and subjects with different diagnoses scored poorly on different sections of the BESTest when assessing a mixed population of individual with and without disease.[65] The psychometric properties of the BESTest in Parkinson's disease reported excellent test-retest reliability (ICC=0.88) and interrater reliability was (ICC=0.96).[89] The BESTest showed excellent convergent validity with BBS (r=0.87). Cutoff scores to identify fallers in Parkinson's disease were 69% for the BESTest.[149, 150]

The Mini-BESTest is a reduced form of the BESTest by using factor and Rasch analysis. Franchignoni and coworker[151] examined performance of the BESTest in a convenience sample of 115 consecutive adult patients with diverse neurological diagnoses and disease severity, referred to rehabilitation for balance disorders. Factor (both explorative and confirmatory) and Rasch analysis were used to process the data in order to produce a new, reduced and coherent balance measurement tool. The factor analysis selected 24 out of the 36 original BESTest items that were likely to represent the unidimensional construct of "dynamic balance" and Rasch analysis was then used to delete 10 items that mis-fitting or showing local dependency and reduced rating categories from 0-3 level to 0-2 level of rating categories. Therefore, Mini-BESTest consists of 14 items focusing on dynamic balance. This test can be conducted in 10–15 min, and contains items belonging evenly to 4 of the 6 sections from the original BESTest.[151] Several studies have shown that the Mini-BESTest was also reliable, valid[152-154] and useful for fall prediction in patients with PD.[149, 150] The use of the Mini-BESTest in community-dwellers with chronic stroke has been recently reported with excellent interrater and intrarater reliability and high correlations with other balance measures such as BBS and TUG but without the floor and ceiling effects seen in these traditional balance tests.[155] However, the feasibility of the Mini-BESTest to assess balance across lower levels of subacute stroke impairment severity has not been reported.

Although, the mini-BESTest represent a singular construction (termed "dynamic balance") that opposed to the original BESTest which sought a global assessment of multiple constructs underlying postural impairment. Thereby, the Brief-BESTest is another shorter version of the BESTest based on its original theoretical construction. The aim of developed the Brief-BESTest is generating a time efficient balance assessment across systems underlying of postural control for use across multiple clinical population.[153] The item with the highest average item-total correlations for each section was selected for inclusion in a new Brief-BESTest included hip abductor strength, functional reach forward, one-leg stance, lateral push-and release, standing on foam with eyes closed and the Timed “Up & Go” Test. The accuracy of differentiate people with and without a neurological diagnosis was 72% for the the Brief-BESTest and Mini-BESTest and 78% for the BESTest.[153] The Brief-BESTest showed highest sensitivity (100% for the Brief-BESTest, 71% for Mini-BESTest, 86% for the BESTest) for identify faller while all version have specificity of 95% to 100% to identify nonfaller in persons with and without multiple sclerosis (MS).[153] However, the BESTest demonstrated highest prospective fall prediction accuracy, sensitivity and specificity over 6 months than the Mini-BESTest and Brief-BESTest in person with PD.[150]

The BESTest has never been used in persons with stroke (Table 4). Therefore, the reliability and validity in patient with stroke needs to be assessed, as the precision of the measure varies across different purpose depending on the particular target population and specific situation. Thus, prior to the implementation of the BESTest in patients with stroke, it is necessary to examine whether the items are appropriate and resolution of scoring adequate and it can be used to assess balance change overtime in stroke patients across functional ability.

6. Psychometric properties of measurement

Psychometric properties are basic assessment process for consideration of the good measurement as well as the feasibility of using an instrument for a given purpose. The basis of psychometric are lie in standardization, reliability and validity.[156]

The development of measurement consists of three steps following set aims and purposed specifications, writing items and standardization and test a reliability and validity.[156-159] Setting aims of measurement in the first step is very important for defining what is to be measured. This definition must be based on nature of attributes, theory or evidence from research. Other proposed specifications are test content, target population, the kind and numbers of items, the times required for completion. Next step is to design and construct items, administering instruction and scoring system, considering the most appropriate response format and trying it in target population for selecting items and standardization. The last important step is the test consistency and accuracy of measurement represented by reliability and validity study. Reliability and validity is a heart of measurement.[160] They are the first prerequisite for representing that the measurement is consistent, free from error and assuring that a test is measuring what it is intended to measure.[160]

6.1 Reliability

Regardless of the fact that some measurement error can be minimized by a carefully design method of measurement, however, error from response of rater, subject and environment may not be controllable.[156, 160] Thus, reliability is necessary to ensure that that measurement is measuring something consistent and free from error and have confidence in drawing rational conclusion.[160] It gives evidence that same measurement in same individual in conditions which different occasion, or different observer, or repeated administration produce the same or similar result.[156, 160, 161] Reliability focuses on the degree of random error or unpredictable factor such as fatigue, inattention, mechanical inaccuracy or simple mistakes.[156, 160, 161] Reliability can be estimated based on the statistical concept of variance of score within a sample that some of this total variance in observed score will be the result of true differences among the scores and some can be attributes to random error.[160, 161] Reliability coefficient is a ratio of subject (true score) variance and observed score that is a sum of subject (true score) variance and measurement error.[160, 161] If reliability reaches maximum (zero error), this ratio give a coefficient rise to 1.00. While the error increases, the reliability coefficient will be closed to zero.[160, 161]

TABLE 4 PSYCHOMETRIC PROPERTIES AND LIMITATION OF CLINICAL BALANCE ASSESSMENT TOOLS.

Tools	Reliability			Validity						Limitation		
				Criterion-related		Construct		Responsiveness (ES&SRM)	Cut off point			
	Internal consistency	Interrater (ICC)	Test Retest (ICC)	Concurrent (*r*)	Predictive (*r*)	Convergent (*r*)	Known groups			Floor effect	Ceiling effect	Time to complete
BESTest	-	0.91	-	ABC : 0.69	-	- -	Norm. Vs balance deficit	-	-	-	-	20-30 min
BBS	Cronbach alpha = 0.92-0.98	0.95-0.98	0.98	Postural sway: 0.50- 0.57 Sit and stand: 0.7 FRT: 0.78 FM: 0.24-0.80 Balance master: 0.48- 0.67	Length of stay: 0.39-0.53 MAS score at D180: 0.82- 0.91 Disability level at D90: 0.81	BI: 0.80- 0.94 FM-B:0.62-0.94 PASS: 0.92-0.95 FIM: 0.76	Based on location at follow up Function dependent	D30:0.80 D30-D90: 0.69 D90-D180: 0.40	45	D14 (23%)	D38 (26%)	10-20 min
PASS	Cronbach alpha 0.95	Kappa 0.88	Kappa 0.72	Pro balance master: 0.48	FIM score at D90: 0.75	FIM: 0.73 LLs strength:0.8	-	-	-	NO	D90	10-20 min
CB&M	Cronbach alpha 0.96 (TBI)	0.98	0.98	-	-	BBS: 0.83 TUG: 0.75	-	M3-M8 0.83	-	May be**	NO	10-20 min
DGI	-	0.96	0.96	BBS: 0.83 TUG :0.77 ABC: 0.68 10m WT: 0.73	-	- -	-	-	-	May be**	-	10-20 min

Note: [a] study in neurological disorder include vestibular disorder, Parkinson's disease and peripheral neuropathy which never been study in stroke population ICC= Intraclass Correlation Coefficient; Norm= normal; min= minute; r=correlation coefficient; FRT= Functional Reach Test; FIM= Functional Independence Measurement; FM-B =Fulg-Meyer Assessment-balance subscale; MAS=Motor Assessment Scale; D= Day; M = Month; BI= Barthel Index; ES= Effect Size; LLs= Lower limbs;

Portney and Watkins recommended reliability coefficient of measurement that is used for decision making or diagnosis need to be higher, perhaps at least 0.90 to ensure valid interpretations of finding.[160] There are several ways to improve reliability by reducing error variance such as rater training, design a standardization and simply scale and careful about floor and ceiling effect.[168]

Test retest reliability is used to establish measurement consistency that it will obtain the same result with repeated administration of test. The method to study test retest reliability is when the same rater administers it in the same subjects on separate occasions which a time interval sufficiently short for keeping all testing condition as constant as possible.[160] Thus, it estimates reliability of an instrument. Inappropriate time interval of separate occasion may affect test retest reliability by changing underlying process, therefore, it should be far enough apart to avoid fatigues, memory effect, but close enough to avoid genuine change in the measure variable. General recommendation is two to fourteen days.[167,168] When the test itself is responsible for observed changes in a measured variable, the change is considered a testing effect.[160] The intraclass correlation coefficient (ICC) has become the preferred index, as it reflects both correlation and agreement.[160, 161]

Sometimes clinical measurement requires rater to be a part of the measurement system, such as provide a physical application of a tool or read or interpret output from instrument.[160] Therefore, rater must be consistency in application test and scoring subject’s responses that reflect rater reliability. Rater reliability is varying importance to the validity of any research study involving tester.[160] To establish rater reliability, the instrument and response variable are assumed stable, so that any different between scores are attributed to rater error.[160, 161] There are two type of rater reliability. Intrarater reliability refers to the stability of scoring by one rater across two or more trials test.[160] Time interval of trials must be as short as possible but should be enough to avoid fatigues and memory effect.[169] Intrarater reliability will be providing strength of measurement accuracy of data and research conclusion.[160] While interrater reliability concerns the variation between two or more raters who measure the same group of subjects. Even with detailed operational definition and equal skill, different rater is not always in agreement about the quality or quantity of the variable being assess.[160] Intrarater reliability should be established for each individual rater before comparing rater to each other.[160] Interrater reliability is best assessed when all raters are able to measure a response during a single trail where they can observe a subject simultaneously and independently because these method minimizes true difference in score from measurement error when comparing rater's scores.[156, 160] Videotapes of subject's performance have proven useful for allowing multiple raters to observe the exact same performance.[160] Interrater reliability allows the researcher to assume that the measurement obtained by one rater are likely to be representative of the subject's true score, and therefore, the result can be interpreted and applied with greater confidence. ICC should be used to evaluate rater reliability for interrater reliability, ICC model 2 or 3 can be use, depending on whether the raters are representative of other similar rater (model 2) or no generalization is intended (model 3) and for intrarater reliability, ICC model 3 should be used.[160, 161]

6.2 Validity

Validity is the second prerequisite to ensure that the instrument measure measuring what it is intended to measure.[162] Although, measurement may have reliability but it is not sufficient for validity. Scores may show consistency and still not be measuring the intended concept or attribute.[161] For measurement that have purpose to use discrimination, evaluation or prediction, it must be tested whether these measurements are capable of discriminating among individuals with and without certain trails, evaluating change in the magnitude and accurate prediction or diagnosis about patients potential function based on the outcome of test.[160] The determination of validity for any test instrument can be made in variety of context, depending on how the instrument will be used, the type of data it will generate, and the precision of response variables.[160, 161] Validity is not inherent to an instrument, but must be evaluated within the context of test's intended use. Validation of instrument requires the use of several strategies to examine whether the scale is performing to expectation.[156] The major types of validity consist of content, criterion and construct.[163]

6.2.1 Content validity

Content validity means whether the items in the scale adequately represent the dimensions and domain of the concept of interest.[141] Because the content universe is theoretical, it must be defined by representative parts of the whole. An instrument will have content validity when their tests cover all part of the universe of theoretical and reflect the relative important of each point.[160] No statistical indices can assess content validity. The determination of content validity is made by a panel of experts who review the instrument and determine if the question or test satisfy the content domain.[156, 164, 165] This process often requires several revision of the test and content validity will be accepted when all experts agree that the content domain has been sampled adequately.[156, 160]

6.2.2 Criterion validity

Criterion validity is the most practical and objective approach to validity testing.[160] It compares the test scores with a gold standard or criterion measure.[160, 161] The criterion measure must have test-retest reliability, measuring the same thing with target test and both criterion and target rating should be independent and free from bias.[156, 160] Therefore, target test will have validity when it has comparable results with gold standard or criterion measure that assumed to be a valid indicator of variable of interest. However, the gold standard for abstract construct is not always available, criterion validation may be based on a reference standard that has already achieved a degree of validation or acceptable.[160] Criterion validity can be divided into two types: concurrent validity and predictive validity. They have different time frame to approach.[160, 161]

Concurrent validity will be tested when having a new or untested measurement tool that potentially have more efficient, easier to administer, more practical, or safer than available tool.[160] In concurrent validity, target test and criterion measure are taken at relatively the same time, so that they both reflect the same incidence of behavior.[160]

While, predictive validity will be used to establish that a target test will be a valid predictor of some future criterion score.[160] For test predictive validity, a target test is given at one session and is followed by a period of time after which the criterion score is obtained. It is important for helping screening future risk, prognosis and setting long-term goal.

6.2.3 Construct validity

Construct validity provides evidence to support the theoretical framework behind the construct.[156, 160, 161] Construct validation is an ongoing process and there is no one single experiment which can unequivocally prove a construct.[156, 160, 161] Several methods are commonly used for construct validity including convergent and discriminative, known group analysis, factor analysis, hypothesis testing, and criterion validation. Each of the constructs needs to be measured in at least two different ways.[156]

Construct validity of the measure can be evaluated in term of how its measure relate to other of the same (convergent validity) and different construct (discriminative validity).[161, 166] Convergent validity indicates that two measures believed to reflect the same underlying construct will show close results or will correlate highly. However, convergent is not a sufficient criterion for construct validity, it is also necessary to show that a construct can be differentiated from other construct.[161] Therefore, discriminant validity will be used, and it indicates that different results or low correlations are expected from the measures that are believed to assess different construct.[161]

Known group method is supported when a measure can discriminate between individuals who are known to have trait and those that do not.[160, 161] To assess known group method, a criterion measure that can identify the presence or absence of particular characteristic will be used to indicate that the theoretical context behind the construct can predict how different groups are expected to behave.[160]

Factor analysis is the common construct validity approach that requires a statistical procedure.[160] The concept of factor analysis is based on the idea that the construct contains one or more underlying dimension or different theoretical component.[160]

These separate grouping of correlated variables represent subset of test items or behaviors that are related to each other, but are not related to item in other factor. In other word, factor represents a unique combination of item that reflects a different theoretical component of construct.[160]

6.3 Responsiveness

Responsiveness is defined as the capacity of instrument to detect clinical change which is important characteristic of instrument for intervention studies.[160, 167, 168] The difference between the outcome score and the initial score is called a change score which is considered as a basis for analysis of treatment outcome effect.[160, 161] For analyzing treatment effect, it is necessary to distinguish those who changed a lot from those who changed a little and draw inference to treatment effect.[161] Therefore, it is essential to concern about responsiveness of the measurement or it ability to detect true clinical change over time.[167, 168] Responsiveness is supported when the score changes in proportion to the change in patient's status or remains stable when the patient is unchanged.[160, 169] This change must be large enough to be statistically significant for research purpose and precise enough to reflect increments of meaningful change in an external criterion for clinical application.[160] Amount of change within-person from one time to another time is a continuum of change as shown in Figure 10. The minimal detectable difference (MDD) or change (MDC) is the smallest amount of change that can be considered above the threshold of measurement error.[160] Such changes can be measured by statistical significant between before and after scores or high correlation with the external standard. The important or meaningful change has been called the minimal clinically important difference (MCID) which defined as the smallest real change in an outcome measure that is perceived as beneficial by the patients, and that would lead to change in the patient's management, assuming an absence of excessive side effect and cost.[170]

