The Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS)

Measurement properties and a longitudinal follow-up

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It is a privilege to be under pressure!

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ABSTRACT

Impaired postural control is common after stroke and might result in a fall. The consequence of a fall might be injuries, fear of falling, fear of movement, physical inactivity and impaired quality of life. It is therefore important to assess the patients' postural control and risk of falling in order to give individualised interventions. Postural control can be assessed using different scales and tests. The aim of this thesis was to evaluate the measurement properties of the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS) and to estimate the longitudinal change in postural control during the first 12 months after stroke. A total of 152 patients with first-ever stroke participated in the studies included in the thesis, and 116 of these patients participated in a prospective follow-up with repeated assessments of postural control and questioners relating to falls at three, six and 12 months. The SwePASS proved to be highly reliable and responsive to change. Used in the first week after stroke onset, the SwePASS is able to identify those patients at risk of falling during the first year after stroke moderately well. Postural control, assessed using the SwePASS, shows an improvement during the first six months after stroke. Rasch analysis of the SwePASS indicates that it works as a global measurement of postural control in patients with stroke but displays disordered thresholds and local dependency. Further studies with a larger better-targeted population with more impaired postural control are needed to confirm these results. To summarise, the results of the measurement properties of the SwePASS indicate that this scale is useful in the clinical setting for patients with stroke.

Keywords: postural balance, stroke, outcome

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LIST OF PAPERS

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I. Persson C U, Hansson P-O, Danielsson A, Sunnerhagen K S. A validation study using a modified version of Postural Assessment Scale for Stroke Patients: Postural Stroke Study in Gothenburg (POSTGOT).
J Neuroeng Rehabil 2011 8:57.

II. Persson C U, Hansson P-O, Sunnerhagen K S. Clinical tests performed in acute stroke identify the risk of falling during the first year: Postural Stroke Study in Gothenburg (POSTGOT).
J Rehabil Med 2011; 43: 348-53.

III. Persson C U, Sunnerhagen K S, Danielsson A, Grimby-Ekman A, Hansson P-O. Responsiveness of a modified version of the Postural Assessment Scale for Stroke Patients and longitudinal change in postural control after stroke: Postural Stroke Study in Gothenburg (POSTGOT).
J Neuroeng Rehabil Accepted for publication.

IV. Persson C U, Sunnerhagen K S, Lundgren-Nilsson Å. Rasch analysis of the Modified Version of the Postural Assessment Scale for Stroke Patients: Postural Stroke Study in Gothenburg (POSTGOT).
Submitted.

CONTENTS

ABBREVIATIONS

AUC	Area Under the Curve
10MWT	The 10 Metre Walking Test
BBS	The Berg Balance Scale
CI	Confidence Interval
d	Activities and Participation
DIF	Differential Item Functioning
GEE	Generalised Estimated Equations
ICF	International Classification of Functioning, Disability and Health
K (k)	Kappa
LOS	Length of Stay
M-MAS	The Modified Motor Assessment Scale Uppsala
UAS-95	Akademiska Sjukhus-95
n	Number of Patients or Number of Assessment Occasions
NPV	Negative Predictive Value
OR	Odds Ratio
PA	Percentage Agreement
PASS	The Postural Assessment Scale for Stroke Patients
POSTGOT	The Postural Stroke Study in Gothenburg
PPV	Positive Predictive Value
PSI	Person Separation Index
RC	Relative Concentration
ROC	Receiver Operating Characteristic
RP	Relative Position
r_s	The Spearman rank-order correlation coefficient
RV	Relative Rank Variance
SwePASS	The Modified Version of the Postural Assessment Scale for Stroke Patients
TUG	The Timed Up & Go
WHO	The World Health Organisation

BRIEF DEFINITIONS

Bias	A systematic error or deviation in results or inferences from the truth. Selection bias= arises from systematic differences in the groups that are compared. Recall bias= a bias arising from mistakes in recollecting events. Item bias= can occur when different groups in the sample respond in a dissimilar manner to an individual item, despite equal levels of the underlying characteristic.
Evidence-Based Medicine	The use of current best evidence in making decisions about the care of individual patients. Integrates individual clinical expertise with the best available external clinical evidence from systematic research and patients' choice.
Items	The questions or the statements of the measurement instrument to be considered for judgment.
Measurement Instrument	A scale or test to record data.
Negative Predictive Value	A measurement of the usefulness of a screening/diagnostic test. It is calculated as follows: number with a correctly diagnosed negative outcome/total number with a negative test.
Observational Study	A study in which the investigators observe events and do not intervene.
Odds Ratio	Method of estimating relative risk by calculating the ratio of odds that each of two groups will possess a certain characteristic.

Positive Predictive Value	A measurement of the usefulness of a screening/diagnostic test. It is calculated as follows: number with a correctly diagnosed positive outcome/total number with a positive test.
Scale	Categorical recording of items, which will be nominal or ordinal.
Sensitivity	Sensitivity relates to the ability of a scale or test to identify a positive result. It is calculated as follows: number with a correctly diagnosed positive outcome /total number with a positive outcome.
Specificity	Specificity relates to the ability of a scale or tests to identify a negative result. It is calculated as follows: number with a correctly diagnosed negative outcome/ total number with a negative outcome.
Unidimensional	If all items of the instrument represent the same variable, i.e. one single domain. It is measured by means of various specific items carrying different aspects of the common domain.

INTRODUCTION

During my clinical work since 1991 as a physiotherapist at Sahlgrenska University Hospital and since 2001 with the specific location at a stroke unit, I have met a large number of in-patients in the acute phase after a stroke. Based on my experience, postural control is central for many of the patients in their rehabilitation. Regardless of the consequences following the stroke, the rehabilitation must be optimal and individualised. This requires a careful assessment. For this assessment and to evaluate the effect of a given treatment or approach, clinical measurement instruments that are reliable, valid and responsive but also easy to handle and quick to perform, are needed. In 1999, Charles Benaim and colleagues published an article, 'Validation of a Standardized Assessment of Postural Control in Stroke Patients, The Postural Assessment Scale for Stroke Patients (PASS)' (1), relating to a reliable clinical scale for assessing postural control, which was moreover easy and quick to perform. This article was the starting point of this PhD project, the Postural Stroke Study in Gothenburg (POSTGOT), although I did not know it then.

The PASS was translated into Swedish. In addition, modifications were made for some of the items. The new scale was named the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS). Before using the SwePASS in the clinic, to assess postural control after stroke, it had to be evaluated.

This thesis is an attempt to improve the knowledge of the measurement properties of the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS) and of the change in postural control after stroke. I dedicate this thesis to the patients, who through their participation enabled the different studies.

The Construct

A construct has been defined as 'a well-defined and precisely demarcated subject of measurement' (2).

The word *balance* can mean many different things. In a clinical setting, balance can be used in association with function, based on the impulses from the eyes, the vestibular system and the somatosensory stimuli from the skin, tendons, muscles and joints. Balance can also be used in association with activity and participation, such as sitting, standing, walking, running, turning around and obtaining information from the environment and not falling. In addition, balance can be associated with fluids or electrolytes. Consequently, there is a risk of confusion regarding the construct without knowing the context. Even if the context is known, there is no single universal definition of balance.

In 2000, in order to create evidence-based practice, where a valid definition of the terminology used is fundamental, Pollock and colleagues presented a proposal for definitions of balance, human balance and their related terms (3). In mechanics, balance is defined as the state of an object when the forces or moments acting upon it are zero (4) (Newton's first law). Balance has also been described as a generic term, describing the dynamics of body posture to prevent falling, related to the action of inertial forces on the body and the inertial characteristics of the body segments (3). *Human balance* is defined as a multidimensional concept, referring to the ability of a person not to fall (5, 6).

Not falling and the inherent ability of a person to maintain, achieve or restore a specific state of balance are also defined as *human stability*. Human stability refers to the motor and sensory systems and to the physical properties of the person (3). In addition, balance is referred to as *postural stability*, defined as the ability to control the centre of mass in relation to the base of support. The base of support is the area of single contact between the body and support surface or, if there is more than one contact with the support surface, the area enclosing all the contacts with the support surface (7). There are further examples of terms used in scientific literature. *Dynamic stability* (8, 9), or the resilience of the loco motor system to the infinite, is small (i.e. 'local')

perturbations that occur naturally during walking. In addition, dynamic stability has been explained as 'the process that allows dynamic equilibrium at every instant'. From the onset to the end, dynamic stability permits a task-oriented movement to be carried out efficiently (10). *Lateral stability* is described as the lateral body motion that occurs in forward and backward steps, and the ability to avoid collision with the stance limb during lateral steps by controlling the lateral foot movement (11).

Walking balance has been defined as 'the ability to control the centre of mass within the base of support to remain upright while walking' (12). *Dynamic balance* has been expressed as anticipatory- transitions (sit to stand, stand on one leg), postural responses (stepping forward, stepping backward), sensory orientation (stance eyes open firm surface, eyes closed foam surface) and dynamic gait (gait natural, change speed, Get Up and Go) (13).

In 2009, *postural balance* was introduced as a Medical Subject Heading (MeSH) term in the National Centre for Biotechnology Information (NCBI). The term is defined as 'providing the body carriage stability and conditions for normal functions in stationary position or in movement, such as sitting, standing or walking' (14).

There are several similar definitions of the term *postural control;* 'the act of maintaining, achieving or restoring a state of balance during any posture or activity' (3) and 'the ability to maintain a given posture and to ensure equilibrium in changes of position' (1). Postural control has been described as having a dual function and goal. First, there is the *stability*, the function to control the body's position in space. Second, there is the *orientation*, the function of orientation of body segments and between body and the environment for a task (15, 16). Postural orientation is defined as 'the ability to maintain an appropriate relationship between the body segments, and between the body and the environment for a task' (15). Both stability and orientation vary as they emerge from an interaction between the individual, the task and the environmental constraints (17). In 'Motor Control', Shumway-Cook and Woollacott describe postural control as a conceptual model, representing an interaction between the following components; musculoskeletal components, internal representations, anticipatory mechanisms,

sensory strategies, individual sensory systems, neuromuscular synergies and adaptive mechanisms (17). In 2009, Horak *et al.* (18) presented a theoretical framework of factors that are proposed to be underlying postural control (corresponding to the sections of the Balance Evaluation Systems Test) (BESTest); biomechanical constraints, stability limits/verticality, anticipatory postural adjustments, postural responses, sensory orientation and stability in gait.

Strategies for postural control may be proactive (anticipatory) or reactive (compensatory) or a combination of both. The responses can be fixed-support, such as ankle and hip strategies (swaying from the ankle or the hip) (19-21), or change-in support, such as stepping strategy and grasping (3).

Which Construct to Use?

As shown above, there are a large number of definitions. What is said in the International Classification of Functioning and Health (ICF) (22)? In order to promote and to facilitate communication and documentation among health professionals worldwide, the World Health Organisation (WHO) developed the ICF (23). The ICF's framework is a biopsychosocial approach, an international standard to describe and measure health and disability. Together, the description and the classification of health or health-related domains are performed at both individual and population levels. These levels represent body, individual and societal perspectives, using a list of body structures and bodily functions and a list of the domains of activity and participation. In addition, the ICF includes a list of environmental factors and personal factors, as the person's functioning and disability occur in a context (23). In the ICF, *balance* is defined as 'vestibular functions', encoded as Body Function (b), *postural balance* is defined as 'involuntary movement reaction functions', also encoded as Body Function (b) while *postural control* is not defined at all (22). To summarise, there is no global definition or demarcation of the subject of measurement, i.e. there is no concept.

Throughout Papers I, III-IV, the term 'postural control' was used as proposed by Benaim and colleagues, as 'the ability to maintain a given posture and ensure equilibrium in changes of position' (1) in different

activities. In Paper II, the term 'postural balance', according to the NCBI (14), and the term 'walking balance' (12) were used. In the thesis postural control refers to the capacity to maintain a given posture and to ensure equilibrium in different activities related to the risk of falling.

What Affects Postural Control?

Postural control develops from birth until shortly after adolescence (24). With ageing, there is a progressive loss of function in the visual, vestibular and somatosensory systems, which can contribute to a deterioration in postural control (25). The significant deterioration in vestibular function and postural control that takes place during ageing has been confirmed by a United States population aged 40 years and older (*n* 5,068) (26) and by a Swedish urban population from the city of Göteborg of 75-years-olds (*n* 571) by Kollén and colleagues (27). The latter established that 36% had problems with impaired balance or dizziness.