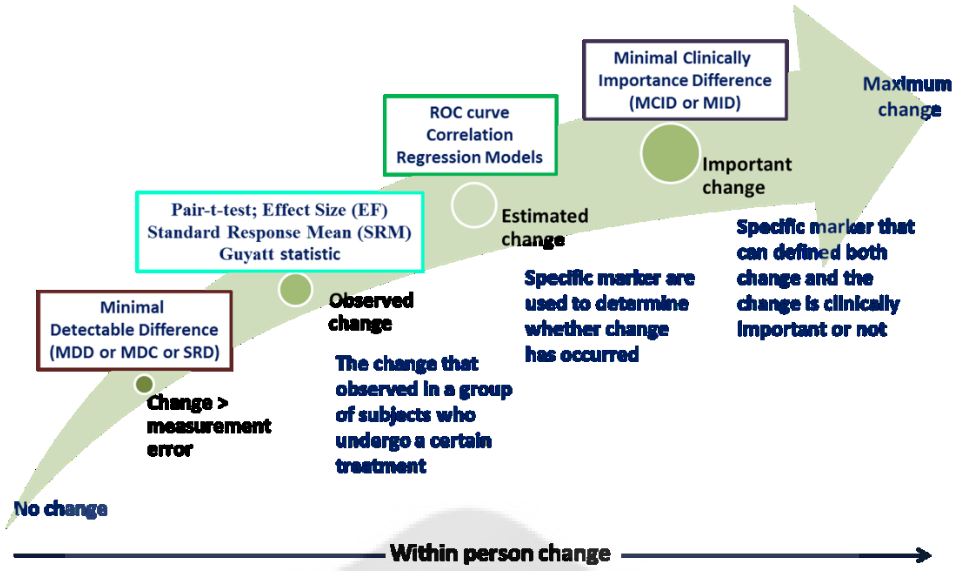

FIGURE 10 A CONTINUUM OF CHANGE AND METHOD FOR MEASURE ITS.[160, 167, 168]

There are several methods to measure responsiveness, but these methods can be classified into two major aspects; internal and external res ponsiveness.[168, 171]

6.3.1 Internal responsiveness

Internal responsiveness or sensitivity to internal change is defined as capacity of a measure to change in determined laps of time[167]; it refers to the possibility of detecting any kind of statistical change.[167] This method is a widely used method of assessing responsiveness which measure the change by using a single group repeated measures design, where patients are assessed before and after a known efficacious treatment.[168] The sensitivity to internal change of a measure evaluated with this method will depend upon both the treatment and outcome measure of therapeutic efficacy.[167, 168] The common statistics used to determine internal responsiveness consists of paired *t*-test, effect size, standardized response mean (SRM) and Guyutt statistic.[160, 167, 168]

6.3.1.1 Paired *t*-test

This test is used to prove the absence change hypothesis of the mean response on the measure over two time-points. The study design is a one-group repeated measure, the observed value for *t* is:[167, 168]

$$t = \Delta mean/(\frac{SD\Delta mean}{\sqrt{n}})$$

The statistical significance of observed change from this method depends on the magnitude of change, size of sample and the variability of the measure, resulting in weak statistic test for evaluating responsiveness to change.[167] However, with a reasonable sample size (n>30), a value of t greater than 1.96 indicates statistically significant change in the measure occurred over time.[168]

6.3.1.2 Effect size

Effect size is wildly considered more acceptable to determine if meaningful change has occurred, because it does take group variability into account. It is a standardized measure of change from baseline to final measurement. Three forms of effect size have been used.[160]

The effect size index (ES) is a ratio of the mean change score divided by the standard deviation of baseline score.

$$ES = \frac{\Delta mean}{SDbaseline}$$

ES is not affected by samples size, but may vary among samples with different baseline variability.[160] The effect size index will be small when the measure has high variability in baseline scores. The effect size of 0.20 or less indicates a small change, 0.50 indicates moderate change and 0.80 or more indicates a large change.[172] As these values are interpreted relative to baseline variability, it is uncertain whether ES reflects a real change or just the variability of baseline score. However, a moderate effect size does reflect a change of at least one-half the baseline standard deviation.[160, 167]

The second form is **standardized response mean (SRM)** or sometimes referred to as the efficiency index.[173, 174] The SRM is a ratio of change from pretest to posttest divided by the standard deviation of change scores.[160]

$$SRM = \frac{\Delta mean}{SD\Delta mean}$$

SRM provides information on magnitude of change in standardized units relative to variability of change, thus SRM will vary as a function of effectiveness of treatment.[175] The distribution of scores that has high variability in the degree of change will result in small

SRM. The criteria for determining the size of SRM is the same as that for effect size index.[160] SRM of 0.20 or less indicates a small change, 0.50 indicates moderate change and 0.80 or more indicates a large change. SRM is independent from size of sample and in addition take into account the variability change, making it the most adequate statistic for study of responsiveness in this type of design.[167]

The third form of effect size is **responsiveness index** or **Guyatt's responsiveness index**.[176] It is also based on the size of effect and consists in the coefficient between the MCID and error of the quadratic mean (MSE) in a variance analysis of repeated measure in clinically stable patient.[167]

$$Guyatt = \frac{MCID}{\sqrt{2 \times MSE}}$$

Guyatt's responsiveness index provides a measure of change relative to variability in scores among patients who are clinical stable. The denominator includes the mean square error from an ANOVA, which may be obtained for test-retest reliability scores, or repeated observations in clinically stable patients.[160] Guyutt statistic is a form of detecting modifications in the different outcome measure of the random changes presented the patients who do not showed detectable improvement. The responsiveness is determined when it can detecting MCID larger than any sudden change.[167] This test is seldom used due to the difficulties inherent to the definition of MCID.[167]

The limitation of internal responsiveness is that it does not relate to corresponding changes on an external clinical or health status measure at the individual level (external responsiveness). Therefore, the internal responsiveness is the indicator of significant change in score but it lacks of information on the quality of changes such as worsening or improvement or clinical relevance.[167]

6.3.2 External responsiveness

The external responsiveness to change is defined as the degree with which change in a measurement with time are related to the corresponding change in a standard measure of health status.[167] It is associated to the concept of clinical relevance which is a property of measurement to measure a clinically important change that is related with change in the external standard.[167, 168] The external responsiveness depends on the magnitude of change and the choice of external standard.[167] The commonly used method for measuring the external responsiveness consists of receiver operating characteristic (ROC), correlation, and regression model.[167, 168]

6.3.2.1 Receiver operating characteristic (ROC)

The ROC curve is used to measure external responsiveness by measuring the instrument capacity to correctly identify individuals who present an important clinical change based on change of the external standard.[167] in this method, responsiveness is described in term of sensitivity (the probability that a measure will correctly classify patients who had change in an external standard indicator change) and specificity (probability that the measure will correctly classify patients who did not show change in the external standard) which are the ability of measure to reflect both change (sensitivity) and no change (specificity) in the external standard.[167, 168] The area under the curve (AUC) in the relationship of sensitivity and false-positive rates (1-specificity) curve represents the discriminative capacity of the instrument or the probability of correctly classifying both patients who show improvement (or worsening) and that do not improve (or worsen).[167] AUC value of 0.90 and above indicates high accuracy, 0.70 to 0.90 indicates moderate accuracy, 0.50 to 0.70 indicates low accuracy and 0.50 and below indicates test due to chance.[177] The cutoff point value is chosen by selecting the score that provides the best balance between high sensitivity and high specificity.[160]

The likelihood ratios (LR) are used to determine the posttest probability of this method. It indicates the power of the cutoff point for increasing certainty of correctly classification; patients who had change and patients who did not show change in the external standard.[160] The likelihood ratios can be determined as positive and negative values. The positive likelihood ratios (LR+) reflect how many times more likely a positive test will be seen in those had changed than in those did not change.[160]

$$LR+=\frac{\text{true positive rate}}{false\ positive\ rate}=\frac{\text{sensitivity}}{1-specificity}$$

The negative likelihood ratios (LR-) indicate how many times more likely a negative test will be seen in those had changed than in those did not change.[160]

$$LR- = \frac{\text{false negative rate}}{\text{true negative}rate} = \frac{1-\text{sensitivity}}{specificity}$$

A good test will have both high LR+ and very low LR-. A LR+ over than 5 and a LR- lower than 0.20 represent relatively important effects. Likelihood ratios between 0.20 to 0.50 and between 2 to 5 may be important, depending on nature of the diagnosis being studied, values close to 1 represent unimportant effects, it means the test is useless.[160]

The limitation of this method are that the classification variable (standard) must be dichotomized, result in loose information on the magnitude of change, and that it requires independent analysis to define responsiveness for improvement and worsening.[178, 179]

6.3.2.2 Correlation

The correlation is used to indicate how the target instrument changes simultaneously with the external standard.[167] Pearson's correlation coefficient is calculated by the change scores between 2 measures (*x* and *y*).[167, 168]

$$r_{xy} = \sum_{i=1}^{n} (D_{xi} - \bar{D}_x)(D_{yi} - \bar{D}_x)/n$$

The correlation coefficient values oscillate between -1 and +1. The r_{xy} close to 1 represents the measurement responding to change in the clinical results.[167] The major limitations of correlation method are the r_{xy} is derived from its variation in the response to the selection of values and the presumption of linearity between both variables, when in truth this relationship can be non-linear.[179]

6.3.2.3 Regression models

The advantage of this method is to examine if the change in measurement are capable of predicting changes in the other. This analysis can be performed though regression models.[167]

$$D_{yi} = \alpha + \beta D_{xi} + e_i$$

The parameter represents mean change in the clinical result (D_y) in the absence of change in evaluated instrument (d_x=0) for each unit of change in the instrument (d_x). β values close to 0 indicate that the important changes in x may not be accompanied by change in y, while elevated values for β indicate that the changes associated in y will also be important.[167] The main disadvantage is related to the choice of an external standard. In spite of an elevated correlation coefficient, the standard may not capture all of the observed changes in patients and on the other hand, the standard and the instrument could be measuring different aspects of one same concept.[167]

CHAPTER 3

METHODOLOGY

The present measurement study has three components consisting of reliability study, validity study and responsiveness study. For the reliability study, intrarater reliability and interrater reliability of the BESTest was examined in patients with stroke. Convergent validity and responsiveness of the BESTest were also determined in patients with stroke.

1. Research design

This study was an observational reliability, validity and responsiveness aimed to determine the reliability, convergent validity, responsiveness and floor, ceiling and responsive ceiling effects of the BESTest in people with stroke.

2. Participants

Participants were patients with subacute stroke (defined as the time since stroke of less than 4 months)[180] referred to Physical Therapy services at Prasart Neurological Institute in Thailand from November 1, 2012, to August 31, 2013. Individuals were included in this study if they passed the screening tests examined by a physician using the following criteria: diagnosis of cerebral hemorrhage or cerebral infarction with stable medical conditions, age between 25-90 years, first unilateral hemispheric stroke and able to follow instructions to complete the assessment. Individuals were excluded from the study if they presented with cognitive impairment as assessed by the Mini-Mental State Examination (MMSE) scored less than 24,[181, 182] cerebral aneurysm, lesion at brainstem which involves sleep-wake and respiratory control center or cerebellum, aphasia as diagnosed by a physician using a Thai adaptation of Western Aphasia Battery,[183] a neurological disorder other than stroke, and presence of major peripheral neuropathy or musculoskeletal problem that is sufficient to disturb balance. All participants signed a consent form approved by the

Human Research Protection Committee at Prasart Neurological Institute Research Center, Thailand.

The sample size for this study was calculated by the following equation.

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

The sample size calculation for the reliability study was based on a power of 0.80 and alpha level of 0.05. A previous correlation coefficient (r) of balance measure ranged from 0.88 to 0.98,[99] therefore, an expect correlation coefficient of this study was an average of this range, 0.93. A correlation coefficient for null hypothesis was at 0.60 that represents moderate to weak correlation.[184] Sample sizes of 12 were sufficient to permit a correlation for reliability study.

The sample size calculation for the validity study was based on a power of 0.80 and alpha level of 0.05. A previous correlation coefficient (r) of balance measure ranged from 0.62 to 0.95 but the average was 0.70 to 0.80,[99] therefore, an expect correlation coefficient of this study was 0.80. A correlation coefficient for null hypothesis was at least 0.50 that represents adequate correlation.[172] Sample sizes of 29 were sufficient to permit a correlation for validity study. However, the inflation 10% will be calculated for accounting to the drop-out for responsiveness study, therefore, a sample size of 35 were selected. Moreover, the functional ability of a stroke patient is a confounding factor; thus, the participants were divided by their functional ability into 2 group; low functional ability and high functional ability. As a result, total participants for validity and responsiveness study were 70 persons.

3. Outcome Measures

To determine whether the balance tools could separate participants into high and low functioning groups, the Fugl-Meyer Assessment motor subscale (FM-Motor) was selected to measure functional recovery from stroke.[185] The FM-Motor consists of 100-

point scoring each scored on a 3-point ordinal scale, ranging from “0 cannot perform” to “2 perform fully”. FM-motor score is used to classify patient with stroke into 4 groups according a level of disability; score 0-35 represents severe, 36-55 represents moderately severe, 56-79 represents moderate and 80 and higher represents mild.[186] In validity study, we referred to patients with stroke as low functional ability group (LFA) using FM-Motor score between 0-55, and as high functional ability group (HFA) for those who had FM-Motor score more than 55.

Four balance evaluation scales, including the Balance Evaluation Systems Test (BESTest), Berg Balance Scale (BBS), Postural Assessment Scale for Stroke Patients (PASS) and Community Balance and Mobility Scale (CB&M) were administered to each participant. Details of these balance scales were described in Chapter 2.

4. Materials and research tools

The materials used in this study included the followings.

1. Masking tape
2. Jerk hammer
3. Measuring tape
4. Posture grid chart
5. 2.5 kg. free weight
6. 10 degree incline ramp
7. Tennis ball and cylinder cup
8. Stopwatch (CASIO Stopwatch)
9. Medium density Temper® foam
10. Sphygmomanometer and stethoscope
11. Stair step 6*8 inches (width and height)
12. Two standard chairs (one with arm rests, one without)
13. Mini – Mental State Examination (Thai version) form
14. Fugl-Meyer assessment: motor function form
15. Balance assessment form

FIGURE 11 INSTRUMENT FOR SCREENING TEST AND FUGL-MYER MOTOR ASSESSMENT.

FIGURE 12 INSTRUMENT FOR BALANCE ASSESSMENT.

5. Procedure

5.1 Reliability

Interrater and intrarater reliability were determined by 5 physical therapists. Raters consisted of a convenient sample of 3 physical therapists from the stroke rehabilitation center with stroke rehabilitation experience of 1, 5 and 10 years, and 2 Physical Therapy PhD students from Srinakharinwirot University and Mahidol University.

Prior to the study, all raters participated in two training workshops for using the BESTest. The training workshop was carried out by a therapist who received the training from the BESTest developer. Each item of the BESTest was demonstrated on normal subjects and the rating criteria were discussed. All raters also scored each participant's performance from a demonstration video and rating criteria were discussed again if there was a discrepancy. When there were differences in the rating scores, the raters were asked to watch the videotape with the trainer who encouraged the discussion until all raters reached the agreement. After the training workshop, a BESTest reliability trial was performed in 12 patients with stroke (figure 13). The BESTest was administered by one rater (BC) and the procedures were video-recorded. The evaluation was performed in a laboratory setting at Prasart Neurological Institute room and videotape recording was performed in the same view in all participants. Rater BC used the same testing instructions to standardize the performance. Before testing, the vital signs of participants were evaluated for ensuring stable medical status. All participants received the same verbal instruction. Participants were permitted to rest as needed during the test.

All raters scored the patient's performance from videotape on 2 separate occasions. The second occasion was performed 7 days after the first occasion. Intrarater reliability of total scores and section scores were assessed by comparing the score of occasion 1 and score of occasion 2 in each rater. Interrater reliability was determined by comparing the score from occasion 1 between 5 raters. Each rater scored videotape separately on the separate scoring sheets for each occasion and did not discuss scoring among subjects and occasions.

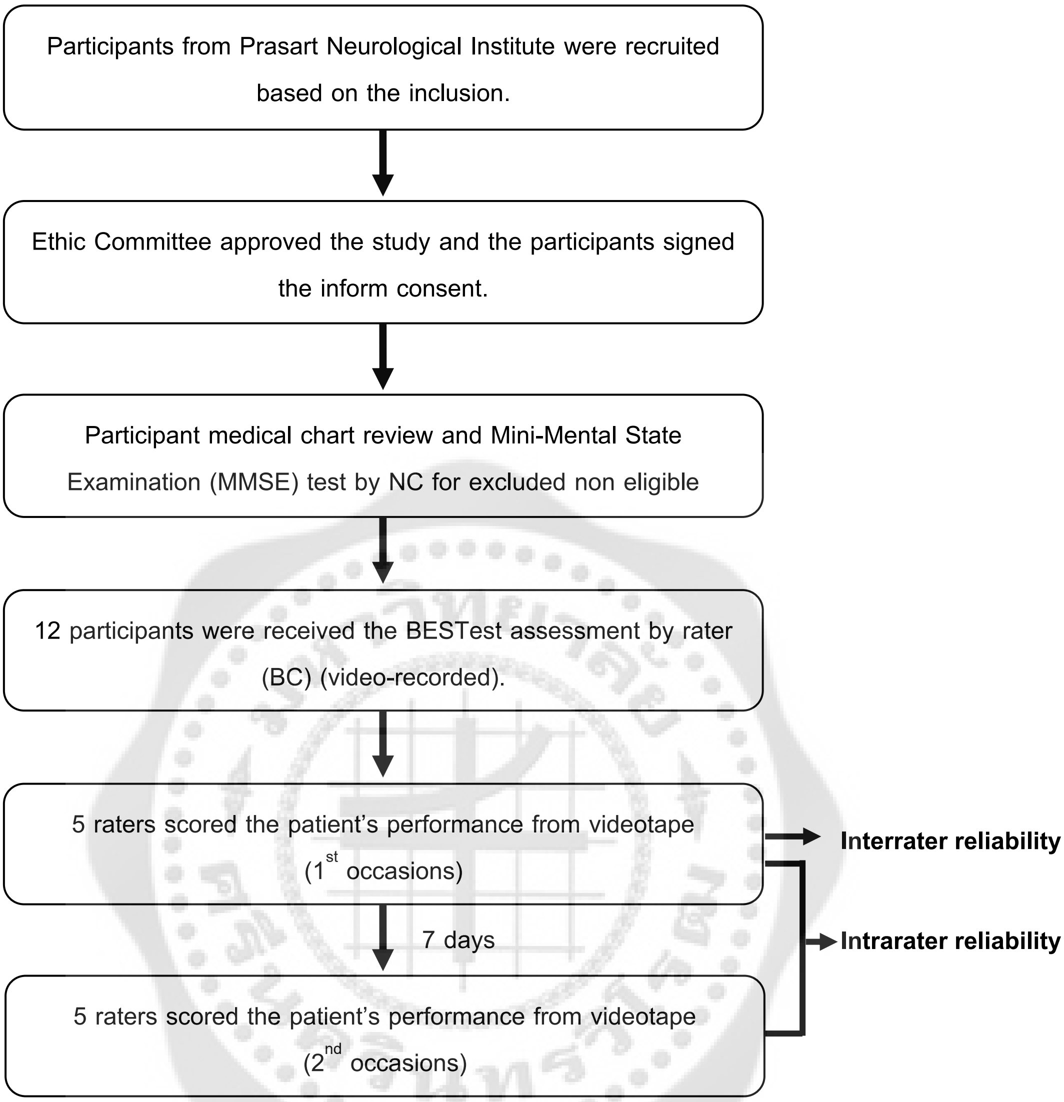

FIGURE 13 PROCEDURE OF RELIABILITY STUDY.

5.2 Validity study

Prior to the validity study, rater BC and NC received additional training for using the BBS, PASS and CB&M and FM-Motor. After signing the approved consent forms, participants completed demographic and clinical information including Barthel Index (BI) score and FM-Motor by rater NC (figure 14). Seventy participants, 35 in each LFA and HFA participated in this study. After that, the participants received balance assessment from the rater BC who was blinded to the basic characteristics and the Fugl-Meyer scores of the subjects. The sequence of the balance tests was randomly performed following the order of the starting position: from lying to sitting to standing and walking. Two patient assistance persons for safety when test start with standing and walking position in patients who have low functional ability. Any test item that was duplicated between the tests was performed only once and then scoring using criteria from each test.[89] The evaluation was performed in the same laboratory setting and all participants received the same verbal instruction. Rest was allowed during each item to avoid fatigue. Total assessment time was approximately 1.5 hours but if the testing could not completed in one day, it was continued on the next day. To ensure the accuracy of the scoring, rater BC reviewed and scored every patient's test performance from the videotape again. In case of the disagreement between concurrent rating and video rating, rater NC was asked to score those items from the videotape to decide the final score.

5.3 Responsiveness study

The repeated FM and balance assessment were carried out once after the end of one rehabilitation course using the same procedure as the validity study. The rehabilitation program consisted of 1 hour physical therapy training per day, 5 days per week. The 1 hour physical therapy training include passive stretching and active exercise, balance training and functional activities training such as bed mobility, sit to stand, and gait training.

Among the seventy original participants, 50 participants received continued rehabilitation after the baseline assessment and thus received balance assessment before discharge from the hospital.

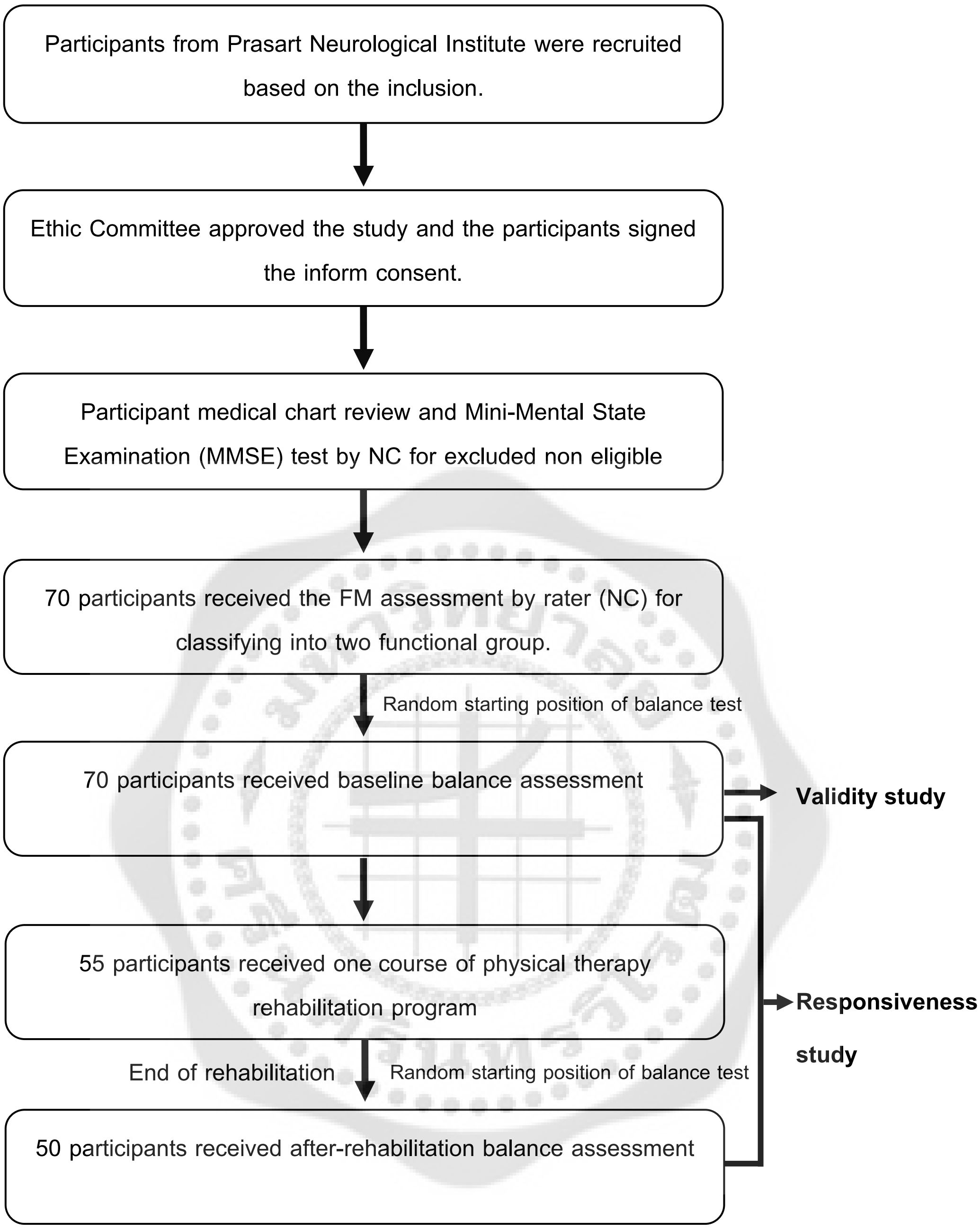

FIGURE 14 PROCEDURES OF VALIDITY AND RESPONSIVENESS STUDIES.

6. Data Analysis

Descriptive statistical analysis of demographic and baseline clinical characteristics of participants were conducted. Independent-sample *t* test was used to compare age, time since stroke, BI score and BBS score whereas Mann-Whitney U test was used to compare

MMSE score, FM score, and other balance measurement scores between the patients with LFA and HFA. Interrater and intrarater were calculated by interclass correlation coefficient (ICC).[160] ICC model 2, k was used for interrater reliability and model 3, k was used for intrarater reliability. ICC value of 0.80 and above indicates excellent correlation (good reliability), 0.80-0.60 indicates adequate correlation (moderate reliability) and 0.60 to 0.40 indicates poor correlation (weak reliability).[184, 186]

To determine the convergent validity of the BESTest, the strength of the relationship among the BESTest, PASS, BBS and CB&M were examined using the Spearman rank-order correlations. Correlation coefficients of 0.00 to 0.49 were interpreted as poor, those of 0.50 to 0.79 as moderate, and those 0.80 or higher as excellent.[172]

The floor and ceiling effects were calculated as the percentage of sample scoring the minimum or maximum possible scores, respectively. Ceiling and floor effects of 20% or greater are considered significant.[187] In this study, we also presented the "Responsive ceiling effect" that represent 20% or greater percentage of participants scored within the top 10% of the test which allows a sufficient amount of scores to measure change over time.[89] The percentage of minimum and maximum scores in each item of the BESTest were calculated as the percentage of participants who received minimum (score 0) and maximum (score 3) in each item. These percentages represented the difficulty of the item, such that a high percentage (>80%) of minimum score reflected a difficult item and a high percentage of maximum score indicated an easy item.

Receiver Operating Characteristic (ROC) curves were used to determine the relative performance of the BESTest score, the BBS score for classifying participants into two groups based on their FM-Motor score, to discriminate between low (FM-Motor $\leq$ 55) and high functional ability (FM-Motor > 55).The accuracy for each balance test was assessed using the area under the curve (AUC), which can be interpreted as the probability of correctly identifying participants with low or high function. AUC value of 0.90 and above indicates high accuracy, 0.70 to 0.90 indicates moderate accuracy, 0.50 to 0.70 indicates low accuracy and 0.50 and below indicates test due to chance.[177] The cutoff point value was chosen by selecting the score that provides the best balance between high sensitivity and high specificity.[160] Furthermore, a likelihood ratio and accuracy were used to determine posttest probabilities that helped to improve certainty for confirming the diagnosis or abandon it. A positive likelihood (LR+) ratio was the probability of a participant having a score above the cutoff point, whereas a negative likelihood (LR-) ratio was the probability of a participant having a score below the cutoff point. A LR+ over 5 and a LR- less than 0.20 indicate that the test is useful due to its high probability to correctly identify patients into the correct level of functional ability group, but the LR values that close to 1 indicates that the test is useless as the probability to correctly and incorrectly identify patients into the correct group is the same.[160] The accuracy of the selected cutoff point in classifying patients into the functional group was calculated as the proportion of the participants in the correctly identified when using that cutoff point to all participants.[160]

Paired *t* test was used to compare balance scores between before and after rehabilitation in responsiveness study. The SRM approach was employed to examine the internal responsiveness. The SRM was obtained by dividing the observed mean change scores by the standard deviation of the change score in the same participant. According to Cohen's criteria,[172] SRM greater than 0.80 indicates large change, 0.50 to 0.80 indicates moderate change, and 0.20 or less indicates a small change. Moderate and large SRM indicated sufficient internal responsiveness.

For the external responsiveness, the BBS was selected as an external criterion. The index of true balance change was based on the change in BBS score of >7.[144] The ROC curve approach was used to evaluate the external responsiveness by determining the relative BESTest score for classifying participants into two groups; patients who did not have balance change (BBS $\leq$ 7) and who have balance change overtime (BBS > 7). The accuracy was assessed using the AUC. The cutoff point value was chosen by selecting the score that provides the best balance between high sensitivity and high specificity.[160] A likelihood ratio and accuracy were used to improve certainty for confirming the diagnosis or abandon it.

7. Ethical Considerations

This research protocol was approved by the Human Research Protection Committee at Prasart Neurological Institute Research Center, Thailand. (number 54053)

CHAPTER 4

FINDINGS

This study aimed to assess the reliability, convergent validity and responsiveness of the BESTest in patients with stroke and to determine if the BESTest could be used to identify patients with low and high functional ability, as classified by the Fugl-Meyer Stroke Assessment-Motor subscale. The results of this study are presented as the following.

1. Reliability

Participants were recruited as a sample of convenience from patient who received rehabilitation at Prasart Neurological Institute from July 1, 2012, to August 31, 2012. Twelve patients with hemorrhagic or ischemic stroke; 4 female and 8 male with the age between 32 to 73 years, and have a wide range of time since stroke from 0.1 to 204 months, participated in the reliability test. Demographic of participants in the reliability test are presented in Table 5.

The intrarater and interrater reliability of the BESTest in person with stroke are presented in Table 6. The intrarater reliability of the BESTest total score was excellent, with ICC (95%CI) of 0.99 (0.99 to 1.00) and subsection ICCs ranged from 0.95 (0.90-0.98) to 0.99 (0.98-0.99). The interrater reliability, ICCs (95%CI) for the total scores of the BESTest was 0.99 (0.98 to 0.99) and subsection ICCs ranged from 0.87 (0.72 to 0.96) to 0.98 (0.95-0.99), indicating excellent reliability.

TABLE 5 DEMOGRAPHIC AND CLINICAL CHARACTERISTICS OF PARTICIPANTS IN RELIABILITY STUDY.

Characteristics	Participants (n=12)	
	Mean (SD)	Range
Age (years):	58.40 (13.40)	32-73
Gender: M/F, n	8/4	
Time since stroke (months):	44.80 (64.20)	0.10-204
Type of stroke: I/H, n	8/4	

Note: All values are presented as mean $\pm$ SD.

TABLE 6 INTRARATER AND INTERRATER RELIABILITY FOR THE BESTEST.

BESTest Section	Intrarater Reliability		Interrater Reliability	
	ICC (3,5)	95% CI	ICC (2,5)	95% CI
Total	.998	.996-.999	.993	.981-.998
Section I	.988	.975-.996	.971	.934-.991
Section II	.953	.900 -.984	.879	.726-.960
Section III	.988	.976-.996	.971	.934-.990
Section IV	.979	.956-.993	.932	.833-.978
Section V	.989	.977-.996	.981	.956-.994
Section VI	.992	.983-.996	.977	.945-.992

Note: All intraclass correlation coefficient (ICCs) were significant, with p value of < 0.001

2. Convergent validity

Figure 15 depicts the number of eligible participants, included participants, excluded participants and reason for excluded. One hundred and thirteen patients with subacute stroke met the eligibility criteria and 70 patients consented to participate in validity testing. Of the 43 patients who were not included in this study, 30 patients did not require continued rehabilitation; 5 patients had cognitive impairment or severe motor aphasia; 2 patients had severe internal carotid artery occlusion that required urgent surgery and 6 patients had major musculoskeletal problems including osteoarthritis and gouty arthritis.