Orthostatic hypotension is another strongly age-dependent factor that affects postural control (28). Hospitalised patients are particularly vulnerable due to bed rest, drug treatment and many acute illnesses, which may disturb the regulation of postural blood pressure. This may persist after discharge and is strongly associated with the risk of cardiovascular complications, such as stroke (28). However, in a previous review, orthostatic hypotension did not predict falls after controlling for other factors in community-dwelling persons aged 65 years or older (29). In the same study, patients who had fallen in the past year were more likely to fall again. Other predictors of further falls were clinically detected abnormalities of gait or balance (29). In addition, *lateral stability* has shown an age-related deterioration, by collisions between the swing foot and stance limb in walk-in place trials (11).

Vitality has been reported to have a protective effect on the likelihood of falls, even when controlling for mental and physical health. The report was based on a large female population (*n* 11,340), observed for up to 13 years (30).

In obese individuals, compared with non-obese individuals, the postural stability, when standing without visual input, may be more vulnerable

with a larger increase in the length and the area of sway (31). Sarcopenia, characterised by a loss of muscle strength and reduced physical performance, is another condition of importance. Based on a population of the old-older (≥80 years), patients with sarcopenia have been found to run a higher risk of incident falls compared with non-sarcopenia patients (32).

Both genders are at risk of falls, across all age groups and regions. Older women and younger children are particularly prone to falls and increased injury severity. In some countries, males have been found be more likely to die from a fall, while females experience more non-fatal falls. The higher mortality rate seen among males might be explained by higher levels of hazards, risk-taking behaviours and within occupations (33). In a cross-sectional population study from Barbados (*n* 1,508) and Cuba (*n* 1,905) (34), men were found to have better balance compared with women. This finding was confirmed in a multicentre study based on seven Latin-American and Caribbean countries (*n 1,894*) (35). Reduced physical function, including balance, appears to occur earlier in life in women than in men (36). When it comes to developing a fear of falling, being female is one of several risk factors (37). In one study performing a dual-task paradigm, in older men and women, there was no difference in gender regarding the attentional demands of walking (38). Neither was any gender effect found on functional balance with a high-intensity functional weight-bearing exercise programme (39).

An uneven walking rhythm indicates an increased risk of falling (40). Fall-prone and balance-impaired elderly individuals have been found to have slower walking capacity, compared with age-matched healthy older adults or young adults. The fall-prone group also demonstrated poor stability of dynamic walking (41). Walking velocity may be a compensatory behaviour to maintain dynamic stability, supported by the fact that local dynamic stability is influenced by walking velocity (9).

It has been suggested that traditional exercise-based, task-specific training involving the whole-body to improve co-ordinated movements of the head, arms and trunk, may reduce falls in older adults. There are differences in the protective actions for a forward-directed fall after a trip compared with that of a backward-directed fall after a slip. Consequently, in the rehabilitation after a fall, it has been recommended

to take the general direction of a fall into account (42). In order to identify individuals running a high risk of falling, clinicians are also encouraged to assess compensatory reaching and stepping reactions (11).

Tai Chi's proposed benefits on the physical and psychological health of older people are yet to be validated in large randomised trials (43). In addition, based on a review of 21 studies of older adults, there is an indication that visual-feedback-based training of balance has an effect on postural control using the Berg Balance Scale (BBS) and the weight-shifting in standing (44).

Falls in Society

As mentioned, many factors can increase the risk of falling in society. The WHO has defined a fall 'as an event which results in a person coming to rest inadvertently on the ground or floor or other lower level' (45). Children are one risk group for falls, a result of 'risk-taking behaviour', inadequate adult supervision and hazardous environment, for example (45). Another risk group for falls comprises individuals aged 65 years and older. Among community-dwelling individuals aged 65 years and older, one out of three fell every year (46, 47). The cause of a fall is multifactorial. A fall can be attributed to biomechanical problems (48), a failing neuromuscular system (deteriorating motor and sensory control mechanisms) (49), diminished cognition, information and stimuli processing (50).

In tests of fast walking, both frail persons with short shuffling steps and healthy persons were exposed to a high risk of multiple falls (51). Solely good health characteristics were reported in individuals who had fallen only outdoors, whereas individuals who had fallen only indoors were generally in poor health, based on a prospective cohort study of more than 700 persons, mostly aged 70 years and more (52). In addition, a larger proportion of the indoor-only recurrent fallers had a gait speed slower than 0.6 m/s and a higher proportion with a BBS score of less than 48 compared with outdoor-only recurrent fallers (52).

Moreover, the use of anti depressive drugs, especially Selective Serotonin Uptake Inhibitors (SSRI), has been shown to be strongly

associated with falls, regardless of the presence of depressive symptoms. This finding is based on 21,900 community-dwelling individuals in Australia, aged 60 and older (53). Anti depressive drugs are known to cause orthostatic hypotension, which might be the explanation of the higher risk of falling.

In another large (*n* 1,682) Australian study, based on geriatric patients, cognitive status and a previous history of falls was shown to be constant risk factors for falls, regardless of setting; inpatient, outpatient and domiciliary (54).

In American adults, 65 years and older, obesity appears to be associated with a greater risk of falling, as well as with greater disability in Activity in Daily Life (ADL) after a fall. However, obesity (BMI ≥ 40) may reduce the risk of injury from a fall (55).

Stop walking when talking might be an effective strategy, but it is also an indication of fall risk (56). Among older adults and frail older adults in particular, variations in performance while dual tasking, 'stops walking when talking', have been shown to be significantly associated with an increased risk of falling. The results are based on pooled data from 15 studies (57).

Fear of falling can cause fear of movement and physical inactivity. which can lead to weakening, an increased risk of falling and impaired quality of life, based on a review of 28 studies (37). The reported prevalence of fear of falling varies between 3% and 85%. The main risk factors for developing fear of falling are a history of at least one fall and being older, in addition to the aforementioned being female (37). One previously published study, reported that a fear of falling might be an appropriate response to unsteadiness, a marker of underlying pathology, and not merely a psychological or physiological consequence of normal ageing (58).

According to the Quality Standards Subcommittee of the American Academy of Neurology (59), there is strong evidence (Level A) for increased risk of falls in patients with disorders of gait and balance, as in patients with the diagnosis of stroke.

Stroke

Stroke is defined by the World Health Organisation (WHO) (60) as 'rapidly developing symptoms and/or signs of focal, and at times global, loss of cerebral function, with symptoms lasting more than 24 hours or leading to death with no apparent cause other than of vascular origin'. Stroke affects many individuals; one in six people worldwide will suffer a stroke in their lifetime (61).

Postural Control after Stroke

After a lesion in the central nervous system, with affected integration of sensory input and the motor pathways and affected processing of information, impaired postural control can occur (62, 63). Reduced muscle tone, proprioception (62, 64), range of motion (62), muscle strength (62), vestibular function (65), visual input (66) and sensory re-weighting (67) may all impair postural control after stroke. Moreover, multimorbidity has been reported to be independently related to postural imbalance after stroke (68).

Pusher syndrome (69), a postural behaviour specific to stroke, is exemplified by patients pushing toward their paretic sides in functional activities, with fierce resistance to passive correction of the change in posture back to the vertical upright position. This is also known as *lateropulsion*. It has been suggested that pusher syndrome guides patients to align their vertical posture with an incorrect reference to verticality (70).

In-patients with severe stroke-related disability early after stroke (71), with impaired balance, visuospatial hemi-neglect and affected performance of activities of daily living (72) have been identified to be at risk for falling during rehabilitation. Deficits in grip strength on the unaffected side and in attention, being single, having a walking aid and Functional Ambulation Category (FAC) ≤3 have also been stated as risk factors for falls (73). In addition, inability to execute a compensatory step with the paretic limb may increase the risk of falls during the first month post stroke (74).

Stroke and older age have been reported as independent factors associated with falls (in addition to depressive symptoms and disability) (75). Patients aged 65 and over have been shown to be the most frequent suffers of multiple falls (71). In individuals with chronic stroke, orthostatic hypotension was found in more than 20%. These persons may run an even higher risk of falling (76). Moreover, individuals recently discharged home from hospital after stroke have been shown run a greater risk of falling than individuals without stroke and attention to the home environment is therefore warranted (77).

In addition, exposure to a risk of falling may increase with increased mobility and physical activity (77). In a randomised controlled trial, the Locomotor Experience Applied Post-Stroke study (LEAPS) (78), patients participating in a loco motor training programme two months post stroke (individuals walking at < 0.4 m/s, who had received early loco motor training) ran a high risk of multiple or injury falls (78). In another study, a faster TUG time was associated with a greater risk of falling in the stroke group, whereas in the controls, a higher fall risk was seen in better walking endurance assessed using the 6MWT (77).

Site of lesion may affect the risk of falling. A right hemispheric infarct has been reported to be more common among fallers (79). Somewhat surprisingly, patients somewhat younger with a left hemisphere lesion were at a greater risk of falling within 10 months after stroke onset (80).

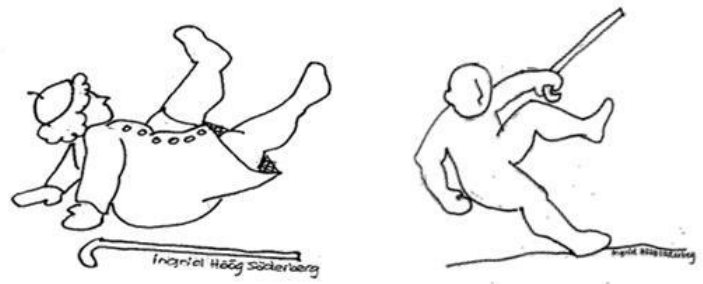
Cognitive impairment prior to stroke is frequent and may partially clarify the high frequency of cognitive impairment post stroke (81). In addition, cognitive impairment before stroke has been shown to lead to poor balance on discharge, as well as one year after stroke (82). This was in line with the results (83), where an inability to stand on one leg for 10 seconds was associated with cognitive impairment, in older community-dwelling elderly persons (*n* 2,115), but this contrasted with another report (*n* 408) (78), where no association was found between falling and cognition.

Diabetes is a risk factor for stroke (84). As a complication of diabetes, stroke subjects have been found to be more likely to develop neuropathy (84), which may increase the risk of falling.

The dual task, 'Stops Walking When Talking' (SWWT), has been shown to have a high positive predictive value (PPV), 78%, for falls in patients with stroke, from discharge to six or 12 months post discharge. When the results of the BBS plus SWWT are added together, the PPV rises further to 86% (85). These results are in contrast to previously published results (86), where SWWT was questionable, because of a PPV of 62% to predict fallers. In the latter study, SWWT was found to be associated with different types of behaviour (risk taking or risk reducing), as well as with the level of disability. Patients that stopped walking when talking were significantly more disabled, i.e. they were more dependent in activities of daily living, had impaired upper and lower limb function and were depressed (86).

As shown, there are many possible causes of impaired postural control in patients with stroke which, by themselves or together, can lead to an increased risk of falls. For the development of postural control after stroke, it has been suggested that a broad cortical network of prefrontal, premotor, supplementary motor and parietal cortical areas is essential (87).

Falls after Stroke



Incidence

Falls after stroke are common. Falls at hospitalisation have been reported in 3.3% to 59% (71, 88-91). During the first six months after discharge, fall frequencies of 35% to 73% have been reported (73, 75, 92-94). Within 10 to 12-months after discharge from a rehabilitation hospital or a stroke unit, 36% to 48% respectively had been reported to have fallen (80, 85). More than one year from discharge from stroke

rehabilitation, the rate of falls for 80 individuals with stroke was 1.77 times the rate compared with 90 patients in a control group (77). In a further follow-up, 40% of the patients were reported to have fallen (95).