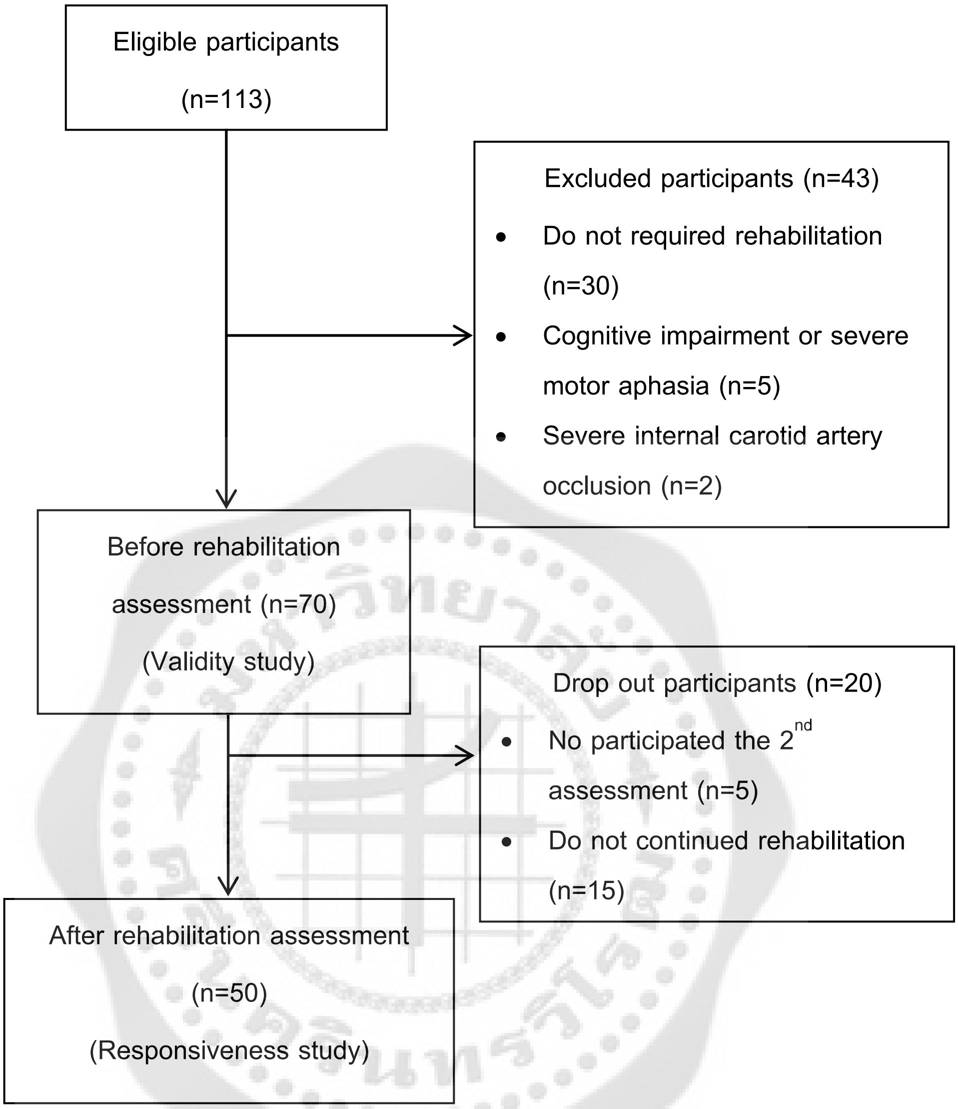

FIGURE 15 THE FLOW CHART DIAGRAM OF A NUMBER OF ELIGIBLE PARTICIPANTS, INCLUDED PARTICIPANTS FOR VALIDITY AND RESPONSIVENESS STUDY, EXCLUDED PARTICIPANTS AND REASON FOR EXCLUDED OR DROP OUT.

The majority of the participants (67 patients) could complete the validity testing within 1 day. Demographic and clinical characteristics of participants in the validity test are classified by their functional ability in Table 7. Participants in LFA and HFA were similar in age, gender, and cognitive impairment as measured by MMSE but the LFA had longer time since stroke and significant lower scores on all of the clinical balance tests.

TABLE 7 DEMOGRAPHIC AND CLINICAL CHARACTERISTICS OF PARTICIPANTS IN THE VALIDITY STUDY, CLASSIFIED BY FUNCTIONAL ABILITY.

Characteristics	All participants (n=70)		Functional ability group			
	Mean (SD)	Range	LFA (n=35)	Range	HFA (n=35)	Range
Age (years):	57.00 (12.20)	28-82	54.90 (12.10)	28-77	59.20 (12.20)	46-82
Gender: M/F, n	38 /32		21/14		17 /18	
Time since stroke (months):	1.10 (2.00)	0.10-12	1.70 (2.60)*	0.1-12	0.05 (0.80)*	0.10-4
Type of stroke: I/H, n	54/16		23/12		31/4	
Affected side: R/L, n	39/31		22/13		17/18	
MMSE (/30):	28.00 (2.40)	24-30	27.10 (2.40)	24-30	28.80 (2.10)	24-30
BI (/100):	61.90 (24.80)	20-100	48.90 (18.90)†	20-100	75.00 (23.20)†	20-100
FM-Motor (/100):	55.50 (34.00)	7-100	24.40 (12.60)†	7-51	86.70 (13.70)†	7-100
BESTest (/100%):	41.70 (28.20)	1-92	23.90 (18.40)†	1-71	59.50 (24.80)†	1-92
BBS (/56):	29.50 (19.70)	0-56	18.40 (15.90)*	0-50	40.60 (15.50)*	8-56
PASS (/36):	26.70 (7.80)	8-36	22.00 (7.70)*	8-34	31.40 (4.30)*	20-36
CB&M (/96):	11.60 (18.90)	0-53	1.40 (4.00)†	0-13	21.90 (22.30)†	0-53

Note: All values are presented as mean (SD). Significant difference between low and high functional ability group (*= $p<0.01$,†=$p<0.001$). Functional ability is classified by Fugl-Meyer Assessment (FM) Motor as low (0-55) and high (>55). LFA= low functional level, HFA= high functional level,I=Ischemia, H=Hemorrhage, MMSE=Mini-Mental State Examination, BI=Barthel Index, FM-Motor=Fugl-Meyer Assessment motor subscores, BESTest=Balance Evaluation Systems Test, BBS=Berg Balance Scale, PASS=Postural Assessment Scale for Stroke Patients, CB&M=Community Balance and Mobility Scale

The convergent validity of the BESTest in patients with subacute stroke was assessed with the clinical reference scales that have been validated in populations with stroke such as BBS, PASS, and CB&M. Figure 16 and Table 8 showed high correlation of the total scores from the BESTest with BBS (r=0.96), PASS (r=0.96), and CB&M (r=0.91), indicating excellent convergent validity.

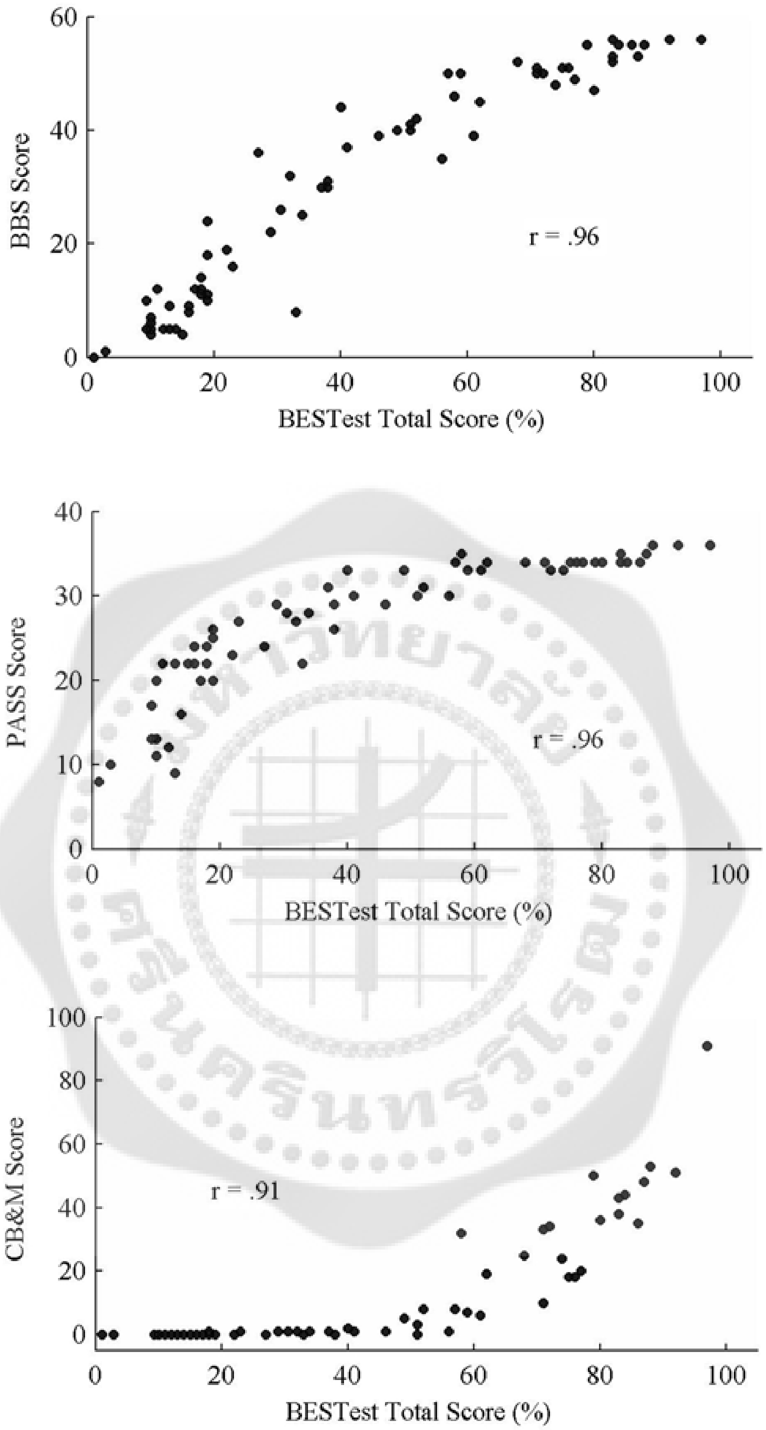

FIGURE 16 RELATIONSHIPS BETWEEN THE TOTAL SCORES OF THE BESTEST AND SCORES FROM OTHER CLINICAL BALANCE SCALES INCLUDING BBS, PASS AND CB&M.

TABLE 8 THE CORRELATION COEFFICIENT OF THE TOTAL SCORES OF THE BESTEST AND SCORES FROM OTHER CLINICAL BALANCE SCALES INCLUDING BBS, PASS and CB&M.

Reference tool	New tool: BESTest					
	All participants (n=70)		LFA (n=35)		HFA (n=35)	
	r	*p* value	***r***	*p* value	***r***	*p* value
BBS	0.96	*<0.001*	0.91	*<0.001*	0.95	*<0.001*
PASS	0.96	*<0.001*	0.91	*<0.001*	0.91	*<0.001*
CB&M	0.91	*<0.001*	0.72	*<0.001*	0.85	*<0.001*
FM-Motor	0.82	*<0.001*	0.70	*<0.001*	0.62	*<0.001*
FM-UE	0.76	*<0.001*	0.63	*<0.001*	0.36	*<0.001*
FM-LE	0.83	*<0.001*	0.58	*<0.001*	0.68	*<0.001*

Note: *r* = correlation coefficient.

3. The BESTest score distribution across levels of functional ability

The distribution of participants' score from each balance measures across levels of functional ability is displayed in Figure 17. It can be seen that the distribution of scores from all observed scales covered the whole range of functional ability, except the CB&M. However, the PASS showed the cluster of scores at one end of the graph, indicating the potential floor or ceiling effects.

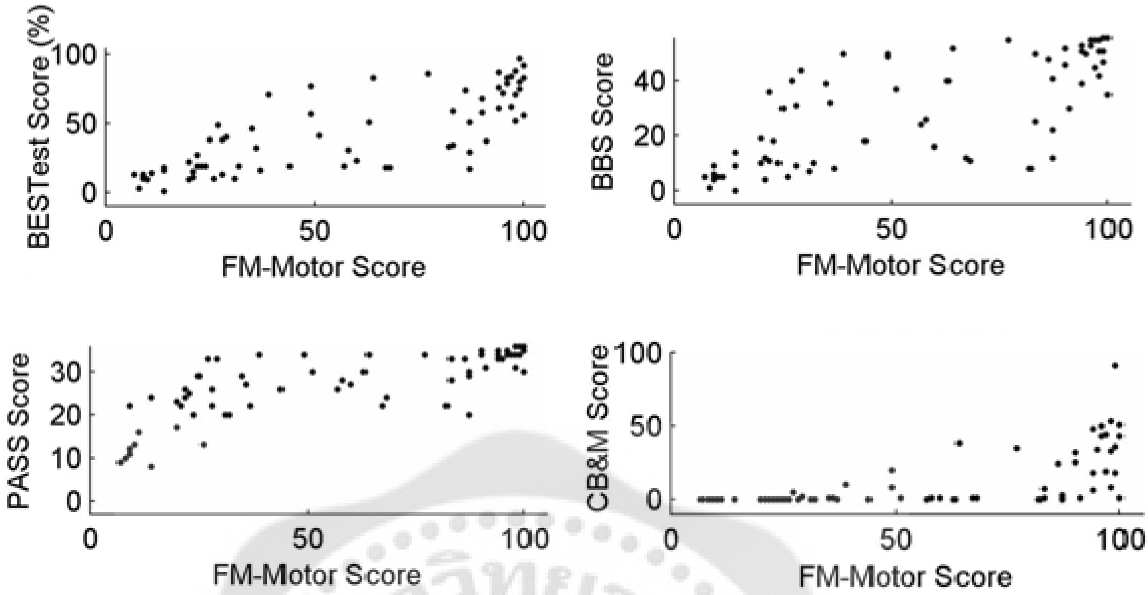

FIGURE 17 DISTRIBUTION OF ALL PARTICIPANTS' SCORE FROM THE BESTEST, BBS, PASS AND CB&M ACROSS LEVELS OF FUNCTIONAL ABILITY, AS DETERMINED BY FM-MOTOR SUBSCALE.

The floor, ceiling and responsiveness ceiling effects of all balance measures in validity study are presented in Table 9. The analysis of the floor effect demonstrated that there were 77.10% (n=27) in the LFA and 11.40% (n=4) in HFA, leading to 44.30% (n=31) of all participants with subacute stroke received zero score on the CB&M. None of the participants received zero score from the BESTest, BBS and PASS. For the ceiling effect, 4.30% (n=3) of participants received full score on the BBS and PASS. However, when calculating by using the score within the top 10%, there was 25.70% of all participants (5.70% LFA and 45.70% HFA) scoring within the top 10% of the BBS, indicating ceiling effect especially in the HFA. Similarly, 37.10% of all participants (14.30% LFA and 60.00% HFA) received score within the top 10% of the PASS. On the contrary, no ceiling effect was observed in the rest of the balance scales, as a few number of all patients received score within the top 10% of the BESTest (4.30%), and CB&M (1.40%).

TABLE 9 FLOOR, CEILING AND RESPONSIVE CEILING EFFECTS OF THE BESTEST, BBS, PASS AND CB&M MEASURES IN VALIDITY STUDY, DIVIDED INTO LFA GROUP AND HFA GROUP.

Variable	BESTest	BBS	PASS	CB&M
All validity participants (n=70)				
Floor effect	0 (0.00)	1 (1.40)	0 (0.00)	31 (44.30)
Ceiling effect	0 (0.00)	3 (4.30)	3 (4.30)	0 (0.00)
Responsive ceiling effect	3 (4.30)	18 (25.70)	26 (37.10)	1 (1.40)
LHA (n=35)				
Floor effect	0 (0.00)	1 (2.90)	0 (0.00)	27 (77.10)
Ceiling effect	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Responsive ceiling effect	0 (0.00)	2 (5.70)	5 (14.30)	0 (0.00)
HFA (n=35)				
Floor effect	0 (0.00)	0 (0.00)	0 (0.00)	4 (11.40)
Ceiling effect	0 (0.00)	3 (8.60)	3 (8.60)	0 (0.00)
Responsive ceiling effect	3 (8.60)	16 (45.70)	21 (60.00)	1 (2.90)

Note: Values are number (%) of participant who reach minimum (floor effect), maximum (ceiling effect) possible score, and scoring within top 10% (responsive ceiling effect).

4. Item score of the BESTest

The scores of each item and section of the BESTest compared between LFA and HFA are shown in Table 10. In general, the section scores were significantly lower in the LFA, suggesting that the BESTest was able to differentiate between LFA and HFA. Several items in the BESTest were too hard to perform for the LFA, as can be seen from the percentage of minimum score of more than 80%. These items included sit on floor, rise to toe, stand on one leg, alternate stair touching, compensatory postural response in all directions, stand on foam with eyes close and all items in the “stability in gait” section with the exception of change in gait speed. In contrast, there were only two items; base of support and sitting verticality, that were shown to be easy (>80% of maximum score) in both LFA and HFA groups.

Comparison of the percentage of minimum and maximum scores between the LFA and HFA subjects also suggested the feasibility of each item to be used in all levels of functional ability. For example, 31.40% of patients in LFA received maximum score in item 6 (lateral lean) and the maximum score was 71.40% in HFA. Similarly, this pattern was shown by the decrease in percentage of minimum score in HFA as compared to LFA and found in all items of the BESTest, except the 3 items-base of support and sitting verticality left and right.

TABLE 10 ITEM SCORE OF THE BESTEST.

BESTest		LFA (n=35)			HFA (n=35)		
		ME (95%CI)	%N		ME (95%CI)	%N	
Sect	Item		Min	Max		Min	Max
I	BIOMECHANICAL CONSTRAINTS		31.43 (17.08)*		57.52 (22.00)*		
	1. Base of support	3 (3-3)	0.0	82.9	3 (3-3)	0.0	91.4
	2. CoM alignment	1 (0-1)	37.1	5.7	2 (2-3)	2.9	48.6
	3. Ankle strength/ROM	0 (0-0)	71.4	2.9	1.5 (1-2)	28.6	8.6
	4. Hip/trunk strength	0 (0-0)	80.0	0.0	0 (0-1)	60.0	8.6
	5. Sit on floor /stand up	0 (0-0)	85.7	5.7	2 (0-2)	42.9	25.7
II	LIMITS OF STABILITY		50.95 (19.57)*		74.29 (14.93)*		
	6. Sitting verticality, right†	3 (3-3)	5.7	82.9	3 (3-3)	0.0	100.0
	6. Lateral lean, right†	2 (1-2)	5.7	31.4	3 (3-3)	0.0	71.4
	7. FR forward	0 (0-0)	65.7	0.0	2 (1-2)	17.1	5.7
	8. FR right†	0 (0-0)	68.6	2.9	2 (1-2)	22.9	8.6
III	ANTICIPATORY ADJUSTMENTS		18.41 (20.73)*		57.46 (26.16)*		
	9. Sit to stand	2 (1-3)	28.6	40.0	3 (3-3)	0.0	85.7
	10. Rise to toe	0 (0-0)	85.7	0.0	2 (1-2)	25.7	22.9
	11. Stand on one leg, right†	0 (0-0)	88.6	0.0	1 (0-1)	40.0	11.4
	12. Alternate stair touching	0 (0-0)	91.4	0.0	2 (1-2)	31.4	31.4
	13. Standing arm raise	0 (0-0)	68.6	20.0	3 (1-3)	17.1	57.1
IV	POSTURAL RESPONSES		12.86 (26.40)*		60.98 (36.7)*		
	14. In-place, front	0 (0-0)	71.4	20.0	3 (3-3)	14.3	71.4
	15. In-place, back	0 (0-0)	74.3	14.3	3 (2-3)	17.1	62.9
	16. Compensatory, front	0 (0-0)	91.4	5.7	2 (1-3)	31.4	42.9
	17. Compensatory, back	0 (0-0)	91.4	5.7	2 (0-3)	37.1	37.1
	18. Compensatory, right†	0 (0-0)	91.4	5 .7	2 (0-2)	42.9	31.4

TABLE 10 (CONTINUED)

BESTest		LFA (n=35)			HFA (n=35)		
		ME (95%CI)	%N		ME (95%CI)	%N	
Sect	Item		Min	Max		Min	Max
V	SENSORY ORIENTATION	23.24 (28.58)*			62.29 (29.90)*		
	19. Firm surface, EO	1 (0-2)	45.7	34.3	3 (3-3)	2.9	80.0
	19. Firm surface, EC	0 (0-1)	54.3	14.3	3 (2-3)	2.9	60.0
	19. Foam surface, EO	0 (0-0)	77.1	2.9	2 (0-3)	17.1	34.3
	19. Foam surface, EC	0 (0-0)	91.4	0.0	0.5 (0-1)	51.4	8.6
	20. Incline, EC	0 (0-0)	62.9	17.1	3 (2-3)	20.0	60.0
VI	STABILITY IN GAIT	6.26 (15.61)*			44.35 (31.68)*		
	21. Gait, level surface	0 (0-0)	82.9	0.0	2 (1-2)	25.7	5.7
	22. Change in gait speed	0 (0-0)	80.0	0.0	2 (1-2)	25.7	22.9
	23. Walk head turn, lateral	0 (0-0)	82.9	0.0	1 (0-1)	42.9	14.3
	24. Walk with pivot turns	0 (0-0)	91.4	2.9	2 (1-2)	28.6	22.9
	25. Step over obstacles	0 (0-0)	91.4	0.0	2 (0-2)	34.3	25.7
	26. TUG	0 (0-0)	91.4	0.0	2 (1-2)	31.4	2.9
	27. TUG test with dual task	0 (0-0)	82.9	0.0	1 (0-2)	25.7	0.0

Note: All section scores are presented as mean (SD). LFA= low functional ability level, HFA= high functional ability level, ME=median, CI = confidence interval, FR= functional reach, EO = eye open, EC = eye close,TUG=Timed “Get Up and Go” test. *Significant difference between LFA and HFA at $p<0.01$, †Item that evaluates both right and left sides, but with similar results on each side, so only the right side was presented.

5. Identification of functional ability level

The ROC plot for the BESTest and BBS are shown in Figure 18. All three scales showed high AUC in identifying patients with stroke in the LFA and HFA; 0.88 for the BESTest and 0.85 for the BBS (Table 11).The suggested cutoff scores for low functional ability were 49% for the BESTest and 19/56 for the BBS (Table 11). Based on these cutoff scores, comparable sensitivity and specificity was found in both measurements, with specificity highest for the BESTest, while the BBS had the highest sensitivity, but lowest specificity. Both scales also showed high posttest accuracy (0.77-0.81) when applying the suggested cutoff point in classifying participants into LFA or HFA group. Although both tests showed similar AUC, sensitivity, specificity and posttest accuracy, the BESTest had LR+ ratios over 5 and LR- ratios close to 0.20, suggesting the BESTest had higher probability to correctly identify patients into the correct level of functional ability than the BBS.

TABLE 11 CUTOFF POINTS WITH ASSOCIATED SENSITIVITY, SPECIFICITY, LIKELIHOOD RATIOS (LR) AND AREA UNDER THE CURVE (AUC) OF THE RECEIVER OPERATING CHARACTERISTIC (ROC) PLOT FOR THE BESTEST AND BBS.

Distinguishing HFA from LFA	**BESTest**		**BBS**	
	values	95% CI	values	95% CI
Optimal cutoff score	> 49		> 19	
Accuracy	0.81		0.77	
AUC	0.88	0.80-0.90	0.85	0.80-0.90
Sensitivity	71.40	54.70-83.70	85.70	70.00-94.10
Specificity	91.40	76.70-97.70	68.60	51.90-81.50
LR+	8.30	2.80-25.10	2.70	1.60-4.50
LR-	0.30	0.20-0.50	0.30	0.20-0.60

Note: CI=confidence interval, LR+= positive likelihood ratio, LR- = negative likelihood ratio

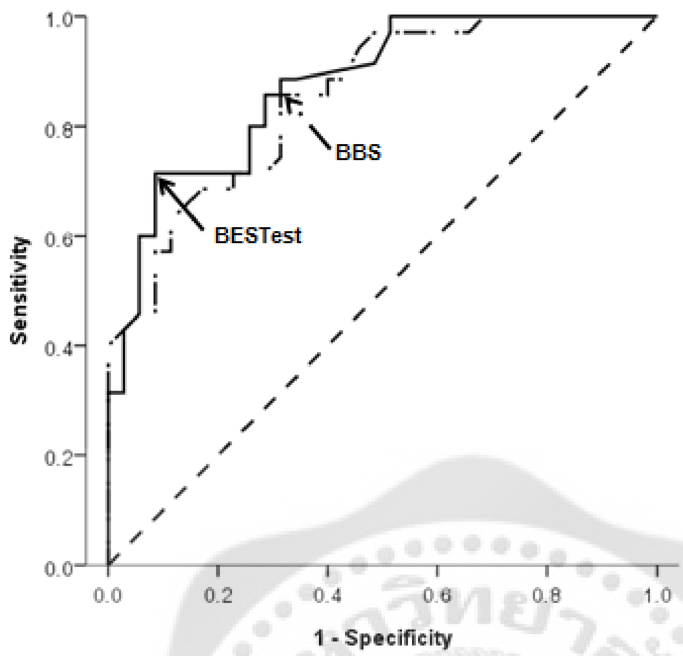

FIGURE 18 RECEIVER OPERATING CHARACTERISTIC (ROC) PLOT OF THE BESTEST AND BBS FOR CLASSIFYING PATENTS WITH SUBACUTE STROKE IN LOW AND HIGH FUNCTIONAL GROUP.

Note: Arrow depicts the cutoff point for group classification.

6. Responsiveness

From seventy participants volunteered in this study, only 50 participants completed the discharge assessment as shown in Figure 15. Fifty participants with stroke were 21 female and 29 male with the age between 28 to 82 years, and have a wide range of time since stroke from 0.10 to 20 months. Twenty participants were lost during the follow up because they did not need to participate in the second assessment (n=5) or did not require continued rehabilitation (n=15).

Demographic and clinical characteristics of study participants and drop out participants are presented in Table 12. Study participants had significantly lower functional ability than drop out participants as measured by FM-motor and BI. The time between before and after assessment was 13.60 (9.30) days, ranging from 5 to 44 days.

TABLE 12 DEMOGRAPHIC AND CLINICAL CHARACTERISTICS OF PARTICIPANTS IN THE RESPONSIVENESS STUDY.

Characteristics	All participants (n=50)		Drop out participants (n=20)	
	Mean (SD)	Range	Mean (SD)	Range
Age (years):	57.80 (11.60)	28-82	61.60 (11.30)	41-82
Gender: M/F, n	29 /21		9/11	
Time since stroke (months):	2.20 (4.00)	0.10-20	1.10 (2.50)	0.10-6
Type of stroke: I/H, n	36/14		18/2	
Affected side: R/L, n	27/23		12/8	
MMSE (/30):	28.40 (2.30)	24-30	28.20 (2.60)	24-30
BI (/100):	50.10 (21.80)	20-100	71.00 (24.40)*	20-100
FM-Motor (/100):	38.10 (27.10)	7-98	78.30 (22.90)*	31-99
Time between two assessment (days)	13.60 (9.30)	5-44	-	-

Note: All values are presented as mean (SD). Significant difference between group (*= p<0.001).

6.1 Distribution scores at before and after the rehabilitation assessment

Table 13 shows the floor, ceiling and responsive ceiling effects before and after the rehabilitation assessment in all participants. There was no floor, ceiling and responsive ceiling effects before the rehabilitation, except from the CB&M that exhibited a significant floor effect with 68%. After the rehabilitation, the PASS demonstrated the responsive ceiling effect (20%), whereas the CB&M still showed the floor effect (42%). It can be noted that the BBS and BESTest did not demonstrate floor, ceiling and responsive ceiling effects.

TABLE 13 FLOOR, CEILING AND RESPONSIVE CEILING EFFECTS THE RESPONSIVENESS STUDY.

Balance measures	Before rehabilitation			After rehabilitation		
	Floor effect	Ceiling effect	Responsive ceiling effect	Floor effect	Ceiling effect	Responsive ceiling effect
BESTest	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
BBS	1 (2.00)	0 (0.00)	2 (4.00)	0 (0.00)	1 (2.00)	6 (12.00)
PASS	0 (0.00)	0 (0.00)	4 (8.00)	0 (0.00)	0 (0.00)	10 (20.00)
CB&M	34 (68.00)	0 (0.00)	0 (0.00)	21 (42.00)	0 (0.00)	0 (0.00)

Note: Values are number (%) of participant who reach minimum (floor effect), maximum (ceiling effect) possible score, and scoring within top 10% (responsive ceiling effect).

6.2 Internal responsiveness

After the end of rehabilitation program, all participants had balance improvement as demonstrated by significant increase in scores of all balance measures as shown in table 14. The BESTest total scores changed over timed was 13.00 in all participants. Similarly, the BBS and the PASS scores improved 10.50 and 4.80, respectively. However, the mean scores changed of the CB&M was low (only 2.40).

SRM values of the BESTest, BBS and PASS were large ranging from 1.10 to 1.20 whereas SRM values of the CB&M were small (0.5). These results indicated that the BESTest, BBS and PASS measures were sensitive to change over time after stroke. In contrast, the SRM value of CB&M was found to be small that indicated less sensitive to change in these participations.

TABLE 14 INTERNAL RESPONSIVENESS OF BALANCE MEASURES (TOTAL SCORE).

Characteristics	Before	After	Change	SRM (95% CI)	No change (N (%))
BESTest total (/100%):	28.40 (20.90)	41.20 (22.70)	13.00 (11.00) *	1.20 (0.90-1.50)	3 (6.00)
BBS (/56):	21.00 (15.70)	31.50 (15.60)	10.50 (9.00) *	1.20 (0.90-1.40)	5 (10.00)
PASS (/36):	23.30 (7.40)	28.10 (5.50)	4.80 (4.20) *	1.10 (0.90-1.40)	7 (14.00)
CB&M (/96):	3.50 (11.70)	5.90 (13.10)	2.40 (5.40)	0.50 (0.20-0.80)	26 (52.00)

Note: N (%) no change = number of subjects showed no change. * = Significant difference between before and after rehabilitation (p<0.001).

The score change after rehabilitation and SRM value of each section of the BESTest are presented in table 15. The BESTest section score change was ranging from 8.40 to 17.90 for all participants. The sensory organization and postural response section had highest score change while the biomechanical constraint had a lowest score change. The SRM of all BESTest sections were high ranging from 0.80 to 1, except the stability in gait section that had moderate SRM. Highest number of patient (58%) who demonstrated no change in the gait section could lead to moderate internal responsiveness.

TABLE 15 INTERNAL RESPONSIVENESS OF SECTION SCORES OF THE BESTEST.

BESTest section (/100%):	Before	After	Change	SRM (95% CI)	No change (N (%))
I	33.40 (16.80)	41.80 (19.90)	8.40 (10.70)*	0.80 (0.50-1.20)	14 (28.00)
II	53.80 (18.60)	64.40 (13.90)	10.60 (11.50) *	0.90 (0.67-1.20)	13 (26.00)
III	23.10 (24.10)	38.40 (26.60)	15.30 (15.20) *	1.00 (0.80-1.26)	9 (18.00)
IV	20.80 (31.70)	38.30 (33.80)	17.60 (21.50) *	0.80 (0.60-1.10)	23 (46.00)
V	26.70 (29.60)	44.50 (29.90)	17.90 (19.90) *	0.90 (0.60-1.20)	15 (30.00)
VI	10.20 (21.80)	20.90 (28.10)	10.80 (18.00) *	0.60 (0.30-0.90)	29 (58.00)

Note: N (%) no change = number of subjects showed no change. * = Significant difference between before and after rehabilitation assessment ($p<0.001$).

The item scores of each assessment time and items score change of the BESTest are shown in Table 16. All of items scores, except base of support and sitting verticality left and right, were significantly higher after rehabilitation, suggesting that the BESTest item was able to depict improvement of each balance performance. The items that have highest percentage (>40%) of patient who have increased score included CoM alignment, functional reach forward and lateral, sit to stand, in-place response front and back and stand on firm surface with eye close. In contrast, the base of support and sitting verticality showed that more than 80% of participants obtained maximum score before rehabilitation, indicating these were easy items for subacute stroke. No significant improvement after exercise in these easy items suggested limitation of responsiveness. On contrary, the difficult items can be seen from the percentage of minimum score of more than 80% at before rehabilitation. Those items were hip/trunk strength, sit on floor, stand on one leg, alternate stair touching, compensatory lateral, stand on foam with eye open and eye close, and all items in the “stability in gait” section with the exception of change in gait speed. However, these items were achievable in patients with subacute stroke as shown by the improvement after rehabilitation.