Consequences for the Patient

Impaired postural control after stroke is shown seriously to affect gait and the ability independently to perform activities of daily living (96). Other reported consequences after falls post stroke are increased dependence, limitation of activity and development of fear of falling (97). Furthermore, a 1.7 to 4-fold increase in the risk of hip or femur fractures after stroke has been reported (98-100). In patients with chronic disability after stroke, physical activity, such as high-impact loading exercise, appears to have a small effect on enhancing or maintaining bone mineral density. It is unknown whether targeted physical activity early after stroke is able to protect bone density and whether this may reduce fracture risk (101). Fractures are also more common after stroke; one study has shown the opposite causal effect. The one-year crude hazard of stroke, among patients with hip fractures, was 1.55 times that of the comparison group, based on a large nationwide longitudinal population study from Taiwan (102).

Prediction of Falls

There is a lack of prospective, controlled studies which quantify fall-risk after stroke (77). Poor balance, assessed using the BBS, was able to predict falls in both a population of 80 people with stroke and their 90 controls during a 13-months period. For none of the groups was balance confidence an independent predictor of falls (77). In the LEAPS study (78), the BBS was found to be a good predictor of multiple or injurious falls, using the cut-off score of ≤ 42, but it had limitations related to the multifactorial nature of the problem. These results are in contrast to the conclusion in a review, comprising 21 studies, from 2008 by Blum *et al*., of the psychometric properties of the BBS specific to stroke. Based on two of these studies, the review concluded that the BBS was a poor predictor of single and multiple falls (103). Another study (104), found low sensitivity, 25% and 45% for any fall and multiple falls respectively,

with a BBS cut-off score of ≤ 45. With the failure to identify the majority of patients at risk of falling, and also with respect to the original idea of the scale, the use of the BBS as a dichotomous scale to identify the risk of falling is not encouraged by the authors (104).

Table 1. Examples of using the Berg Balance Scale to predict the risk of falling in different populations.

Authors	Year	Population	*n*	Cut-off	Sens	Spec
Thorban and Newton	1996	Elderly community residens	66	Predetermined cut-off <45	53	96
Lajoie and Gallagher	2003	Elderly community, fallers n 45, non-fallers n 80	125	Optimal cut-off 46	82.5	93
Mackintosh *et al* .	2006	Persons with stroke were followed from discharge to 6 months after stroke	55	Optimal cut-off <49	83	91
Andersson *et al.*	2006	Persons with stroke followed from discharge to 6 or 12 months after discharge	141	Predetermined cut-off <45	63	65
Ashburn *et al.*	2008	People with stroke followed from discharge to 12 months after discharge	110	Optimal cut-off ≤48.5	85	49
Muir *et al.*	2008	Community-dwelling older volunteers	187	Predetermined cut-off ≤45 for any fall	25	87
			187	Optimal cut-off for any fall ≤54	61	53
			187	Predetermined cut-off ≤45 for multiple falls	42	87
			187	Optimal cut-off for multiple falls ≤53	69	57
Tilson *et al.*	2012	Community-dwelling stroke survivors 2 months post stroke	408	Optimal cut-off score for multiple or injuries fallers ≤42	73	53

Abbreviations: *n;* number of included patients, cut-off; cut-off value, Sens; Sensitivity in percentage, Spec; Specificity in percentage

In addition, when dichotomising the results, the precision of the test may be lost and the use of other cut-offs may produce different results (85). Even so, several studies have used the BBS as a dichotomised scale with various cut-off levels and abilities to predict the risk of falling in the elderly or in patients with stroke (Table 1) (78, 85, 92, 104-107). One alternative to the dichotomisation of the BBS is the use of BBS as a multilevel scale with likelihood ratios. Using this method, a gradient of

risk across scores has been shown, with fall risk increasing as scores decreased (104). Furthermore, it has been suggested that the use of selected items from the BBS is more accurate and less time consuming (108). Other tests have also been used with the aim of predicting falls. Low scores for the 6MWT, the Four Square Step Test and the Step Test were fall predictors at discharge (95).

Preventive Strategies

There is strong evidence that balance training post stroke improves outcome (109). Early mobilisation and fall prevention after stroke are included in most guidelines (101). In the on-line version of the 2009 Swedish National Guidelines for Stroke Care (110), training with physiotherapy is a recommended action (as 2 on a priority list from 1 to 10 in descending order) for patients with impaired balance and walking after stroke. However, there is conflicting evidence when it comes to the form of balance training that yields the most effective result and that falls prevention programs are effective following stroke (109). The European Stroke Organisation Guidelines name interventions to reduce falls in stroke rehabilitation as a priority area for further research (111).

In clinical settings, prevention strategies can be implemented at both group and individual level, or a combination of both. Examples of simple actions at population level at a stroke unit, which aim to facilitate postural control, are good lighting and the use of non-slip socks for the patients in the absence of shoes. Examples of actions at individual level, after the identification of persons running a risk of falling, might be supervision or assistance in activities when the patient walks or transfers. It can also mean prescribing of individually customised walking aids or hip protection pants. Finally, patients with an identified risk of falling can be offered individualised physiotherapy. It has been proposed that the assessment and management of falls is multifactorial (including age, disability, use of assistive devices, reduced balance, motor function and walking speed) and, at the same time, involves exercise interventions to improve walking and mobility (78).

In a review by Campbell and Matthew, based on 14 studies, it was suggested that clinicians should focus on preventive interventions, for

those in-patients during rehabilitation with stroke-specific deficits, such as impaired balance, visuospatial hemi-neglect, and self-care deficits because of an increased likelihood of falls (72).

Patients with stroke have been shown to improve balance and weight-bearing by performing Tai Chi exercises, based on a review of Rabadi (112). A High Intensity Exercise Programme (HIEP), three to six months after stroke onset, is feasible for individuals aged ≥ 55 years. The HIEP did not show any differences in postural balance using the BBS versus a control group, however (113).

The value of using devices has also been assessed. More specifically, in 41 patients with chronic deficits after stroke, the whole-body vibration (WBV) with leg exercise was no more effective in reducing falls during six months after three training sessions a week for an eight-week period compared with 41 controls practising leg exercise alone (114). In a Swedish study with the same focus, patients with chronic stroke who performed balance training on WBV for six weeks experienced only small effects on balance. Furthermore, this effect was no more efficient than a placebo vibrating platform (115). Moreover, the usefulness of orthoses has been investigated. In chronic spastic hemiparetic patients, the use of ankle-foot orthoses has produced improved balance and a smaller risk of falling (116).

Psychological aspects have also been studied. At discharge from in-patient rehabilitation, it has been suggested that supportive interventions and physical therapies, designed to treat confidence, should be initiated in order to prevent the patient falling (117). In a study of 77 individuals with chronic stroke, balance self-efficacy was independently associated with activity and participation (118). Balance confidence, associated with poor balance and a high state of anxiety, remained lower during the first year after stroke, compared with gender- and age-matched controls (117). For stroke survivors, rehabilitation interventions have to be integrated both to improve fall efficacy and to minimise dependence in activities of daily life (119). Fall efficacy can be explained as confidence in one’s own ability. Fear of falling and fall efficacy are two different concepts, which are related but not identical (120).

Mental practice has as well been studied. In young stroke survivors, mental practice has been shown to have a statistically significant effect on postural balance. The results are based on a small population, however (121).

For people returning home after in-patient rehabilitation, a multifactorial fall-prevention programme was no more effective than standard care (122). In this recently published randomised controlled trial with a 12-months follow-up after discharge, standard care was defined as improving gait, strength and balance, however (122). Exercises to increase physical activity, walking and to prevent falling compared to exercises to improve cognitive and upper limb function showed no differences in the rate of falls or in the proportion of fallers (123).

In a systematic review from late 2010 (44), for training-specific aspects in older patients post stroke, there were indications of added effectiveness by applying biofeedback while training balance, sit-to-stand transfers or gait.

In a review by Batchelor and colleagues (122), it was stated that randomized controlled interventions, such as early mobilisation, extra training to perform an independent sit-to stand, symmetrical body-weight distribution training and loco motor training, had no significant effect on falls.

Rehabilitation

Rehabilitation is a process aimed at enabling people with disabilities to reach and maintain their optimal physical, sensory, intellectual, psychological and social functional level. Rehabilitation provides disabled people with the tools they need to attain independence and self-determination (124). In addition, rehabilitation has been described as a set of treatments, therapies and philosophies that, when combined with natural recovery, aim to improve patients' potential for participating in meaningful life experiences (125).

Rehabilitation Medicine

Rehabilitation medicine is a clinical speciality, which is distinguished, in research and clinically, by multidisciplinary teamwork. Rehabilitation medicine can be given as in- or out-patient treatment to patients with complex needs. One of the main groups is patients with stroke. In rehabilitation medicine, the functional consequences of the disease must be discovered in a broad perspective. Previous and current medical problems are simultaneously incorporated and taken care of. The cornerstone in rehabilitation medicine is an *accurate patient evaluation*, on which the therapeutic intervention must be based (126).

Stroke Units

The integration of the rehabilitation of patients with stroke into stroke units, organised in-patient care, has been successful. Patients cared for at stroke units, regardless of the sub-group of patients, are more likely to be alive, independent and living at home one year after a stroke (127). In Sweden, in 2003, over 60% of patients with acute stroke were initially admitted to a stroke unit in direct connection with the stroke onset (128). The corresponding figures for 2005 and 2010 were 61% and 68% respectively (129, 130). In 2010, 88% of patients with acute stroke received care at stroke units at some time during the hospitalisation. This is probably the highest percentage in the world (130).

The mean length of stay (LOS) at stroke units, from a Swedish national perspective, has been 12-13 days since the start of 2000s, with a median LOS of around eight days (130). Lower LOS have been found in teams with higher team functioning scores (131). Furthermore, team characteristics were significantly associated with indicators of well-organised stroke care. The use of protocols, observation of consciousness, patient education, relevant education of provider, multidisciplinary consultation and monitoring of performance, are examples of indicators (132). Physician support, shared leadership, supervisor team support, 'teamness' and team effectiveness, have all been stated as essential components of team functioning (133).

Recovery after Stroke

In rehabilitation, the goal is recovery. The recovery of function, including body function, structure and activity and participation, can be described as the returning capability of the individual to perform a task using mechanisms previously used (17). In a study of 101 stroke survivors, most of the recovery of functional ability, arm function, walking and speech occurred within three months. Improvement after that time span was seen, even if it did not reach statistical significance (134). Further studies confirm that neurological recovery takes place early after stroke (135-137). Nevertheless, functional improvement has been found beyond six months after stroke (138). Moreover, recent studies have shown that aggressive rehabilitation beyond the first time after stroke, increases aerobic capacity, sensor motor function and cardiovascular fitness (139-142). Even if there is a significant physical recovery, social isolation may be evident (142). Since the results are somewhat contrasting, further studies of recovery are needed. Recovery includes two concepts, restitution and compensatory strategies.

*Restitutio*n is based on plasticity (17), the return of nerve function with a movement performance like that before the stroke. When the nerve tissue develops new features, external stimuli with the practice of skills are necessary. The movement is performed in a novel way. In ICF terms, restitution is coded as body function (b). Furthermore, at the level of body function, the neurobiological term *neural plasticity* has been defined as the ability of the nervous tissue to adapt and learn from experience. The neural plasticity, the complexity and number of axons, dendrites and neurons and the density of synapses, is at the structural level. After a stroke, there is increased neural plasticity in the secure regions, a remapping (143). This remapping allows the neurons to take over the motor or sensory function that was previously performed by the damaged brain areas. In the recovery of function, this remapping of function is critical. When neural plasticity reaches its peak, within one to three months after brain injury, physiotherapy is most effective (143).

C*ompensatory strategies* (17) can be defined as atypical approaches to meeting the requirements of the task using alternative mechanisms that are not normally used. Compensation can also reflect modifications to

the environment and/or use of walking aids, which make the demands of the task easier. In ICF terms, compensation refers to activity (d). In a review by Teasell and colleagues from 2009 (109), it is stated that improvement in body function observed in stroke rehabilitation cannot be explained on the basis of the neurological impairment or natural recovery alone.

Illustrations: Lisa Brobjer

The Physiotherapist in Stroke Rehabilitation

Stroke rehabilitation is multi professional. One of the professions in the team surrounding the patient and his/her relatives is the physiotherapist. The framework for the physiotherapist when it comes to clinical intervention can be explained as being based on the ICF (already described), theories of motor control, the physiotherapy process, Evidence-Based Physiotherapy (EBP), Evidence-Based Medicine (EBM) (144, 145) and hypothesis-oriented clinical practice.

There are many *theories of motor control*, but, at present, there is not sufficient evidence to conclude that any one physiotherapy 'approach' is more effective in promoting the recovery of disability than any other

(146). Systems theory, referred to as the task-oriented approach, presented by Woollacott and Shumway-Cook (147), is one of the more recent theories of motor control. According to the Systems theory, movement emerges from an interaction of multiple processes (perceptual, cognitive and motor) within the individual and from an interaction between the individual, the task and the environment, in which the task is being carried out. To improve the efficiency of compensatory strategies, the rehabilitation intervention should focus on being functional. The patients are the active problem solvers. Adaptation to changes is also important for the recovery of function. In addition, learning a variety of ways to solve the task in the environmental context is essential (17).

The *physiotherapy process* is a model of practice. This model includes methods for gathering information, performing a plan of rehabilitation based on the patient's problem and needs and the implementation of interventions based on the patient's goal. Setting goals that replicate the specific rehabilitation aims of an individual might improve outcome (148). The objectives could be *Specific, Measurable, Agreed upon, Realistic and Time-bound,* SMART (149). Though, the scientific evidence for goal setting in stroke is limited (148). Regular monitoring, where the clinical measurement instruments form an important part, evaluates the effectiveness of interventions and the achievement of objectives. This is followed by the reformulation of new treatment targets until the final goal is reached. In this process, it is important that the physiotherapist understands the stroke survivor's barriers and motivators for physical activity, and act accordingly.

Just as in Evidence-Based Medicine (150), *Evidence-Based Physiotherapy* involves patients' preferences and actions, patients' clinical state and circumstances and research evidence. When integrated, these components constitute the fourth element, called clinical expertise. The model has been described as being incomplete and under development, as it does not take any account of the roles of society or the health-care organisation (150).

In a Cochrane review from 2007 (146) it was stated that physiotherapy interventions using a 'mix' of components from different 'approaches' are more effective than no treatment, in attaining functional

independence following stroke. Another systematic review from 2009 (151), confirmed that no evidence is available to prove the superiority of any approach, in overall terms. However, there is limited evidence of *balance control* in favour of the techniques presented as the Bobath Concept (151). An additional review from 2009 (152) showed improvements in *balance* with repetitive task training, training with a moving platform, biofeedback, physical fitness training and high-intensity therapy (commonly physiotherapy).

One of the more recent actions in stroke rehabilitation and several other diseases, is Physical Actions in the Prevention and Treatment of Disease (153) and Physical Activity on Prescription (154). Training to enhance *balance* and co-ordination, twice or three times a week, is one of four recommendations considering physical activity and exercise for stroke survivors that in 2004 was put forward by the American Heart Association (155). To evaluate the long-term effect of regular physical activity on the risk of a recurrent stroke, further studies are needed (156).

Hypothesis-oriented clinical practice clarifies the cause/s of functional movement problems and the relationship between functional limitations and underlying impairment and the physiotherapist needs to generate several alternative hypotheses. The hypothesis can be explained as a suggestion to explain certain facts about the potential cause/s (157). To assist the physiotherapist to rule out the hypotheses, several clinical scales or tests, e.g. *measurement instruments*, can be used. To provide evidence-based interventions, valid, reliable measurement instruments are required.

Measurement and Assessment

The quantification of an observation against a standard is a measurement, while the process of interpreting measurement is also included in assessment. The most common reasons for performing measurements are to establish outcome, diagnosis, prognosis or severity (158).

Indirect and Direct Measurements

Measurements can be *direct* or *indirect*. One example of direct measurement is blood pressure. Indirect measurements are substitutes for direct measurements. One example of indirect measurements is multi-item measurement instruments, which estimate an unobservable construct (2) e.g. postural control in the current thesis.

Levels of Measurement

Each measurement leads to a result. The outcome of a measurement can be just a categorisation or an ordinal, an interval or a ratio scale. The level of measurement will determine the statistical methods that are used (158).

Categorical Data

Both nominal and ordinal data use classifications and are known as categorical data (2).

Nominal data consists of items or classes that do not have any logical order. The measurements are not really measurements, more a way of categorising. Examples of classes with no logical order are different types of diagnosis and gender; female and male. If the number of classes is two, the item is described dichotomous (2). Nominal values are independent of magnitude (159).

Ordinal data have some kind of order, which, if there are more than two levels, can be put in some sort of logical order (158). Ordinal data are ranked according to magnitude (159). There are two types of ordinal measurement. One is where patients are scored as managing or failing to perform a skill. The other is where patients are rated according to having absent, mild, moderate or excellent ability in a skill (158), for example. Items that are scored at ordinal level are often called Likert items (2). The majority of measures used in rehabilitation are ordinal.

One limitation of ordinal scales is that the hierarchy and redundancy of items, known as scaling properties, are seldom considered (160).

Another limitation of ordinal scales is that the distance between the scores is unknown (161). Assessments on scales produce ordinal data with rank-invariant measurement properties, which means that there is a lack of consistent distance, magnitude and linearity (159, 162). Consequently, parametric statistics cannot be used (161). One approach to overcome this deficiency of mathematical properties is to transform ordinal data to ranks (163). Non-parametric statistical methods, such as the Spearman rank-order correlation coefficient and the Wilcoxon-Mann-Whitney U-test, are used on ranked data (161).

Continuous Data

Interval and ratio data are continuous data, suggested to be able to take all values, which makes quantification possible. When the variable is unable to take all values, the data are described as discrete (2).

In *interval* data, the measurement results are expressed as numbers. An interval scale has one additional feature compared with ordinal data; the differences between the scores are known and identical. In the management of interval data, using body temperature and date, for example, addition and subtraction can be used. If the data level is interval, it is always possible to choose a lower level of measurement, but information is lost (2).

In *ratio* data, there is an absolute zero point which, in addition to adding and subtracting scores, makes it possible to calculate the ratio of two scores. Examples of ratio data are age, height, length and weight (2).

Measurement Properties

When choosing a measurement instrument, it is necessary to know whether it is relevant, reliable, valid, suits the purpose and is sensitive to detect the anticipated differences (responsive to change), but also whether it is simple and capable of being interpreted by others without difficulty (158).

Reliability

When repeated measurements are made in clinical practice and research, it is essential that the measurement instruments that are used are reliable. Reliability is defined as 'the degree to which the measurement is free from measurement error'. Reliability is not a uniform concept, however. The extended version is 'the extent to which scores for patients who have not changed are the same for repeated measurement under several conditions: e.g. using different sets of items from the same multi-item measurement (internal consistency); over time (test-retest); by different persons on the occasion (inter-rater); or by the same persons (i.e. raters or responders) on different occasions (intra-rater)'. For this reason, patients, observers, measurements and circumstances under which the measurements are taken are all sources of variance (164).

Reliability parameters can range in value from 0 (entirely unreliable) to 1 (perfect reliability). Reliability should be studied in a sample of those patients we plan to study and in the situation (routine care or perfect situation) in which we intend to use the measurement instrument. For reliability studies, at least 50 patients are required (2). A sufficient sample size is essential to attain an adequate confidence interval around the estimated reliability parameter. There is no golden standard for the time interval between the measurements. The choice of time interval is based on the stability of the characteristic we intend to measure and to possible interferences. Examples of interferences that can occur in performance tests are tiredness and pain while that of questionnaires can be memory aspects (2).

Reliability Using Categorical Data

For categorical variables, Cohen's *kappa* (165) is used in studies of reliability for nominal variables that adjusts for the agreement that is expected by chance. Kappa has been defined as a relationship between the observed proportion of agreement and the expected proportion of agreement by chance (166). Kappa values range from -1 to 1. A kappa value of 1 means total agreement, with all the scores in cells along the diagonal. A kappa value of 0 signifies that there is no agreement other

than by chance (167), but it does not differentiate between disagreements (168). *Kappa* is an example of a coefficient that provides information about absolute reliability or concordance (169). Using kappa, all disagreements are considered equally serious. Weighted kappa, another measure used in studies of reliability, uses linear but, even more frequently quadratic weights (167). The value of weighted kappa depends on the choice of weights. The weighting procedure ignores the rank-invariant properties of ordinal data (170).

For ordinal data, *Spearman's rank-order correlation coefficient* is used when assessing relative reliability or association (169).

For categorical variables, nominal and ordinal data, there are no parameters of measurement errors. Instead, the percentage of measurements that are classified in the same categories, percentage agreement (PA), can be used (167). A percentage agreement that reaches at least 70% is often regarded as satisfactory (171). Regarding assessments of ordinal data, reliability largely refers to the quality of the raters using the instrument (170).

For measurements of changes in health status, parameters of measurement error are relevant. The magnitude of measurement error can be assessed by parameters of measurement error. Cronbach's alpha, also known as internal consistency is a reliability parameter which can be based on a single measurement or a multi-item measurement, based on a reflective model where each item measures the construct repeatedly.

In instruments with several ordered categories, the rater's use of each category can increase the systematic disagreement/bias (170). In addition, with different raters using a rating scale, there is a risk that systematic disagreement/bias will occur (172).

In the first half of the 1990'-s, *E Svensson* introduced *the augmented ranking (aug-rank) approach* for the statistical analysis of systematic and random disagreement in paired ordinal data (170, 173). This approach takes account of the marginal distribution given one two-way augmented ranking approach of observations in a contingency table of X columns and Y rows. In the columns the X stands for the values from the first set of observations. Consequently, in the rows, the Y stands for the

values from the second set of observations (163, 170, 173, 174). In the event of complete agreement, *Percentage Agreement* (PA) = 100%.

E Svensson's method presents empirical measurement of systematic disagreement; there are two sorts (170, 173). First, the *Relative Position* (RP), which estimates the parameter of systematic shift in position between the pairs of ordered categorical assessments. Second, there is the *Relative Concentration* (RC), which estimates the systematic difference in concentration of assessments on the scales categories between X and Y.

In addition, of the empirical measure of individual variability, there is one kind, the *Relative Rank Variance*, (RV). RV is defined by the sum square of the mean aug-rank differences and is an indicator of disagreement caused by noise that cannot be explained to systematic disagreement related to the population (170, 175). In reliability studies, large individual variability might be a warning of reduced quality of the scale since it permits occasional disparities and uncertainty in the paired assessments. The presence of RV is an indication of weak reliability on the basis of doubt in the interpretation of the scale categories. An RV might also be a sign that the assessments are sensitive to disturbing factors (163).

Reliability Using Continuous Data

For continuous variables, the *Intraclass correlation coefficient (ICC)* is a reliability parameter that is frequently used (176). There are several ICC formulas, all of which consist of a ratio of variances (2). The ICC values range between 0 and 1. If a value approaches 0, the error variance is extremely high. If a value approaches 1, the error variance is very small. It has been suggested that a value of 0.70 is judged acceptable (177) and the larger the better (2). The ICC is a measurement of *relative reliability* (169). The *Pearson product moment correlation* is another example of a correlation coefficient that gives information about relative reliability or associations (169).

The *standard error of measurement (SEM*), a statistic used to measure *absolute reliability* (169), uses the standard deviation (SD) around a single instrument to measure how far apart the outcomes or repeated

measurements are. The standard error of measurement (SEM) and reliability are allied concepts, but they do not represent the same concept. Population (homogeneity/heterogeneity) and the size of the measurement error affect the reliability parameter. When discriminating between patients in a population with high variation and a low measurement error, the measurement error is hardly affected and the reliability parameter is high. Even with a considerably high measurement error, in a population with even greater variation, the reliability is high, as the measurement error is small in relation to the variation between patients. Consequently, reliability is not just a characteristic of an instrument but of an instrument used in a population (2).

Validity

Validity is defined as 'the degree to which an instrument truly measures the construct(s) it purports to measure' (164). Validity consists of testing hypotheses, whether the scores of the instrument are consistent with the theoretical model of the construct (178). For a sound validation process, a detailed understanding of the construct is fundamental.

A unidimensional construct is often easier to validate compared with a scale, which represents different dimensions, as each part of a construct should be validated. Validation is dependent on situation; a scale should therefore be re-validated if it is applied in new situations or new populations (2). It has been said that it is wrong to establish that a measurement is valid. Instead, there are recommendations to state that a measurement provides valid scores in the explicit situation in which it has been tested (2). In addition, Borsboom *et al.* (179) stated a conception of test validity based on two concerns. First, a test is valid for measuring a construct if the construct exists. Second, a test is valid if variations in the construct casually produce variation in the measurement outcomes. Moreover, validation research should be directed at the processes that convey the effect of the measured construct on the test scores (179). Regarding the assessment of ordinal data, validity refers to the quality of the instrument (180).