6.3 External responsiveness

The BESTest score change of 10 points (out of 100) and higher was an indicator of change in balance performance based on the BBS score change < 7 and higher as shown in Table 17. The ROC plot for the BESTest change score is shown in Figure 19. In all participants, AUC was excellent (0.92). The posttest accuracy was 0.84 when applying the suggested cutoff point in classifying participants into balance change or no balance change. The sensitivity and specificity of the cutoff point at 10 was 80.8 and 87.50. In similar way, these cutoff points had positive likelihood ratio over 5 and negative likelihood ratio close to 0.20, suggesting the BESTest had high probability to correctly identify patients who have balance change.

TABLE 16 ITEM SCORES OF THE BESTEST AT BEFORE, AFTER THE REHABILITATION AND SCORE CHANGE.

BESTest		Before rehabilitation			After rehabilitation			Change		
		ME	%N		ME	%N		ME	%N	
Sect	Item	(IQR)	Min	Max	(IQR)	Min	Max	(IQR)	Improve	No change
I	1. Base of support	3 (3-3)	0.00	82.00	3 (3-3)	0.00	80.00	0 (0-0)	10.00	80.00
	2. CoM alignment	1 (0-2)	30.00	8.00	2 (1-2)	10.00	20.00	0 (0-1)*	40.00	58.00
	3. Ankle strength/ROM	0 (0-1)	68.00	2.00	0 (0-1)	56.00	4.00	0 (0-0)*	24.00	70.00
	4. Hip/trunk strength	0 (0-0)	82.00	0.00	0 (0-1)	60.00	0.00	0 (0-0)*	28.00	68.00
	5. Sit on floor /stand up	0 (0-0)	84.00	6.00	0 (0-1)	66.00	8.00	0 (0-0)*	18.00	82.00
II	6. Sitting verticality, right†	3 (3-3)	6.00	90.00	3 (3-3)	2.00	98.00	0 (0-0)	10.00	90.00
	6. Lateral lean, right†	2 (2-3)	6.00	46.00	3 (2-3)	2.00	58.00	0 (0-0)*	34.00	62.00
	7. FR forward	0 (0-1)	60.00	0.00	1 (0-1)	30.00	2.00	0 (0-1)*	40.00	58.00
	8. FR right†	0 (0-1)	64.00	0.00	1 (0-1)	32.00	2.00	0 (0-1)*	40.00	58.00
III	9. Sit to stand	2 (0-3)	28.00	46.0	3 (2-3)	8.00	70.00	0 (0-1)*	42.00	58.00
	10. Rise to toe	0 (0-1)	74.00	8.00	1 (0-2)	50.00	12.00	0 (0-0)*	30.00	70.00
	11. Stand on one leg, right†	0 (0-1)	82.00	2.00	0 (0-1)	64.00	4.00	0 (0-0)*	30.00	68.00
	12. Alternate stair touching	0 (0-0)	80.00	0.00	0 (0-1)	62.00	4.00	0 (0-0)*	26.00	72.00
	13. Standing arm raise	0 (0-3)	60.00	22.00	2 (0-3)	38.00	42.00	0 (0-0)*	32.00	66.00
IV	14. In-place, front	0 (0-3)	62.00	28.00	3 (0-3)	32.00	60.00	0 (0-1)*	40.00	60.00
	15. In-place, back	0 (0-3)	64.00	28.00	3 (0-3)	32.00	50.00	0 (0-1)*	40.00	60.00
	16. Compensatory, front	0 (0-0)	76.00	10.00	0 (0-2)	58.00	14.00	0 (0-0)*	20.00	80.00
	17. Compensatory, back	0 (0-0)	78.00	8.00	0 (0-2)	58.00	12.00	0 (0-0)*	20.00	78.00

TABLE 16 (CONTINUED)

BESTest		Before rehabilitation			After rehabilitation			Change		
		ME (IQR)	%N		ME (IQR)	%N		ME (IQR)	%N	
Sect	Item		Min	Max		Min	Max		Improve	No change
	18. Compensatory, right†	0 (0-0)	86.00	6.00	0 (0-1)	70.00	6.00	0 (0-0)*	16.00	84.00
V	19. Firm surface, EO	2 (0-3)	38.00	44.0	3 (3-3)	12.00	76.00	0 (0-0)*	38.00	62.00
	19. Firm surface, EC	1 (0-2)	48.00	20.00	2 (1-3)	24.00	42.00	0 (0-1)*	42.00	56.00
	19. Foam surface, EO	0 (0-0)	82.00	6.00	0 (0-2)	62.00	18.00	0 (0-0)*	26.00	74.00
	19. Foam surface, EC	0 (0-0)	90.00	2.00	0 (0-1)	72.00	4.00	0 (0-0)*	18.00	82.00
	20. Incline, EC	0 (0-2)	66.00	12.00	1 (0-2)	42.00	24.00	0 (0-0)*	32.00	64.00
VI	21. Gait, level surface	0 (0-0)	80.00	2.00	0 (0-1)	58.00	4.00	0 (0-0)*	26.00	74.00
	22. Change in gait speed	0 (0-0)	78.00	6.0	0 (0-2)	64.00	12.00	0 (0-0)*	20.00	80.00
	23. Walk head turn, lateral	0 (0-0)	88.00	0.00	0 (0-1)	72.00	2.00	0 (0-0)*	26.00	74.00
	24. Walk with pivot turns	0 (0-0)	80.00	4.00	0 (0-2)	62.00	4.00	0 (0-0)*	18.00	82.00
	25. Step over obstacles	0 (0-0)	84.00	4.00	0 (0-1)	70.00	4.00	0 (0-0)*	14.00	86.00
	26. TUG	0 (0-0)	88.00	2.00	0 (0-1)	68.00	4.00	0 (0-0)*	22.00	78.00
	27. TUG test with dual task	0 (0-0)	82.00	0.00	0 (0-1)	62.00	4.00	0 (0-0)*	24.00	74.00

Note: ME=median, IQR= Interquartile range, I= Biomechanical constrains, II= Stability Limits/Verticality, III= Anticipatory Postural Adjustment, IV= Postural Response, V= Sensory Organization, VI= Stability Gait, FR= functional reach, EO = eye open, EC = eye close, TUG=Timed "Get Up and Go" test. Values of number (%) were percent of participant receiving minimum item score (Min), maximum item score (Max), have item score improved (improve) and no changed (no change) item score after rehabilitation. Significant difference: * = between before and after rehabilitation assessment (p<0.01).

TABLE 17 CUTOFF POINTS WITH ASSOCIATED SENSITIVITY, SPECIFICITY, LIKELIHOOD RATIOS (LR) AND AREA UNDER THE CURVE (AUC) OF THE RECEIVER OPERATING CHARACTERISTIC (ROC) PLOT FOR THE BESTEST FOR IDENTIFY BALANCE CHANGE BASED ON THE BBS SCORE CHANGE MORE THAN 7

Characteristics	All participants	
	values	95% CI
Optimal cutoff score	10	
Accuracy	0.84	
AUC	0.92	0.87-0.97
Sensitivity	80.80	60.60-93.40
Specificity	87.50	67.60-97.20
LR+	6.50	1.50-23.30
LR-	0.20	0.10-0.50

Note: CI=confidence interval, LR+= positive likelihood ratio, LR- = negative likelihood ratio

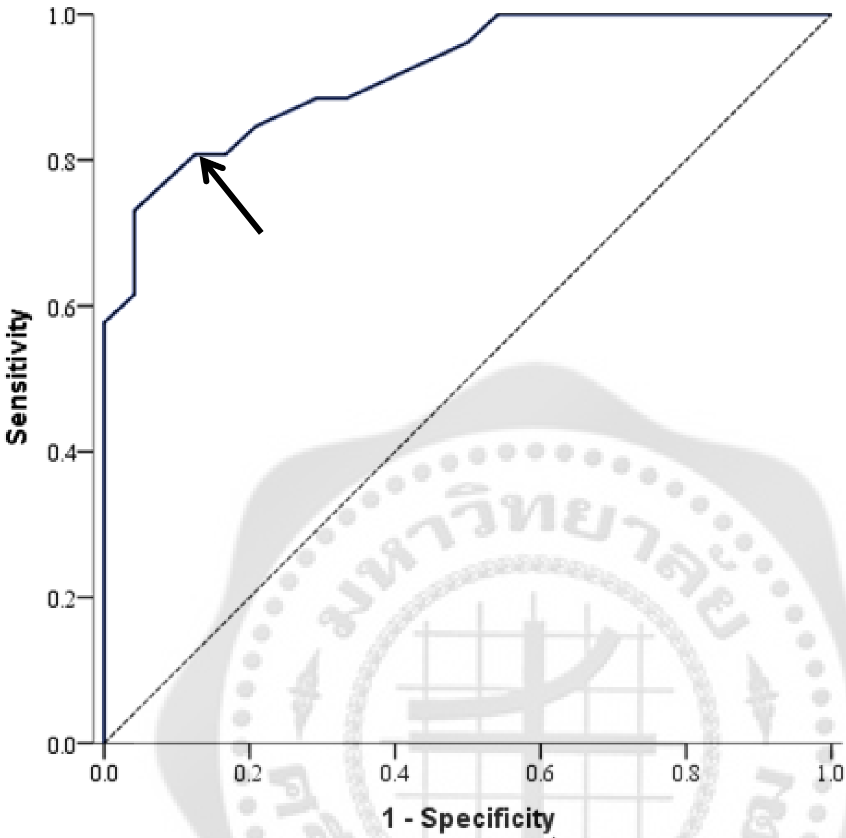

FIGURE 19 RECEIVER OPERATING CHARACTERISTIC (ROC) PLOT OF THE BESTEST SCORE CHANGE IN IDENTIFYING REAL BALANCE PERFORMANCE CHANGE ACCORDING TO THE BBS SCORE CHANGE $\leq$ 7 VS. >7 IN PERSONS WITH STROKE. ARROW DEPICTS THE CUTOFF POINT FOR INDICATED BALANCE PERFORMANCE CHANGE.

CHAPTER 5

CONCLUSION AND DISCUSSION

Discussion

This is the first study to examine whether the BESTest is reliable, valid to assess balance impairments and responsiveness in patients with subacute stroke. Our results confirmed that the BESTest had excellent interrater and intrarater reliability, excellent convergent validity with commonly used clinical balance scales and high internal and external responsiveness in patients with subacute stroke.

The high intrarater and interrater reliability of the BESTest in patients with subacute stroke agreed with previous studies in neurological patients or healthy elderly subjects.[65, 89] For example, the total score interrater reliability was 0.91 (ICC) with section score ICCs ranging from 0.79 to 0.96 in patients with neurological diseases and healthy subjects[65] and total score interrater reliability of 0.96 with section scores ranging from 0.79 to 0.96 in patients with PD.[188] The high correlations (r>0.90) between the BESTest and other clinical balance measures indicated that, to some extent, the BESTest measures similar balance constructs as the BBS, PASS, CB&M. Our results are in line with the previous findings of a high correlation between the BESTest, BBS (r=0.87) in patients with PD.[89, 188]

The ability of a measure to detect change over time is a key important in clinical practice to evaluate the effectiveness of particular intervention or monitor the recovery progression after stroke.[139] Floor and ceiling effect are an important limitation of ability to detect change of instrument. Although all of the clinical balance measures observed in this study can be used to assess balance impairments in patients with subacute stroke, this study demonstrated that the BESTest may be more desirable than other balance scales due to its lack of floor and ceiling effects. The BESTest was shown to be suitable for patients with subacute stroke across many levels of functional ability, as evidenced by the distribution of BESTest scores that covered the whole range of functional ability. In contrast, a significant floor effect was found a significant floor effect was present in all patients with subacute stroke using the CB&M. The CB&M included dynamic balance in standing and walking and advance balance tasks that are frequently encountered while living in the community, but most patients in LFA group did not yet regain their ability to stand or walk independently, thus they received zero scores on these items in the CB&M, resulting in floor effect (77.10%). However, no floor effect has been reported when using the CB&M in community-dwelling persons with chronic stroke.(139) The previous study has been recommended for ambulatory patients with stroke who have moderate to mild post-stroke deficits(139) and our results supported that the assessment tasks in the CB&M were too difficult for the patients with low functional ability.

In this study, the calculation of the ceiling effect was performed two ways; the use of maximum score and the use of the score within top 10% of test (Responsive ceiling effect). Our results are in agreement with Leddy et al,(89) who found that the use of score within the top 10% would give more information about the ability of the scale to measure balance progress over time rather than using only the maximum score. Our results demonstrated the responsive ceiling effect of the BBS (45.70%) and PASS (60%) in the HFA group, suggesting that the BBS and PASS may have limited ability to detect balance progress over time that is very important for evaluating the effectiveness of balance rehabilitation in patients with high functional ability.(139) The scores within the top 10% of BBS and PASS were 51-56 scores and 34-36 scores, respectively, and the scores must change at least 6.90 points on the BBS(144, 154) and by 2.20 points on the PASS(136) to indicate a true change that is not due to measurement error. Therefore, the BBS and PASS would not be proper to administer in patients with high functional stroke, as they have insufficient space for detect real balance progression.

Although, this study has a wide range of time between two assessments ranging from 5 to 44 days, our study showed the BESTest had high responsiveness in patient with subacute stroke who received rehabilitation. The SRM of the BESTest was as large as the BBS and the PASS, indicating that the BESTest has high internal responsiveness for people receiving rehabilitation after stroke. Our findings are the first to provide in-depth details regarding the responsiveness of the BESTest and are in line with the studies of the BBS and PASS inpatients with subacute stroke.[60, 61, 136, 137, 147, 165, 189, 190] The BBS and PASS demonstrated high significant sensitivity to change when assessment between 14 to 90 days after stroke. This period of assessment was also applicable to our study of the BESTest. The CB&M is only measure that had limited sensitivity to change as presented small SRM. The possible reason is a notable floor effect as discussed above. The external responsiveness was also exhibited in this study using the BBS score as reference standard. We suggested a change of 10 points to represent balance change in the BESTest in patients with stroke. At this cutoff point, the BESTest was high accurate (84%), sensitive (80.8%) and specific (87.50%) in detecting balance change. Moreover, this selected score showed high LR+ and low LR- to help confirm the correction in classification of patients who had true balance change.[188]

The BESTest was developed to provide information on which particular balance systems were underlying balance impairments. Results from our study confirmed that balance deficits in patients with subacute stroke covered impairments of all postural control subsystems represented in the BESTest (Table 2) but the amount of subsystem deficit varied depending on the level of motor impairments. For example, patients with LFA had deficits in all postural control systems (mean score of the BESTest was less than 50%), except the stability limit and verticality subsystem. In contrast, patients in the HFA group showed more deficits in the stability in gait. Therefore, the use of the BESTest in patients with subacute stroke can guide clinicians to tailor their intervention to impairments of specific postural control subsystems.

The BESTest have ability to detect balance change as it had high internal and external responsiveness. All BESTest sections were high sensitive to detect balance change, except the stability in gait section that had moderate sensitivity. This result suggested the BESTest section except stability in gait section can used to evaluation balance change separately. Most patients in our study cannot walk independent; there were only 10% that can walk independent before rehabilitation assessment and 24% at after rehabilitation assessment. These results limited the ability to detect change in stability in gait section. All items in the BESTest, with the exception of base of support and sitting verticality left and right, showed the improvement of balance ability before and after rehabilitation assessment. The items that showed highest improvement included CoM alignment, functional reach forward and lateral, sit to stand, in-place response front and back and stand on firm surface with eye close.