In general, four different types of validity can be distinguished; *face, content, criterion and construct validity* (2).

The very first aspect of validity is *face validity*. Face validity has been defined as 'the degree to which a measurement instrument indeed looks as though it is an adequate reflection of the construct to be measured' (164). Face validity is based on subjective assessments without any standards and is therefore not quantified.

Content validity has been defined as 'the degree to which the content of a measurement instrument is an adequate reflection of the construct to be measured' (164). The purpose of a content validation study is to assess whether or not the measurement adequately represents the construct under examination. The relevance of a measurement can be investigated by answering the following three questions. First, do the relevant aspects of the construct that are going to be measured refer to all items? Second, with respect to disease, setting, gender and age, are all the items relevant for to the study population? Third, are all the items relevant to the purpose of the application of the instrument (discrimination, evaluation and prediction) (2)?

Criterion validity is defined as 'the degree to which the scores of a measurement instrument are and adequate reflection of a gold standard' (164). Criterion validity, also known as diagnostic accuracy, is expressed in terms of sensitivity and specificity. For ordinal data or continuous data, receiver operating characteristic curves (ROCs) are suitable for use. The condition for the evaluation of criterion validity is that there is a gold standard. If the gold standard is continuous data, correlation coefficients (ICCs) can be calculated to assess the diagnostic accuracy. Criterion validity can be divided into concurrent validity and predictive validity. *Concurrent validity,* which is assessed when the score for the measurement and for the golden standard is considered simultaneously, is often used for diagnostic and evaluation purposes. *Predictive validity*, which is assessed when we consider whether the measurement instruments predict the gold standard in the future, is frequently used in predictive applications (164).

Construct validity is defined as 'the degree to which the scores of a measurement instrument are consistent with hypotheses' (164).

Structural validity is defined as 'the degree to which the scores of a measurement instrument are an adequate reflection of the

dimensionality of the construct to be measured' (164). This can be assessed by factor analysis, which is applied when there is no clear information about the types or numbers of dimension. Structural validity can also be assessed by confirmatory factor analysis if a previous hypothesis of the construct and the dimensions is accessible.

Responsiveness

Responsiveness is defined as 'the ability of an instrument to detect change over time in the construct to be measured' (164). In addition, there are other distinctions of responsiveness. Husted *et al*. (181) draw a distinction between *internal* and *external responsiveness*. The first has been defined as 'the ability to detect important clinical changes'. The latter has been defined as 'the extent to which changes in a measure over time relate to corresponding changes in a reference measure of health status'.

In a report of clinical effectiveness after rehabilitation, responsiveness is an important element (182), an *aspect of validity* (2), not a separate property of the instrument (183). More specifically; responsiveness refers to the validity of a change score, estimated on the basis of two measurements in a longitudinal study. The time-period between the assessments can be short, the important thing is that it is relevant, i.e. that we can expect patients to change their score during the period. The aim is that the scale or test used is able to measure this expected change in score on the construct that is going to be measured. To calculate change scores, at least two measurements should be made. To be able to decide whether a scale or test is able to detect changes, at least some proportion of the patients should improve or deteriorate on the construct to be measured. If the study design does not provide these conditions, it is difficult to assess whether patients really did not change character or whether it was the scale or test that was not sensitive to demonstrate/measure that change had occurred (2).

There is a plethora of concepts regarding responsiveness. In a review from 2003, Terwee and colleagues (184) presented 31 different measurements of responsiveness, which were classified into three

groups based on the kind of change a responsive instrument should be able to detect.

In the first group, responsiveness was defined as 'the ability to detect change in general'. This responsiveness is often defined as a statistically significant change after treatment (184), equivalent to the concept 'sensitivity to change' (185). Responsiveness relying on statistical properties is also called *distribution based* (186). Examples of measurements that are used include a paired t-test, Wilcoxon, unpaired t-test, ANOVA, repeated measures analysis of variance, standard error of measurement, effect size, standardised response mean and responsiveness index.

In the second group, responsiveness was defined as 'the ability to detect clinically important change', which requires a judgement of what is important. This judgement is often subjective. Responsiveness relying on clinician-rated or patient-rated improvement is also called *anchor based* (186). Examples of measurements that are used include a paired t-test, unpaired t-test, responsiveness coefficient, effect size, standardised response mean, responsiveness ratios, Guyatt's responsiveness index and responsiveness index (184).

In the third group, responsiveness was defined as the ability to detect real changes in the concept being measured. This requires both a judgement of what is important and a gold standard for the construct being measured. Examples of measurements that are used include sensitivity/specificity, ROC curve with area under the curve, correlations with changes in clinical variables, correlation with overall improvement and regression models (184).

Based on the assumption that responsiveness is an aspect of validity, de Vet and colleagues (2) have proposed two main approaches for assessing responsiveness. One is the *criterion approach,* where a gold standard for change, if available, assesses the criterion validity of change scores. This is comparable with assessing criterion validity, with the exception of assessing single scores. The other is the *construct approach*, with no golden standard available, where an assessment of responsiveness relies on testing a hypothesis (184).

So, there is no obvious consensus on the definition of responsiveness and there is criticism of objections to several of the measurements used to assess responsiveness. The following issues were raised by Husted *et al*. (181). In the case of internal responsiveness, statistical significance depends on sample size and the variability of the measurements but also on the magnitude of the observed change. Sample size has nothing to do with responsiveness and for valid comparisons, t_0 statistics must be based on a study population of the same size. Furthermore, variability and magnitude of change, both of interest for responsiveness, should be examined separately. Consequently, the use of paired t-test statistics to assess responsiveness is the subject of debate. The effect size value (187) and the standardised response mean (SRM) will be small if a measurement has a high level of variability at baseline in relation to mean change scores. In the case of external responsiveness, and the use of ROC curves, the main shortcoming is that the score for external clinical change has to be dichotomised, which loses information. When using correlations, there are two clear-cut issues. First, by selecting particular values of one variable, its value may be influenced. Secondly, correlations measure the nearness to a linear relationship, but the relationship between two measurements might be non-linear, even if they are close. Moreover, the use of regression models generates an easily interpreted index, such as coefficient b, in addition to the fact that the ability to perform a goodness-of-fit assessment can check the fairness of the regression model.

In the assessment of responsiveness, E Svensson's method can also be used (163), since that approach analyses the change. When studying change, an observed disagreement is the main interest, as disagreement is evidence of change. An RP value that is not equal to zero can be explained as an indication that the group has systematically moved its assessments to higher or lower scale categories on the second assessment.

An RC not equal to zero can occur when there is a breaking point in status on the scale. Patients below central categories ('modest status') on the first assessment run a higher risk of deterioration than of improvement on the second assessments compared with patients with a higher status.

An RV > 0 is a sign of heterogeneity in treatment effects or in other changes among patients (163).

Interpretability

One of the most essential issues of instrument evaluation and development is the aspect of interpretability (184). Interpretability have been defined as 'the degree to which one can assign qualitative meaning – that is, clinical or commonly understood association – to an instrument's quantitative scores of change in scores' (164). Interpretability, also described as 'the degree to which it is clear what the scores or change scores mean' (2), is not a measurement property as it refers to what the scores on an instrument mean and not the quality of an instrument (164).

There are issues in the concept of interpretability; they include the following two questions (164).

First, what is the *distribution* of the scores on the instrument? The distribution of the scores over the scale supplies information about the location of the study sample on the measurement. Furthermore, the distribution demonstrates whether the population is homogenous or distributed all over the scale and whether the studied population has low or high scores. Using Classical Test Theory (CTT), mean and standard deviations of the scores can be used, but it is impossible to differentiate the sample characteristics from the measurement instrument characteristics. Using Item Response Theory, such as the Rasch rating model (188), enables the acquisition of both the studied sample and the items (2). The *Rasch* measurement model (189), named after the Danish mathematician Georg Rasch, is intended for the development and examination of education. The Rasch model, which refers both to the quality of the scale and to the interpretability, expresses item location (difficulty) and respondent location (ability), the difference between them is central to the model, and it models the probability of the observed response. The Rasch model (189), described in (190), is a unidimensional measurement model based on the assumption that all items measure a single underlying dimension, can be used for analyses of the psychometric properties of composite measures which are

considered to capture a unidimensional construct. Rasch analysis is a method which, if a scale is fit to the model, provides a non-linear transformation of ordinal raw scores to interval measures. Using the Rasch model has advantages over CTT. In the Rasch model ordinal data can be used. Given fit to the model, the ordinal raw data can be transformed into interval data (a metric measure). Detailed information about persons, items and response categories are given and there is no presumption of normal distribution.

Secondly, are there *floor* and *ceiling effects*? One of the most elementary requirements for the scales that are used as measures of outcome is that they must evenly detect both improvements and deteriorations in the studied population. This may be impossible if the population is at one extreme on the scale (191). The presence of floor/ceiling effects may indicate that a measurement has a limited ability to make a distinction between subjects (192). If more than 15% of the patients achieve the lowest or highest possible score respectively, floor and ceiling effects can occur (193).

Why to Evaluate Postural Control?

In addition to rule out hypotheses and as a guide for individualised interventions, it is known that falls are frequent after stroke and can have negative consequences for those who have fallen, why the assessment of postural control is important. As postural control can change over time, it is essential to assess these changes and adjust the treatment accordingly. When working with rehabilitation, the desired objective is to achieve a change, so measurement instruments (clinical scales and tests) that can reflect, elucidate and quantify these changes in patients are desirable. The use of measurement instruments as feedback may act as a facilitator to motivate the patients. Finally, decisions that influence the patient's rehabilitation is partly based on the results from clinical measurement instruments (ordinal scales). The adequacy of these decisions and how the results from these scales should be communicated is therefore depending on the quality of the measurement properties of the scales that are used. The rehabilitation begins at admission to the stroke unit. Consequently, it is important to

have valid and reliable information from the measurement instruments that is based on the acute phase after stroke.

How to Evaluate Postural Control?

In clinical settings, observational measurement instruments are used to examine postural control. These measurement instruments can be functional performance tests grouped as reaching, stepping and timed tests and ordinal scales to assess balance activity (160). There is no golden standard for assessing postural control after stroke (including pusher and walking balance). A plethora of measurement instruments, indices (an instrument consisting of multiple dimensions, which are summarised in one score, based on formative models (2)) or indicators are available; Fugl-Meyer Assessment of Balance and mobility (FMA-B) (194), Birgitta Lindmark's motor assessment (BL-motor assessment) (195), the Postural Assessment Scale for Stroke Patients (PASS) (1), the Short Form of the Postural Assessment Scale for Stroke Patients (SFPASS) (196), the Berg Balance Scale (BBS) (197-199), the Balance Evaluation Systems Test (BESTest) (18), Mini-BEST (13, 200), the lateropulsion scale (201), Timed Up & Go (TUG) (202), Brunel Balance Assessment (203), the Four Square Step Test (FSST) (204, 205), the Downton Fall Risk Index (206, 207), the Modified Motor Assessment Scale of Uppsala University Hospital, version 95 (M-MAS UAS-95) (208), five-times-sit-to-stand (FTSTS) (209, 210), the Unified Balance Scale (211) and so on. In the papers included in this thesis, the M-MAS UAS-95, BBS, 10MWT, TUG as well as the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS) were used.

The Modified Motor Assessment Scale

The Modified Motor Assessment Scale (M-MAS UAS-95), is a task performance ordinal scale of 11 items (208). The eight different items, named A to H, include transfer, walking and arm- and hand function. The items concerning arm- and hand function are bilaterally assessed and scored on a 6-point scale from 0 to 5, where 5 indicate better capacity. The M-MAS UAS-95 has been shown to be reliable and valid in patients in the acute period after stroke (208).

The Berg Balance Scale

In the early 90th century, Berg and colleagues introduced the Berg Balance Scale (BBS) (197-199). Originally, the BBS was designed to assess balance in older community-dwelling adults through direct observation of task performance (199). The ordinal scale consists of 14-items, which are scored on a 5-point scale from 0-4 according to the patient's ability to maintain positions and complete moving tasks of varying difficulty. A score of 0 represents an inability to complete the task, while a score of 4 represents independent item completion.

The BBS has proved to be reliable when assessing balance in patients with acute and chronic stroke (192, 197, 212, 213). The BBS has also shown to be valid in patients with acute stroke (199). In addition, the BBS has been shown to be responsive to change, from the acute to the chronic phase after stroke, with higher effect sizes closer to stroke onset (192, 214-216). A difference of 5.8 in the score on the BBS has been suggested as a real difference in clinical outcome (212). Similar results, a change of 6.5 in the score on the BBS, were reported in a population of community-dwellers with a history of falls or near falls (217).

The 10 Metre Walking Test

The 10 Metre Walking Test (10MWT) (158, 218), means that the patient is asked to walk over a distance, 10 m, at own preferred speed, using aid and including personal support if desired, while time is taken with a stop-watch (158).

The 10MWT is commonly used in the assessment of walking speed in stroke rehabilitation (114, 219-231). Self-paced gait speed (10MWT) has been shown to be related to the severity of impairments after stroke (231). In healthy older individuals, the 10MWT has shown excellent test-retest reliability (232). In chronic stroke, the 10MWT has also been shown to be valid, with significant correlations with the maximum isometric strength of the quadriceps muscle (233). In addition, the 10MWT has been shown to be responsive to change. For substantial meaningful change using the 10MWT, a gait speed of 0.14 m/s has been

presented. The results are based on populations of patients with both acute and chronic stroke (234).

The Timed Up & Go

The Timed Up & Go (TUG) (202), a task performance method of testing basic mobility manoeuvres, measures the time, in seconds, required for an individual to stand up from a standardized chair, walk a distance of three meters, turn, walk back to the chair and sit down again. The TUG is targeted at the fragile elderly, with a broad variety of physical conditions: Parkinson's disease, multiple sclerosis, rheumatoid arthritis, osteoarthritis, hip fracture, cerebellar degeneration, general deconditioning and stroke. In the manual it is stated that the patients are instructed to walk at a comfortable and safe pace and that before timing patients become familiar with the test, by walking it through once.

In community-dwelling older people, in addition to cognitive function and health status, there are indications that TUG performance is prejudiced by lower limb strength in particular but also by balance, vision, reaction time and pain (235).

In studies of patients with chronic mild to moderate stroke and in healthy controls, the test-retest reliability of the TUG has been found to be excellent (236, 237). The TUG has shown excellent correlations between the peak torque of the affected plantar flexion, gait velocity, comfortable and fast gait speed, the distance covered during the 6MWT and the step length of the affected and the unaffected legs (238). In 'The Irish Longitudinal Study on Ageing' (239), a slower TUG time has been shown to be independently associated with poorer performance on global cognition, executive function, memory tests and slower processing speed. Using the mean time to complete the TUG, the TUG has also been shown to be capable of differentiating patients with stroke (22.6 seconds) from healthy elderly individuals (9.1 seconds) (238). Based on a study of 50 individuals with chronic stroke, the smallest real difference (SRD) (symbolising the smallest change that indicated a real improvement) was small (SRD 23%). To detect small changes, the TUG appears to be suitable for use in clinical settings (237).

The Postural Assessment Scale for Stroke Patients

The French Postural Assessment Scale for Stroke Patients (PASS) (1), derived from the Fugl-Meyer Assessment of balance and mobility (194) and the Birgitta Lindmark Motor Assessment (195), was created specifically to assess postural control in patients with stroke and involves a patient's capacity to roll in a lying position.

The PASS has presented high internal consistency, with a Cronbach alpha-coefficient of 0.95, and high inter-rater and test-retest reliability, with average kappa values of 0.88 and 0.72 respectively (1). In a study of Mao *et al.* (192), the PASS has also demonstrated good individual item agreement, with weighted k statistics of 0.88 (0.61-0.96) and excellent total score agreement 0.97.

In addition, the PASS has shown good construct validity, through high correlation with the Functional Independence Measure (FIM) scores, and with lower-limb motricity scores (1) and a good predictive validity, a high correlation between the PASS score at 30 days after stroke onset and FIM scores at 90 days after stroke onset (1). The PASS also appeared to have good convergent validity with high correlations to the Barthel Index and good predictive validity (high correlations) (192). High concurrent validity was indicated by high inter-correlations between the PASS and BBS, the PASS and Fugl-Meyer Assessment - Balance (FMA-B) and between the BBS and FMA-B (192).

In addition, Mao *et al.* (192) found the PASS to have fair to good responsiveness within the first 90 days after stroke, with a peak 14 to 30 days after stroke. At 90 to 180 days after stroke there was low level of responsiveness (192). Recently, Clark and colleagues published a paper (240) where the PASS appeared to be a responsive scale. The analyses were based on assessments from admission to rehabilitation/geriatric units, 15-21 days from stroke and 4 weeks ahead, with a standardised response mean (SRM) of 1.76 and from initial assessment to 8 weeks, a SRM of 1.87. Despite the ordinal nature of the scale, means were used in the calculations (240). This use of parametric statistics can be debated, as (according to our knowledge); it has not yet been made any Rasch analysis of the original PASS with a transformation of ordinal data into interval data.

The Short Form of the Postural Assessment Scale for Stroke Patients

In 2007, a reduction of the items and the categories in the original PASS were performed. The new scale was named the Short Form of the Postural Assessment Scale for Stroke Patients (SFPASS) (241). SFPASS was developed by reducing the number of items to five and by collapsing the four-level (0–1–2–3) scale into a three level (0–1.5–3) scale, with the total sum score ranging from 0 to 15. The 5-items three level PASS contains the following items: 'Sitting to lying supine', 'Changing supine to sitting up', Sitting to standing up', 'Standing on non-paretic leg' and 'Standing to sitting down'. This short form of PASS has, except for a floor effect, shown to be psychometrically sound with good reliability, validity and responsiveness and also to be proficient to administer on patients with stroke (241).

Based on test–retest reproducibility, in 52 individuals with chronic stroke, the SFPASS has been indicated that a change score of 2.16 is a real change (196). The use of parametric statistics when dealing with ordinal data can be discussed, however.

The Modified Version of the Postural Assessment Scale for Stroke Patients

In spite of the good measurement properties illustrated for the PASS (1), a need for some modifications and clarifications was noted in clinical practice. Consequently, a modified version of the PASS was created, the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS) (Appendix). Figure 1 illustrates the construct map for the SwePASS.

Before implementing new measurement instruments in medicine, more specifically in stroke rehabilitation in this case, an evaluation of their measurement properties in terms of reliability, validity and responsiveness is required (2). This also applies to the SwePASS.

Capacity or Performance

It is possible to measure different constructs. The construct *capacity* is defined by the World Health Organization (242) defined as ‘a construct that indicates the highest probable level of functioning that a person may reach in a domain at a given moment’ or is identified in terms of ‘executing tasks in a standard environment’ without adaptations. In addition, capacity has been defined as ‘measuring what patients can do when they are requested’ (2).

The construct of ‘perceived ability’ measures what patients think they can do (2). *Performance* describes what an individual does in his/her current environment (242). This has also been described as ‘physical activity’, which measures what patients actually do (2).

The use of the clinical measurement instruments in the thesis, refer to the patient’s capacity when performing several different activities. These activities are supposed to act as indicators for postural control, which was aimed to be assessed.

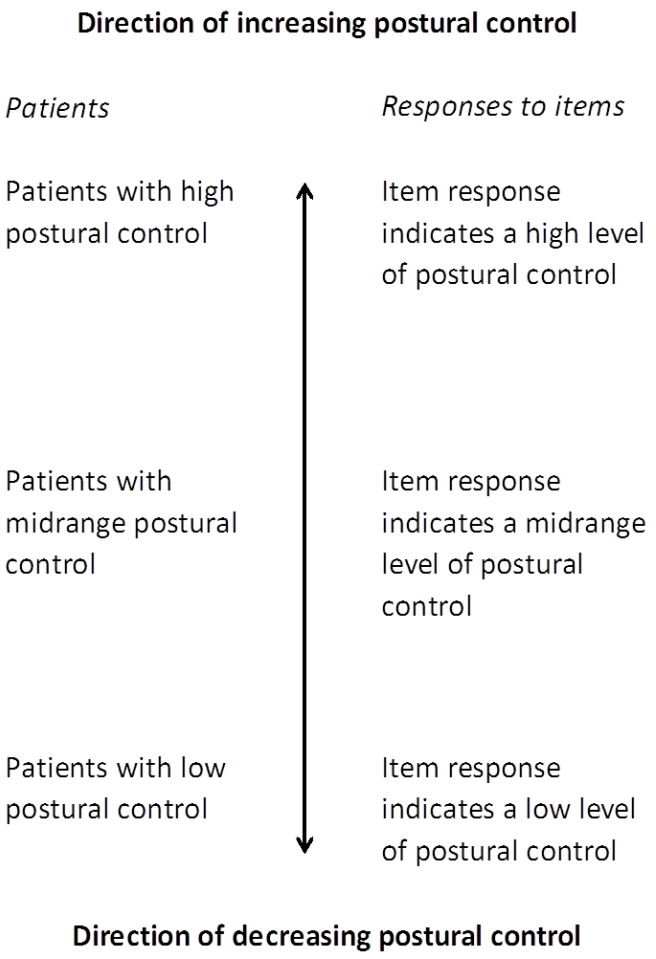


Figure 1. A map of the construct of postural control.

AIMS

The overall aim of this thesis was to evaluate the measurement properties of the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS).

The specific aims of the thesis were to:

- assess the intra-rater and the inter-rater reliability of the grading of postural control using the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS) in patients at a stroke unit, in the acute phase after their first event of stroke

- assess how results from the SwePASS, as well as other clinical measurement instruments of postural balance, walking and motor skills, performed during the first week after stroke, were able to identify the risk of falling during the following year

- investigate the responsiveness of the SwePASS in patients with their first event of stroke between the first week to three months after stroke

- estimate the longitudinal change in postural control during the first 12 months after stroke using the SwePASS

- evaluate the measurement properties of the SwePASS using Rasch analysis

PATIENTS AND METHODS

In this chapter, patients and methods are described.

The Postural Stroke Study in Gothenburg (POSTGOT)

All four papers in this thesis are based on data from the Postural Stroke Study in Gothenburg (POSTGOT). Table 2 gives an overview of the designs and the assessed measurement properties in the different papers.

Study Designs and Measurement Properties

Table 2 gives a summary of the different study designs and the measurement properties included in the thesis.

Table 2. Overview of the different study designs and measurement properties included in the thesis.

	Paper I	Paper II	Paper III	Paper IV
Design	Paired observations of relationship	Longitudinal, prospective, observational analysis of relationship	Longitudinal, prospective, observational analysis of relationship and recovery	Cohort study
Measurement property	Intra-rater and inter-rater reliability	Face validity, criterion validity and predictive validity	Distribution based responsiveness (validity)	Internal construct validity, Internal consistency

Ethics

The study protocol was approved by the Regional Ethics Committee in Göteborg, Sweden. Oral and written informed consent was obtained from all participants or their next of kin prior to entry into the study in compliance with the ethical principles set forth in the Helsinki Declaration (243). For ethical reasons, patients who initially had severe neurological sequelae were not asked to participate in the study. The

National/Local Computer Data Inspection Board approved the data handling procedures.

Inclusion Criteria

We aimed to include patients using consecutive enrolment. Patients were recruited at the Stroke Unit at Sahlgrenska University Hospital/Östra, Göteborg, Sweden, in 2002, 2003-2004 and 2012, corresponding to cohorts I-III respectively (Figure 2). The inclusion criterion was a first-ever stroke, defined according to the World Health Organisation (WHO) (60).

Exclusion Criteria

Patients were excluded if they had any co-morbidity, such as leg amputation, diagnosis of dementia or severe psychiatric diseases, which could interfere with their postural control or their ability to co-operate in the assessment situations. Patents were also excluded if computed tomography (CT) scans showed signs of prior strokes, or if they did not live permanently in the vicinity of Göteborg (Cohorts I, II), as the study included follow-up assessments at the stroke unit.

Study Population

A total of 152 patients were included in the four studies. Table 3 gives the median age, distribution of gender, number of ischaemic and haemorrhagic strokes and side of the lesion.

Table 3. An overview of the demographics for the different papers.