These findings agree with previous studies showing the sequence of functional recovery in patients with stroke.[191] Patients were able to maintain standing upright, but most of patients had weight bearing asymmetry and increase postural sway.[43, 191] The balance recovery in the first 3 months post stroke may come from several mechanism included restoration of paretic leg muscle function,[192] improved stabilization of the head and trunk in space,[192] more effective muscular compensation through the non-paretic leg for weight-bearing and response to internal perturbation,[43, 192] adapted multisensory integration result in reduction of visual dependency[31] and progressive internalization of the altered body dynamic.[192] The base of support and sitting verticality were easy items for subacute stroke, there showed more than 80% of participants received maximum score at before rehabilitation. Our participants were received daily rehabilitation program which included intervention for maintain joint range of motion and prevent deformity. Therefore, Deformity or pain in the feet was rare in our participants, resulting in initial high score in the base of support item. Inaccurate representation of vertical is often found in patients with stroke who have neglect or 'pusher syndrome'.[128, 193] However, none of our participants had been diagnosed with either neglect nor pusher syndrome and they all had perfect score in the verticality items.

In this study, we also questioned if the scores from the BESTest and BBS could classify patients with a higher versus low level of functional ability as measured by FM-Motor. This study demonstrated that the scores from both balance scales could be used to classify patients with stroke into two functional ability groups. However, the slightly larger LR+ suggests the BESTest may be more preferable to the BBS for functional classification.

Limitation and further study

Although the time for administering the BESTest (30-35 minutes) is twice as long as the BBS (10-15 minutes), the information gathered from the BESTest is more useful than the BBS in customizing balance intervention. However, we question some items in the BESTest that were scored maximum in the first assessment such that these items may not be applicable to assess the change of those tested functions in patients with subacute stroke. Therefore, further analysis, such as Rasch analysis, may be required on BESTest data from patients with subacute stroke to eliminate the least sensitive and redundant items, which will shorten the assessment time. Future studies about sensitivity to detect change and minimal detectable changes of the BESTest are also essential for evaluating the effectiveness of treatment programs. Furthermore, our study was carried out only in patients with early stroke so the results cannot be generalized to patients with chronic stroke.

Implications

The BESTest can be used to assess balance impairment, underlying systems of balance impairment and evaluate the effectiveness of rehabilitation program aiming to improve balance in patients with stroke.

Conclusion

The BESTest is a balance measure that is reliable, valid and sensitive to in persons with subacute stroke throughout different levels of functional ability.

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APPENDICES

APPENDIX A

APPENDIX A

DEMOGRAPHIC AND CLINICAL CHARACTERISTICS FORM

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

Location:……………………………………… Date:……………………………………...

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

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

Stroke type: ………………………………… Time since stroke:………………………...

Onset:……………………….……

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

……………………………………………….. ……………………………………………....

Tel……………………………………………. Address: …………………………………...

………………………………………...

BI score: ………………………………...……

MMSE score:………………………………..FM score:………………………

group:………………...

Study: ☐ Pilot ☐ Reliability ☐ Validity

Evaluation: ☐ Before ☐ < 7 days ☐ After

BP:………………………………………………………

History:

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APPENDIX B

APPENDIX B

MINIi–MENTAL STATE EXAMINATION (THAI VERSION)[181, 182]

1. Orientation for time (5 คะแนน) บันทึกคำตอบไว้ทุกครั้ง คะแนน
(ตอบถูกข้อละ 1 คะแนน) (ทั้งคำตอบที่ถูกและผิด)

1.1 วันนี้วันที่เท่าไร ☐
1.2 วันนี้วันอะไร ☐
1.3 เดือนนี้เดือนอะไร ☐
1.4 ปีนี้ปีอะไร ☐
1.5 ฤดูนี้ฤดูอะไร ☐

2. Orientation for place (5 คะแนน) (ให้เลือกข้อใดข้อหนึ่ง) (ตอบถูกข้อละ 1 คะแนน)

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 สถานที่ตรงนี้เรียกว่าอะไร และบ้านเลขที่อะไร ☐
2.2.2 ที่นี่หมู่บ้าน หรือละแวก/คุ้ม/ย่าน/ถนนอะไร ☐
2.2.3 ที่นี่อำเภอเขต / อะไร … ☐
2.2.4 ที่นี่จังหวัดอะไร ☐
2.2.5ที่นี่ภาคอะไร . ☐

3. Registraion (3 คะแนน)

ต่อไปนี้เป็นการทดสอบความจำ ดิฉันจำบอกชื่อของ 3 อย่าง คุณ (ตา , ยาย....) ตั้งใจฟังให้ดีนะ เพราะจะบอกเพียงครั้งเดียว ไม่มีการบอกซ้ำอีก เมือ ผม (ดิฉัน) พูดจบ ให้ คุณ(ตา,ยาย....) **พูดทบทวนตามที่ได้ยิน ให้ครบ ทั้ง 3 ชื่อ** แล้วพยามจำไว้ให้ดี เดี๋ยวดิฉันจะถามซ้ำ

∗ การบอกชื่อแต่ละคำให้ห่างกันประมาณหนึ่งวินาที ต้องไม่ช้าหรือเร็วเกินไป (ตอบถูก 1 คำได้ 1 คะแนน)

○ ดอกไม้ ○ แม่น้ำ ○ รถไฟ ☐

ในกรณีที่ทำแบบทดสอบซ้ำภายใน 2 เดือน ให้ใช้คำว่า

○ ต้นไม้ ○ ทะแล ○ รถยนต์ ☐

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

ข้อนี้เป็นการคิดเลขในใจเพื่อทดสอบสมาธิ คุณ (ตา,ยาย....) คิดเลขในใจเป็นไหม ?
ถ้าตอบคิดเป็นทำข้อ 4.1 ถ้าตอบคิดไม่เป็นหรือไม่ตอบให้ทำข้อ 4.2
4.1 “ข้อนี้คิดในใจเอา 100 ตั้ง ลบออกที่ละ 7 ไปเรื่อยๆ”

ได้ผลเท่าไรบอกมา .... ☐

บันทึกคำตอบตัวเลขไว้ทุกครั้ง (ทั้งคำตอบที่ถูกและผิด) ทำทั้งหมด 5ครั้ง
ถ้าลบได้ 1,2,หรือ3 แล้วตอบไม่ได้ ก็คิดคะแนนเท่าที่ทำได้ ไม่ต้องย้ายไปทำข้อ 4.2
4.2 "ผม (ดิฉัน) จะสะกดคำว่า มะนาว ให้คุณ (ตา , ยาย....) ฟังแล้วให้คุณ (ตา , ยาย....)
สะกดถอยหลังจากพยัญชนะตัวหลังไปตัวแรก คำว่ามะนาวสะกดว่า
มอม้า-สระอะ-นอหนู-สระอา-วอแหนว ไหนคุณ(ตา,ยาย....)สะกอถอยหลัง 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 ☐

7. Repetition (1 คะแนน) (พูดตามได้ถูกต้องได้ 1 คะแนน)
ตั้งใจฟังผม (ดิฉัน) เมื่อผม (ดิฉัน) พูดข้อความนี้ แล้วให้คุณ (ตา,ยาย)พูดตาม ผม (ดิฉัน)
จะบอกเพียงครั้งเดียว "ใครใคร่ขายไก่ไข" ☐

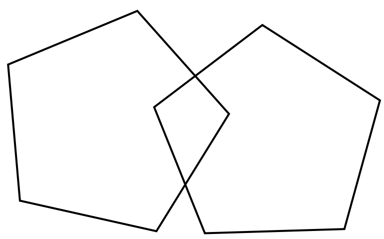
8. Verbal command (3 คะแนน)
ข้อนี้ฟังคำสั่ง "ฟังดีๆ นะเดี๋ยวผม (ดิฉัน)จะส่งกระดาษให้คุณ แล้วให้คุณ (ตา , ยาย....)
รับด้วยมือขวา พับครึ่งกระดาษ แล้ววางไว้ที่ ...."(พื้น,โต๊ะ,เตียง)
ผู้ทดสอบแสดงกระดาษเปล่าขนาดประมาณ เอ-4 ไม่มีรอยพับ ให้ผู้ถูกทดสอบ
○ รับด้วยมือขวา ○ พับครึ่ง ○ วางไว้ที่"(พื้น,โต๊ะ,เตียง) ☐

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 1ประโยค".............................. ○ ประโยคมีความหมาย ☐

11. Visuoconstruction (1 คะแนน)
ข้อนี้เป็นคำสั่ง "จงวาดภาพให้เหมือนภาพตัวอย่าง" (ในช่องว่างด้านขวาของภาพตัวอย่าง) ☐

คะแนนเต็ม ....



APPENDIX C

APPENDIX C

FUGL-MEYER MOTOR ASSESSMENT

Test	Item	Score		Scoring Criteria
		Pre	Post	
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
V. Normal Reflexes (sitting)	Knee flexors, Patellar, Achilles (This item is only tested if the patient achieves a maximum score on all previous UE 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

Fugl-Meyer assessment: Motor function (continued)

Test	Item	Score Pre	Score Post	Scoring Criteria
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
Motor Function- Upper Extremity				
I. Reflexes	Biceps Triceps			0-No reflex activity can be elicited 2-Reflex activity can be elicited
II. Flexor synergy	Elevation Shoulder retraction Abduction (at least 90°) External rotation Elbow flexion, supination			0-Cannot be performed at all 1-Performed partly 2-Performed faultlessly
III. Extensor synergy	Shoulder add./int. rot. Elbow extension Forearm pronation			0-Cannot be performed at all 1-Performed partly 2-Performed faultlessly
IV. Movement combining synergies	Hand to lumbar spine			0-No specific action performed 1-Hand must pass anterior superior iliac spine 2-Performed faultlessly

Fugl-Meyer assessment: Motor function (continued)

Test	Item	Score Pre	Score Post	Scoring Criteria
IV. Movement combining synergies	Shoulder flexion to 90°, elbow at 0°			0-Arm is immediately abducted, or elbow flexes at start of motion 1-Abduction or elbow flexion occurs in later phase 2-Performed faultlessly
	Pronation/supination of forearm with elbow at 90° & shoulder at 0°			0-Correct position of shoulder and elbow cannot be attained, and/or pronation or supination cannot be performed at all 1-Active pronation or supination can be performed even within a limited range of motion, and at the same time the shoulder and elbow are correctly positioned 2-Complete pronation and supination with correct positions at elbow and shoulder
V. Movement out of synergy	Shoulder abduction to 90°, elbow at 0°, and forearm pronated			0-Initial elbow flexion occurs or any deviation from pronated forearm occurs 1-Motion can be performed partly, or, if during motion, elbow is flexed, or forearm cannot be kept in position. 2-Performed faultlessly
	Shoulder flexion 90°-180°, elbow at 0°, and forearm in mid-position			0-*Initial* flexion of elbow or shoulder abduction 1-Elbow flexion or shoulder abduction occurs during shoulder flexion 2- Performed faultlessly
	Pronation/supination of forearm, elbow at 0° and shoulder 30°-90° of flexion			0-Supination and pronation cannot be performed at all, or elbow and shoulder positions cannot be attained

Fugl-Meyer assessment: Motor function (continued)

Test	Item	Score		Scoring Criteria
		Pre	Post	
V. Movement out of synergy				1-Elbow and shoulder properly positioned and pronation/ supination performed in a limited range 2-Performed faultlessly
VI. Normal reflex activity	Biceps and/or finger flexors and triceps (This item is only tested if the patient achieves a maximum score on all previous UE 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
VII. Wrist	Stability, elbow at 90°, shoulder at 0°			0-Patient cannot dorsiflex wrist to required 15° 1-Dorsiflexion is accomplished, but no resistance 2-Position can be maintained with some resistance
	Flexion/extension, elbow at 900, shoulder at 0°			0-Volitional movement does not occur 1-Patient cannot actively move the wrist joint throughout the total ROM 2-Faultless, smooth movement
	Stability, elbow at 0°, shoulder at 30°			0-Patient cannot dorsiflex wrist to required 15° 1-Dorsiflexion is accomplished, but no resistance is taken 2-Position can be maintained with some (slight) resistance
	Flexion/extension, elbow at 0°, shoulder at 30°			0-Volitional movement does not occur 1-Patient cannot actively move the wrist joint throughout the total ROM 2-Faultless, smooth movement

Fugl-Meyer assessment: Motor function (continued)

Test	Item	Score		Scoring Criteria
		Pre	Post	
VII. Wrist	Circumduction			0-Cannot be performed 1-Jerky motion or incomplete circumduction 2-Complete motion with smoothness
VIII. Hand	Finger mass flexion			0-No flexion occurs 1-Some flexion, but not full motion 2-Complete active flexion (compared with unaffected hand)
	Finger mass extension			0-No extension occurs 1-Patient can release an active mass flexion grasp 2-Full active extension
	Grasp I - MCP joints extended and proximal & distal IP joints are flexed; grasp is tested against resistance			0-Required position cannot be acquired 1-Grasp is weak 2-Grasp can be maintained against relatively great resistance
	Grasp II - Patient is instructed to adduct thumb, with a scrap of paper interposed			0-Function cannot be performed 1-Scrap of paper interposed between the thumb and index finger can be kept in place, but not against a slight tug 2-Paper is held firmly against a tug
VIII. Hand	Grasp III - Patient opposes thumb pad against the pad of index finger, with a pencil interposed			0-Function cannot be performed 1-Pencil interposed between the thumb and index finger can be kept in place, but not against a slight tug 2-Pencil is held firmly against a tug

Fugl-Meyer assessment: Motor function (continued)

Test	Item	Score		Scoring Criteria
		Pre	Post	
VIII. Hand	Grasp IV - The patient should grasp a can by opposing the volar surfaces of the 1st and 2nd digits.			0-Function cannot be performed 1-A can interposed between the thumb and index finger can be kept in place, but not against a slight tug 2-Can is held firmly against a tug
	Grasp V - The patient grasps a tennis ball with a spherical grip or is instructed to place his/her fingers in a position with abduction position of the thumb and abduction flexion of the 2nd, 3rd, 4th & 5th fingers			0-Function cannot be performed 1-A tennis ball can be kept in place with a spherical grasp but not against a slight tug 2-Tennis ball is held firmly against a tug
IX. Coordination/ Speed- Finger to nose (5 repetitions in rapid succession)	Tremor			0-Marked tremor 1-Slight tremor 2-No tremor
	Dysmetria			0-Pronounced or unsystematic dysmetria 1-Slight or systematic dysmetria 2- No dysmetria
	Speed			0-Activity is more than 6 seconds longer than unaffected hand 1-(2-5.9) seconds longer than unaffected side 2-Less than 2 seconds difference
Upper Extremity Total				Maximum = 66
Total Motor Score (Upper + Lower Extremity)				Maximum = 100

APPENDIX D

APPENDIX D

BALANCE ASSESSMENT FORM

TABLE D1 BALANCE ASSESSMENT FORM IN LYING POSITION.

Balance Test: Lying position				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Supine to affected side lateral	PASS 6			0=cannot perform the activity 1=can perform the activity with much help 2=can perform the activity with little help 3=can perform the activity without help
Supine to nonaffected side lateral	PASS 7			
Supine to sitting up on the edge of the table	PASS 8			

TABLE D2 BALANCE ASSESSMENT FORM IN SITTING POSITION.

Balance Test: sitting				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Sitting on the edge of the table to supine	PASS 9			0=cannot perform the activity 1=can perform the activity with much help 2=can perform the activity with little help 3=can perform the activity without help
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)	PASS 1			0=cannot sit 1=can sit with slight support, for example, by 1 hand 2=can sit for more than 10 seconds without support 3=can sit for 5 minutes without support
	BBS 3			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 6			(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
Verticality right	BEST 7			
Lateral lean left	BEST 8			(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)
Lateral lean right	BEST 9			

TABLE D2 (continued)

Balance Test: sitting				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Transfers You may use two chairs (one with and one without armrests) or a bed and a chair.	BBS 5			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
Sitting to standing up	PASS 10			0 = cannot perform the activity 1 = can perform the activity with much help 2 = can perform the activity with little help 3 = can perform the activity without help
Sitting to standing up	BBS 1			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 13			(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

TABLE D3 BALANCE ASSESSMENT FORM IN STANDING POSITION.

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Standing with support (feet position free, no other constraints)	PASS 2			0=cannot stand, even with support 1=can stand with strong support of 2 people 2=can stand with moderate support of 1 person 3=can stand with support of only 1 hand
Standing without support (feet position free, no otherconstraints) < 30 s	PASS 3			0=cannot stand without support 1=can stand without support for 10 s. or leans heavily on 1 leg 2=can stand without support for 1 minute or stands slightly asymmetrically 3=can stand without support for more than 1 minute and at the same time perform arm movements above the shoulder level
	BBS 2			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 25			(3) 30s stable (2) 30s unstable (1) < 30s (0) Unable
Base of support	BEST 1			(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

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
CoM alignment	BEST 2			(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			(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 4			(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

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Standing to sitting	BBS 4			4-sit safely with minimal use of hand 3-controls decent by using hands 2-use back of legs against chair to control descent 1-sits independently but has uncontrolled descent 0-needs assist to sit
	PASS 11			0 = cannot perform the activity 1 = can perform the activity with much help 2 = can perform the activity with little help 3 = can perform the activity without help
Sit on floor and stand up	BEST 5			(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 6			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 26			(3) 30s stable (2) 30s unstable (1) < 30s (0) Unable

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Standing with feet together	BBS 7			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
Eye open/foam surface Trial 1 ______sec, 2 ______sec	BEST 27			(3) 30s stable (2) 30s unstable (1) < 30s
Eye close/foam surface Trial 1 ______sec, 2 ______sec	BEST 28			(0) Unable
Incline eyes closed	BEST 29			(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

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Reaching forward with outstretched arm	BBS 8			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
	BEST 10			(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 11			(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	BEST 12			
Rise to toes	BEST 14			(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

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Standing arm raise	BEST 18			(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
In place response-forward	BEST 19			(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
In place response-backward	BEST 20			
Compensatory stepping correction-forward	BEST 21			(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
Compensatory stepping correction-backward	BEST 22			
Compensatory stepping correction-lateral: Right	BEST 23			(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
Compensatory stepping correction-lateral: Left	BEST 24			

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Standing, picking up a pencil from the floor Acknowledgments	PASS 12			0 = cannot perform the activity 1 = can perform the activity with much help 2 = can perform the activity with little help 3 = can perform the activity without help
Standing, picking up a pencil from the floor Acknowledgments	BBS 9			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 10			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 11			4-able to turn 360 degrees safely in 4 seconds or less 3-able to turn 360 degrees safely one side only 4 seconds/ less 2-able to turn 360 degrees safely but slowly 1-needs close supervision or verbal cuing 0-needs assistance while turning

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Placing alternate foot on stool	BBS 12			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
Placing alternate foot on stool	BEST 17			(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 13			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

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Standing on nonparetic leg (no other constraints)	PASS 4			0=cannot stand on nonparetic leg 1=can stand on nonparetic leg for a few seconds 2=can stand on nonparetic leg for more than 5 s. 3=can stand on nonparetic leg for more than 10 s.
Standing on nonparetic leg (no other constraints	BBS 14			4-able to lift leg independently and hold > 10 s. 3-able to lift leg independently and hold 5-10 s. 2-able to lift leg independently and hold ≥ 3 s. 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 15			(3) Normal: Stable for > 20 s. (2) Trunk motion, OR 10-20 s. (1) Stands 2-10 s. (0) Unable
	CB&M 1			0) unable to sustain 1) 2.00 to 4.49 s. 2)4.50 to 9.99 s.. 3) 10.00 to 19.99 s.. 4) > 20.00 s.. 5) 45.00 s.., steady and coordinated
Standing on paretic leg (no other constraints)	PASS 5			0=cannot stand on nonparetic leg 1=can stand on nonparetic leg for a few seconds 2=can stand on nonparetic leg for more than 5 seconds 3=can stand on nonparetic leg for more than 10 seconds

TABLE D3 (continued)

Balance Test: Standing				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Standing on paretic leg (no other constraints)	BEST 16			(3) Normal: Stable for > 20s (2) Trunk motion, OR 10-20 s (1) Stands 2-10s (0) Unable
	CB&M 2			0) unable to sustain 1) 2.00 to 4.49 sec. 2) 4.50 to 9.99 sec. 3) 10.00 to 19.99 sec. 4) > 20.00 secs. 5) 45.00 sec., steady and coordinated

TABLE D4 BALANCE ASSESSMENT FORM IN WALKING.

Balance Test: Walking				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Gait-level surface *Time________secs.*	BEST 30			(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 31			(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 32			(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.

TABLE D4 (continued)

Balance Test: Walking				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Walk with pivot turns	BEST 33			(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________s.*	BEST 34			(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 __________s.	BEST 35			(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.

TABLE D4 (continued)

Balance Test: Walking				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Timed “Get Up & Go” with dual task	BEST 36			(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
Tandem walking	CB&M 3			0= unable 1= 1 step 2= 2 to 3 consecutive steps (heel-toe distance < 3") 3= > 3 consecutive steps (heel-toe distance < 3") 4 => 3 consecutive steps (in good aligment) 5 =7 consecutive steps (in good)
180° tandem pivot	CB&M 4			0) unable to sustain tandem stance 1) sustains tandem stance but unable to unweight heels or initiate pivot 2) initiates pivot but unable to complete 180° turn 3) completes 180° turn but discontinuous pivot 4) completes 180° turn in a continuous motion but can’t sustain reversed position 5) completes 180° turn in a continuous motion and sustains reversed position

TABLE D4 (continued)

Balance Test: Walking				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Lateral foot scooting: left	CB&M 5			0) unable 1) 1 lateral pivot 2) 2 lateral pivots 3) > 3 pivots but < 40 cm 4) 40 cm in any fashion and/or unable to control nal position 5) 40 cm continuous, rhythmical motion with controlled stop.
Lateral foot scooting: right	CB&M 6			0) unable 1) 1 lateral pivot 2) 2 lateral pivots 3) > 3 pivots but < 40 cm 4) 40 cm in any fashion and/or unable to control nal position 5) 40 cm continuous, rhythmical motion with controlled stop.
Hopping forward: left	CB&M 7			0) unable 1) 1 to 2 hops, uncontrolled 2) 2 hops, controlled but unable to complete 1 m. 3) 1 m. in 2 hops but unable to sustain landing 4) 1 m. in 2 hops but difficulty controlling landing 5) 1 m.in 2 hops, coordinated with stable landing

TABLE D4 (continued)

Balance Test: Walking				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Hopping forward: right	CB&M 8			0) unable 1) 1 to 2 hops, uncontrolled 2) 2 hops, controlled but unable to complete 1 m. 3) 1 m. in 2 hops but unable to sustain landing 4) 1 m. in 2 hops but difficulty controlling landing 5) 1 m.in 2 hops, coordinated with stable landing
Crouch and walk	CB&M 9			0) unable to crouch 1) able to descend only 2) descends and rises but hesitates, unable to maintain forward momentum 3) crouches and walks in continuous motion, time < 8.00 sec. protective step 4) crouches and walks in continuous motion, time < 8.00 sec. excessequilibrium reaction 5) crouches and walks in continuous motion, time < 4.00 sec.
Lateral dodging	CB&M 10			0) unable to perform 1 cross-over in both directions without support 1) 1 cross-over in both directions in any fashion 2) 1 or more cycles, but does not contact line every step 3) 2 cycles, contacts line every step 4) 2 cycles, contacts line every step 12.00 to 15.00 sec. 5) 2 cycles, contacts line every step < 12.00 sec. coordinated direction change

TABLE D4 (continued)

Balance Test: Walking				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Walking & looking: left	CB&M 11			0) unable to walk and look e.g. stops 1) performs but loses visual fixation at or before 4 m m 2) performs but loses visual fixation after 4 mmark 3) performs and maintains visual fixation between 2-6 m mark but protective step 4) performs and maintains visual fixation between 2-6 m mark but veers 5) performs, straight path, steady and coordinated < 7.00 sec.
Walking & looking: right	CB&M 12			0) unable to walk and look e.g. stops 1) performs but loses visual fixation at or before 4 m m 2) performs but loses visual fixation after 4 m mark 3) performs and maintains visual fixation between 2-6 m mark but protective step 4) performs and maintains visual fixation between 2-6 m mark but veers 5) performs, straight path, steady and coordinated < 7.00 sec.
Running with controlled stop	CB&M 13			0) unable to run 1) runs, time > 5.00 sec. 2) runs, time > 3.00 but < 5.00 s., unable to control stop 3) runs, time > 3.00 but < 5.00 s., with controlled stop, both feet 4) runs, time < 3.00 s., unable to control stop 5) runs, time < 3.00 s., with controlled stop, both feet on line, coordinated and rhythmical

TABLE D4 (continued)

Balance Test: Walking				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Forward to backward to walking	CB&M 14			0) unable 1) performs but must stop to regain balance 2) performs with reduced speed, time > 11.00 sec. or requires 4 or more steps to turn 3) performs in < 11.00 sec. and/or veers during backward walking 4) performs in < 9.00 sec. and/or uses protective step during or just after turn 5) performs in < 7.00 sec., maintains straight path
Walk, look and carry: left	CB&M 15			0) unable to walk and look e.g. stops 1) performs but loses visual fixation at or before 4 m mark 2) performs but loses visual fixation after 4 m mark 3) performs and maintains visual fixation between 2-6 m mark butprotective step 4) performs and maintains visual fixation between 2-6 me mark but veers 5) performs, straight path, steady and coordinated < 7.00 sec.
Walk, look and carry: Rt.	CB&M 16			

TABLE D4 (continued)

Balance Test: Walking				
Item	Test	Score		Scoring Criteria
		Pre	Post	
Descending stairs	CB&M 17			0) unable to step down 1 step, or requires railing or assistance 1) able to step down 1 step with/without cane 2) able to step down 3 steps with/without cane, any pattern 3) 3 steps reciprocal or full flight in step-to pattern 4) full flight reciprocal, awkward 5) full flight reciprocal, rhythmical and coordinated +1 bonus for carrying basket
Step-ups X 1 step: left	CB&M 18			0) unable to step up, requires assistance or railing 1) steps up, requires assistance or railing to descend 2) steps up and down (1 cycle) 3) completes 5 cycles 4) completes 5 cycles in > 6.00 but < 10.00 sec. 5) completes 5 cycles in < 6.00 sec., rhythmical
Step-ups X 1 step: right	CB&M 19			0) unable to step up, requires assistance or railing 1) steps up, requires assistance or railing to descend 2) steps up and down (1 cycle) 3) completes 5 cycles 4) completes 5 cycles in > 6.00 but < 10.00 sec. 5) completes 5 cycles in < 6.00 sec., rhythmical

APPENDIX E

APPENDIX E

CONSENT FORM

วันที่ ……………….……

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

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

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

ขอทำหนังสือนี้ให้ไว้ต่อหัวหน้าโครงการวิจัยเพื่อเป็นหลักฐานแสดงว่า

ข้อ 1. ข้าพเจ้า ได้รับทราบโครงการวิจัยของ ผศ.ดร.รัมภา บุญสินสุข เรื่อง “การพัฒนาเครื่องมือประเมินทางคลินิกเพื่อใช้ตรวจวัดความบกพร่องสมดุลการทรงตัวและวิเคราะห์สาเหตุของความบกพร่องสมดุลการทรงตัวในผู้ป่วยโรคหลอดเลือดสมอง”

ข้อ 2. **ข้าพเจ้า ยินยอมเข้าร่วมโครงการวิจัยนี้ ด้วยความสมัครใจ โดยมิได้มีการบังคับขู่เข็ญหลอกลวงแต่ประการใด และจะให้ความร่วมมือในการวิจัยทุกประการ**

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

ข้อ 4. ข้าพเจ้า ได้รับการรับรองจากผู้วิจัยว่าจะเก็บข้อมูลส่วนตัวของข้าพเจ้าเป็นความลับ จะเปิดเผยเฉพาะผลสรุปการวิจัยเท่านั้น

ข้อ 5. ข้าพเจ้า ได้รับทราบจากผู้วิจัยแล้วว่า หากมีอันตรายใด ๆ **อันเกิดขึ้นจากการวิจัยดังกล่าว** ข้าพเจ้าจะได้รับการรักษาพยาบาลจากคณะผู้วิจัยโดยไม่คิดค่าใช้จ่าย ตลอดจนมีสิทธิ์ได้รับค่าทดแทนความพิการที่อาจเกิดขึ้นจากการวิจัยตามสมควร

ข้อ 6. ข้าพเจ้า ได้รับทราบแล้วว่าข้าพเจ้ามีสิทธิ์จะบอกเลิกการร่วมโครงการวิจัยนี้ และการบอกเลิกการร่วมโครงการวิจัย จะไม่มีผลกระทบต่อการดูแลรักษาโรคที่ข้าพเจ้าจะพึงได้รับต่อไป

ข้อ 7. หากข้าพเจ้ามีข้อข้องใจเกี่ยวกับขั้นตอนของการวิจัย หรือหากเกิดผลข้างเคียงที่ไม่พึงประสงค์

จากการวิจัย สามารถติดต่อกับ ผศ.ดร.รัมภา บุญสินสุข ที่อยู่ สาขาวิชากายภาพบำบัด คณะสหเวชศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ 63 หมู่ ถ. รังสิต-นครนายก ต.องครักษ์ อ.

องครักษ์ จ.นครนายก 26120 โทรศัพท์: 02-649-5000 ต่อ 2253 โทรสาร: 02-6495450 โทรศัพท์มือถือ 089-666-1731

ข้อ 8. หากข้าพเจ้า ได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าจะสามารถติดต่อกับประธานคณะกรรมการจริยธรรมสำหรับการพิจารณาโครงการวิจัยที่ทำในมนุษย์ หรือผู้แทน ได้ที่ ....

ข้าพเจ้าได้อ่านและเข้าใจข้อความตามหนังสือนี้โดยตลอดแล้ว เห็นว่าถูกต้องตามเจตนาของข้าพเจ้า จึงได้ลงลายมือชื่อไว้เป็นสำคัญพร้อมกับหัวหน้าโครงการวิจัยและต่อหน้าพยาน

ลงชื่อ .... ลงชื่อ ....

(...) (...)

ผู้ยินยอม ผู้ให้ข้อมูลและขอความยินยอม /หัวหน้าโครงการวิจัย

ลงชื่อ ....พยาน ลงชื่อ .... พยาน

(...) (...)

ในกรณีที่ผู้เข้าร่วมการวิจัย อ่านหนังสือไม่ออก ผู้ที่อ่านข้อความทั้งหมดแทนผู้เข้าร่วมการวิจัยคือ ....

จึงได้ลงลายมือชื่อไว้เป็นพยาน

ลงชื่อ ....พยาน

(...)

<u>หมายเหตุ</u>

กรณีผู้ยินยอมตนให้ทำวิจัย ไม่สามารถอ่านหนังสือได้ ให้ผู้วิจัยอ่านข้อความในหนังสือให้ความยินยอมนี้ให้แก่ผู้ยินยอมตนให้ทำวิจัยฟังจนเข้าใจแล้ว และให้ผู้ยินยอมตนให้ทำวิจัยลงนาม หรือพิมพ์ลายนิ้วหัวแม่มือรับทราบ ในการให้ความยินยอมดังกล่าวด้วย

APPENDIX F

APPENDIX F

PUBLICATION

Physical Therapy
Journal of the American Physical Therapy Association and de Fysiotherapeut
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Reliability and Validity of the Balance Evaluation Systems Test (BESTest) in People With Subacute Stroke

Butsara Chinsongkram, Nithinun Chaikeeree, Vitoon Saengsirisuwan, Nitaya Viriyatharakij, Fay B. Horak and Rumpa Boonsinsukh

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VITAE

VITAE

Name:	Miss Butsara Chinsongkram
Date of Birth:	January 23, 1980
Place of Birth:	Nakhon Sawan
Address:	73/110 Moo 9 Klong Nueng, Klong Luang Pathumthani 12120

Educational Background:

1998	Secondary Certificate Tunyaburi School
2003	Bachelor of Science Program (Physical Therapy) Rangsit University
2006	Master of Science Program (Physical Therapy) Khonkhan University
2014	Doctor of Philosophy (Physical Therapy) Srinakharinwirot University