Demographics	Paper I		Paper II	Paper III			Paper IV
	Intra-rater reliability	Inter-rater reliability	Fall prediction	Responsiveness 0-3 months	Change over time 3-6 months	6-12 months	Rasch
Patients, *n*	114	15	96	72	71	65	150
Median age, years	74	77	73	73	73	73	76
Female/Male, *n*	46/67	7/8	40/56	33/39	27/44	26/39	64/86
Ischemic/Haemmorrhagic, *n*	111/3	15/0	86/10	66/6	64/7	57/8	138/12
Side of lesion, right/left, *n*	54/60	7/8	45/51	35/37	32/39	28/37	75/75

Figure 2 shows the cohorts included in the thesis.

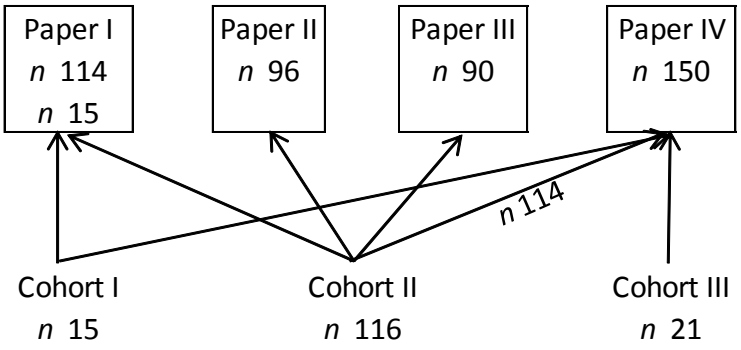


Figure 2. The papers and the cohorts included in the thesis are presented numerically, based on when the data were collected and when the studies were performed.

Measurement Instruments Used

Table 4 gives an overview of the scales and tests used and in which paper/s. The M-MAS UAS-95, BBS, 10MWT and TUG have thoroughly been described in the introduction.

Table 4. The clinical scales and tests used in the different papers.

Scale/test	Paper I	Paper II	Paper III	Paper IV
Modified Version of Postural Assessment Scale for Stroke Patients	x	x	x	x
Modified Motor Asssessment Scale, Uppsala University Hospital-95	x	x	x	
Berg Balance Scale	x	x	x	
10 Metre Walking Test		x		
Timed Up & Go		x		

The Modified Version of the Postural Assessment Scale for Stroke Patients

The Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS) with explanations and clarifications of the items are given in the manual (Appendix).

In the SwePASS, 'much help' is defined as 'support from two persons' and 'little help' is defined as 'support from one person'. The phrases 'support from two persons' and '…support from one person' are used every day at clinic, while we found that the terms 'little help' or 'much help' were not clear enough.

In Item 4; 'Sitting without support', the SwePASS manual specifies that the patient's feet should be supported on the floor.

In Item 7; 'Standing without support', 'Arm movements above shoulder level' was a definition that was felt to be too vague. On a scale designed to be used repetitively over time, it is fundamental that the same movements are measured from one occasion to the next. For this reason, 'arm movement above shoulder level' is specified in the SwePASS as standing and performing the task '*…draw hand/s from the forehead to the neck (like pulling your fingers through your hair) alternating with the arms hanging parallel to the trunk to avoid tiredness*'.

Item 10, 'Standing and picking up an *object/pencil*' has been changed and defined as 'Standing and picking up *a shoe',* with the aim of minimising the potential impact of fine motor skills.

In addition, a translation was made by merging the original French version, supplied by the authors, and their English version published in 1999. 'Forward-backward-translation' was performed in the way recommended by Streiner and Norman (244).

The Modified Version of the PASS (SwePASS), like the original PASS, is a multi-item instrument based on a reflective model. The SwePASS comprises 12 items, each an indicator or reflector of the construct, postural control. The SwePASS' items comprise 'changing basic body position', 'maintaining body position', 'sitting', 'standing', 'maintaining a

standing position', 'picking up' and 'lying down', all of which could be linked to Activity (and Participation) in the ICF browser (22). Every item has four categories or scores. The scores are ordinal data, named from 0 to 3, representing a ranking, where a score of 0 represents a low level of postural control and a score of 3 characterises a high level of postural control. When the scores for each item are added together, the total score is between 0 and 36. In the manual for the SwePASS, which differs from the original PASS, the items are scheduled in the same order as they are logically carried out in clinical use. The original developers of the PASS have accepted the final version of the SwePASS.
Using the SwePASS, the target population is patients with stroke and the purposes are to describe postural control, to predict the risk of falling and to evaluate postural control after the given intervention at individual level.

Assessments

The assessments were performed at four different time points. The first time point was during the first week after onset, also entitled baseline assessments. Baseline assessments encompass assessments performed as clinical routine and as study assessments. At the second, third and fourth time points, at three, six and 12 months after stroke onset respectively, assessments entitled follow-up assessments were made.

Baseline Assessments

According to *clinical routine*, as soon as possible, between one and seven days after the stroke event, the patients were examined using the Modified Motor Assessment Scale (M-MAS UAS-95) (208) and the Berg Balance Scale (BBS) (197-199). The assessments were made in the patient's room at the stroke unit, by his/her usual physiotherapist, who was not involved in the research, a median of two days (range 1-7 days) after stroke onset. Only one attempt per item was allowed in the assessments using the M-MAS UAS-95 (differs from the manual) and the BBS (according to the manual). Data from these assessments are presented in Papers I-III.

According to the study protocol, the *study assessments* at baseline were made between days four and seven after the stroke event. Within the time limit, the patients were assessed, at the stroke unit, using the SwePASS, the 10 Metre Walking Test (10MWT) (158, 218) and the Timed Up & Go (TUG) (202).

The SwePASS assessments were performed at bedside on the ward. For both the intra-rater and the inter-rater reliability study (Paper I), the patients were assessed with the SwePASS twice, within a 24-hour interval. For the inter-rater reliability, the assessments were made in a randomised order (by two physiotherapists). The first SwePASS assessments were made a median of five days after stroke onset. Only one attempt per item was allowed in the assessments using the SwePASS (according to the manual). Data from the assessments using the SwePASS are presented in Papers I-IV.

The 10MWT was performed in the corridor on the ward. The patients were asked to walk at a self-selected pace and started just in front of a taped line on the floor. Using an analogue stopwatch, timing began when the first leg crossed the taped line on the floor and stopped when the first leg crossed the other taped line 10 m away. Only one attempt was allowed. Data from the assessments using the 10MWT are presented in Paper I.

The TUG was performed in the corridor on the ward. The patients were instructed to stand up from a standardised armchair, walk 3 m (marked by a tape) and turn, return and sit down as quickly and as safely as possible. The time taken to complete the test was recorded using an analogue stop-watch. Patients started sitting in the chair with their back supported. The time recording began when the patient's back left the chair back and stopped when the patient sat down again, with his/her back supported by the chair back. For safety reasons, without interfering with the test, the physiotherapist stood in close proximity to the subject while he/she performed the test. Only one attempt was allowed, which differs from the manual (202). Data from the assessments using the TUG are presented in Paper I.

All the assessments were made by one of five study physiotherapists, who were trained in how to perform the test prior to the study start but

who were not involved in the patients' rehabilitation at the stroke unit. Author CUP was one of the raters in the inter-rater reliability study in Paper II and performed 21 of the 150 SwePASS assessments in Paper IV.

Follow-Up Assessments

Follow-up study assessments were made three, six and 12 months after stroke onset, with a time-window of 14 days before or after. Assessments of postural control using the SwePASS were made and the patients were asked structured questions about any fall. At the three-month follow-up, the patients were asked questions about any fall since stroke onset and at the six- and 12-month follow-up visits, about any fall since their last follow-up visit. A fall was defined as an event in which the person unintentionally found himself or herself below sitting level or on the ground (45). On occasions, when the patient was unable to attend the follow-up, the structured questions about any fall/falls were sent by mail.

Statistical and Mathematical Analyses

Table 5 gives an overview of the methods used for the data analysis. For Elisabeth Svensson's methods, the calculations were made using a free software program, a specially programmed Excel file (245). All the other statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS©) (Version 17 SPSS Inc., Chicago, IL, USA). For the mathematical analyses, Rasch, the RUMM 2030 program was used (246).

Table 5. Methods used for data analysis throughout the thesis.

Methods	Paper I	Paper II	Paper III	Paper IV
E Svensson's method	x		x	
Relative Position	x		x	
Relative Concentration	x		x	
Relative rank Variance	x		x	
Spearman's rank-order correlation coefficient	x			
Kappa coefficient	x			
Percentage Agreement	x			
Sensitivity, Specificity,		x		
Receiver Operation Characteristic Curves		x		
Positive and Negative Predictive Value		x		
Generalized Estimated Equations		x		
Mann-Whitney U Test			x	
Rasch analysis				x

E Svensson´s Rank-Invariant Method

To assess reliability, responsiveness and change over time, Elisabeth Svensson's augmented rank-invariant method for ordinal data (170), was used. For the Relative Position (RP) and the Relative Concentration (RC) values range from (-1) to 1. An RP or RC value of 0 means that there is no systematic disagreement (refers to reliability) or change (refers to responsiveness or change over time) related to the group (170). An identified systematic disagreement could be explained and adjusted for (163).

For the Relative rank Variance (RV), the empirical measurement of individual randomness variation, the variance in the rank differences between judgements lies between 0 and 1 (173). An RV value of < 0.1 could be regarded as negligible (170). An identified noise, such as RV,

can be neither adjusted for nor explained by the measurements of systematic disagreement (163).

The analyses were made item by item in the reliability study (Paper I) and item by item in the responsiveness study (Paper III). In the assessment of change over time (Paper III), the analyses were made, both item by item and by total sum.

Correlation Coefficient

To estimate the strength of a correlation within a data set of two variables and whether the correlation is positive or negative, Spearman's rank-order correlation (r_s) coefficient was used. For the definition of strength of correlation, Currier's definition was used (247); poor correlation= ≤ 0.69, fair = 0.70-0.79, good = 0.80-0.89 and high correlation = 0.90-0.99.

To evaluate the strength of agreement, the kappa coefficient (k) was used. A value of 1 implies perfect agreement. For supplementary evaluations of the strength of agreement, Fayer's guideline values of k were employed (248); poor agreement = <0.2, slight = 0.21-0.40, moderate = 0.41-0.60, good = 0.61-0.80 and, finally, very high agreement = 0.81-1.00.

Percentage Agreement

To assess exact agreement, Percentage Agreement (PA) (Paper I), the formula (agreements/(agreements + disagreements)) * 100 = PA% (249) was used.

Sensitivity and Specificity

In the assessment of prediction rules for binary outcome, two measurements are frequently used. First, there is sensitivity, which shows the proportion of individuals with the condition that are correctly classified. Second, there is specificity, which shows the proportion of individuals without the condition that are correctly classified. High values for both sensitivity, ≥0.7 (≥70%), and specificity, >0.6 (>60%),

have been considered correctly to predict disability (fall) and absence of disability (no fall) (250).

Receiver Operating Characteristic Curves

To assess how well the clinical scales, the SwePASS, M-MAS UAS-95, BBS and the tests, 10MWT and TUG, predict falling, receiver operation characteristic (ROC) curves were used. A ROC curve plots the sensitivity against the specificity (i.e. 1 minus the specificity), to illustrate test performance. A prediction value can vary between 0 and 1. An optimal cut-off level was used for each measurement instrument. Optimal was considered to be the cut-off value that maximises the sum of sensitivity and specificity with one condition. That condition was that high sensitivity was the most important factor, as the focus was on the risk of falling, and should therefore be the highest. These calculations were made by hand from information from columns given in the ROC analysis in SPSS. The half scores presented in SPSS were approximated to whole scores.

The patients who were unable to perform the 10MWT/the TUG, because of their inability to walk, were included in the ROC analysis with a surrogate time set at infinity.

In addition, retrospectively calculations of the sensitivity and the specificity, using the predetermined cut-off score of < 45 using the BBS, were performed.

Area under the Curve

As a reference, the diagonal line, with a value of 0.5, is usually interpreted as representing the ROC curve for a test that is no better than the flip of a coin (251). The area under the curve (AUC), also known as the c-statistic (concordance), provides an overall measurement of classification accuracy. The area under the curve illustrates the predictive validity (251). A c-statistic of 0.70-0.80 indicates an acceptable level of predictive accuracy of a model, 0.80-0.90 an excellent level, 0.90-1.0 an outstanding level and 1.0 a perfect level of predictive accuracy of a model (252).

Positive and Negative Predictive Value

The Positive Predictive Value (PPV) is a measurement of the usefulness of a screening/diagnostic test. The PPV is the proportion of the subjects with a positive test result who are correctly diagnosed.

The Negative Predictive Value (NPV) is a measurement of the usefulness of a screening/diagnostic test. The NPV is the proportion of subjects with a negative test result who are correctly diagnosed.

Generalised Estimated Equations

To assess the risk of falling, the logistic regression in the context of the generalised estimating equation methodology (GEE) (251) was used. The odds ratio (OR) for each of the tests or scales were calculated by exponentiation of coefficients estimated by the regression model.

The reason to use GEE was that there was more than one observation for each study participant. That introduces correlation between observations. In GEE, the standard errors of the model coefficients are adjusted for the correlation above so that neither false high p-values nor false too narrow confidence intervals are given.

Before creating of the model, the Spearman's rank-order correlation coefficient (r_s) was used in order to identify the level of correlation between the SwePASS, M-MAS UAS UAS-95, BBS, 10MWT and TUG. Consequently, to avoid co-linearity, the GEE was made in five different models, one for each measurement instrument. In each model we controlled for age and gender. In an additional analysis, length of stay (LOS) was added as a covariate. The linkage was made through logit (number of events). Of several structures to choose, the exchangeable (correlations typically estimated from the data) was used.

Test for Differences between Two Independent Groups

To analyse whether or not there was any statistically significant difference in outcome (SwePASS score) between the subjects who at discharge from the stroke unit were referred to training and those that

were not, a Mann-Whitney U Test was performed. The Mann-Whitney U Test compares medians, by converting the scores to ranks (253).

Rasch Analysis of the SwePASS

To further evaluate the SwePASS, Rasch analysis (189) was used to evaluate the use of the response categories, the targeting of persons to items, the reliability of the scale, unidimensionality, local independence and invariance. Initially, the Likelihood-Ratio test in RUMM 2030 was performed, to formally test if the Rating Scale Model or the Partial Credit Model should be used.

The overall fit to the Rasch model is given as a result of a chi-square item-trait interaction statistic by adding the chi-square values for the individual scale items (254).

Throughout the analysis, a significance value of 0.05 was used and Bonferroni correction was applied to adjust for the number of tests. When the Bonferroni adjusted summary chi-square statistic is non-significant, overall fit to the model is considered to have been attained (255). A non-significant probability value indicates that there is no considerable deviation from the model and that the hierarchical ordering of items is consistent across all levels of the underlying trait, in this case, postural control. Consequently, a significant chi-square statistic indicates misfit to the model.

In RUMM 2030, a Person Separation Index (PSI) is given to provide an estimate of the internal consistency reliability of the scale. For the individual use of the scale, a minimum PSI value of 0.85 is required.

The examination of the use of the categories begins with a visual inspection of the threshold diagram and the Category Probability Curves. A threshold is the point at which the probability of a response in either one or two adjacent categories is equal. Each item of the SwePASS has three thresholds, one less than the number of response categories. Failure by the physiotherapist to interpret or use the scale categories in a manner consistent with the level of the trait being measured, here: postural control, indicates disordered thresholds. Too many response

options or the confusing labelling of options can cause disordered thresholds.

By examining the distribution of thresholds for each item using post-hoc scoring content analysis, a substantive explanation can be found and the problem can be corrected. To deal with disordered thresholds, categories should be collapsed. To examine how well the individual items belong to the underlying trait, the individual item and person fit residual values, transformed to approximate a z-score (representing a standardised normal distribution) are used. Fit Residuals should demonstrate values inside a range of ± 2.5 (Bonferroni corrected) for every item (256). For an ideal fit, the overall item and person residuals should display a mean of 0 and an SD of ±1.

Differential Item Functioning (DIF) (257) is a type of item bias that can occur when different groups (age groups, gender and stroke location) in the sample respond in a dissimilar manner to an individual item, despite equal levels of the underlying trait: postural control. There are two sorts of DIF.

Uniform DIF, which is indicated by a main effect for the person factor, is when one group expresses a consistent systematic difference in its response to an item across the entire trait being measured. This could be dealt with by splitting the item by group and calibrating an item for each group separately.

Non-uniform DIF is pointed out by a significant interaction effect (person * class interval). Class interval can be described as person data arranged into grouped data in convenient classes with the same width. If there is presence of non-uniform DIF, no corrections can be made, as it is characterised by the differences between the persons varying across the level of the attribute. An evaluation of DIF is made by performing an analysis of variance (ANOVA) (257). In the study, DIF was assessed for age groups (here: group 1 ≤ 76 and group 2 ≥77 years), gender and stroke localisation (left or right hemisphere).

In a scale with sum scores to be used, to calculate change scores, for example, the responses to an item must be independent of the responses to the other items conditioned on the trait being measured. This is called local independency (258). Local dependence is indicated

when the values of the residual correlations for each pair of items are above 0.3 (256). Local dependence affects the estimation of the test information and item discrimination parameters (inflate of reliability). It can also result in the undesirable latent trait dimension.

The local dependence of items can be established in two ways.

First, local dependency can be revealed through response dependency, where the items are significantly associated to one another. These items are defined through a residual correlation matrix. Combining the dependent items into a larger item, a testlet, is the way to deal with this local dependence through response dependence.

Second, trait dependence is multidimensionality. Unidimensionality was also formally tested using the method described by Everett Smith (259). If the content of the scale is unidimensional, the estimate of person 'ability', here: capacity in postural control, should be the same. The sets of items that are the most likely to violate the assumption of unidimensionality are the subsets of the most strongly loaded residual factors (positive >0.3 and negative < -0.3 loading) on the first Principal Component. To hold sufficient power to be reliable, each subset of residual factors for the items should contain at least 12 thresholds. In Paper IV, this meant four items in each group. Rasch-derived person estimates from these subsets were compared using a sequence of t-tests. If the proportion of positive t-tests (PST) is less than 5%, the scale is strictly unidimensional.

In order to assess how well targeted the items are for the patients in the sample, the centre of the scale is compared with the mean location score obtained for the patients. The centre of the scale is by default set to the value of zero logits representing the item of average difficulty. The mean location for patients would also be roughly zero. A positive mean value for patients would indicate that the sample as a whole is located at a higher level of postural control than the average for the scale, while a negative value would suggest the reverse (260). In several publications (260-262), additional details on performing the Rasch analysis are available.

RESULTS

The Reliability of the SwePASS (Paper I)

One hundred and twenty-six patients were found to be eligible in the intra-rater reliability study. Six of these patients refrained from participating and the remaining 120 patients gave their informed consent to participate. After inclusion, a review of the medical records revealed that four of these 120 patients did not meet the inclusion criteria. Consequently, these patients were excluded. Of the included 116 patients, the analysis is based on 114 patients, as two patients had to be excluded due to missing data. These patients represent Cohort II, included in the study between January 2003 and April 2005 (with the exception of holiday periods during the summers). In a retrospective review of medical records, another 56 patients were found who had met the inclusion criteria but were not included.

The inter-rater reliability analysis is based on 15 patients from another study population, at the same stroke unit. These patients represent Cohort I, included in the study between October 2000 and February 2001.

The principal findings are that the SwePASS has high intra-rater reliability in the acute stage after stroke. The results for the inter-rater study indicate high reliability, despite the small sample size. The results are based on both traditional analyses, such as Spearman's rank-order correlation coefficient, the kappa coefficient and the percentage agreement, and more modern statistical analyses, such as the augment-ranking method developed by Svensson.

An additional finding is that the SwePASS was quick to administer in the clinic (median time eight min).

Intra-Rater Reliability

In the intra-rater reliability analysis, ten of the items have PA values of 94% or higher. Item 8, 'Standing on non-paretic leg' and Item 9, 'Standing on paretic leg', had lower values; 82% and 86% respectively.

Using E Svensson's method, the RP varied between -0.01 and 0.04. Ten of the items have small and non-significant RP values. Item 1, 'Supine to affected side lateral', and Item 7, 'Standing without support', show a small yet statistically significant difference in RP, which means that there is a small systematic disagreement (a disagreement related to the population).

Item 7 also shows also a statistically significant yet small difference in the concentration of score chosen (RC).

For all the items, the RV is negligible.

Inter-Rater Reliability

In the inter-rater reliability analysis, nine items have a PA of 87% or higher. The lowest PA is found for Item 8 (67%) and Item 9 (73%).

Using E Svensson's method, RP values vary between -0.16 and 0.05, with the largest disagreement for Item 9 and Item 2 (-0.16 and -0.12 respectively), with no statistically significant disagreement.

Nor is any statistically significant difference found in the concentrations of the scores. However, three items (Item 1, Item 3 and Item 4) diverge with a higher RC.

For all the items, the RV is close to negligible or negligible.

Prediction of the Risk of Falling (Paper II)

Of the same 116 patients from Cohort II, a total of 96 patients (83%) participated in at least one follow-up visit at three, six and 12 months after stroke onset. This study is based on data obtained from these 96 patients. Of the 20 patients who did not participate in the follow-up assessments, one patient died within three months after inclusion, two had a recurrent stroke, one moved, and 16 withdrew their consent (did not wish to continue the study, mainly due to severe disability). A review of the medical records showed that the 20 patients who did not participate in any of the follow-up visits were older (median 82 years) versus those who participated (median 73 years) (p=0.002).

At the first follow-up, 90 patients were assessed, at six months, 80 patients were assessed and, at 12 months, 81 were assessed. At least one recorded fall during the first year after stroke was found in 46 (48%) of the 96 patients. Of those who fell, 19 patients had one recorded fall, 10 patients had two falls and 17 patients had more than two falls. The highest rate of falls (18 times) was recorded in one 72- year-old man with a very high level of physical activity.

The optimal cut-off value, area under the curve, sensitivity, specificity, positive predictive value and negative predictive value for each of the five measurement instruments are shown in Table 6.

The retrospective calculations that were performed, using a predetermined cut-off BBS score of <45, demonstrated 74% sensitivity and 59% specificity respectively.

Table 6. The cut-off value, specified with area under the curve, and sensitivity, specificiy, positive predictive value and negative predictive vale for each clinical test.

Variable	n	Cut-off	AUC	*P*	95% C.I.	Sensitivity	Specificity	PPV	NPV
SwePASS	95	≤32	0.73	<.0.001	0.63-0.83	37/45 (82%)	25/50 (50%)	37/62 (60%)	25/33 (76%)
M-MAS UAS-95	83	≤50	0.72	0.001	0.61-0.83	31/42 (74%)	24/41 (58%)	31/48 (65%)	24/35 (69%)
BBS	88	≤42	0.69	0.002	0.58-0.80	29/42 (69%)	30/46 (65%)	29/45 (64%)	30/43 (70%)
10 MWT	96	≥12	0.74	<0.001	0.64-0.81	37/46 (80%)	29/50 (58%)	37/58 (64%)	29/38 (76%)
TUG	96	≥15	0.70	0.001	0.60-0.81	29/46 (63%)	29/50 (58%)	29/50 (58%)	29/46 (63%)

SwePASS; Swedish Postural Assessement Scale for Stroke Patients (score 0-36)
M-MAS UAS-95; Modified Motor Assessment Scale, Uppsala Akademiska Sjukhus (score 0-55)
BBS; Berg Balance Scale (score 0-56)
10 MWT; 10 Metre Walking Test (seconds)
TUG; Timed Up & Go (seconds)
AUC; Area Under the Curve obtained from Receiver Operation Characteristic Curves
95% C.I; 95% Confidence Interval
PPV; Positive Predictive Value
NPV; Negative Predictive Value

The main findings in Paper II are that all the tests, the SwePASS, M-MAS UAS-95, BBS, 10MWT and TUG are significant, yet moderate predictors of falling. The odds ratios (OR), illustrated in Figure 3, vary between 2.44 and 4.88. The highest OR was found for the SwePASS. All the ORs have overlapping CIs.

When the patients were divided into three different groups; over cut-off value, under cut-off value or unable to perform the test, for the 10MWT and TUG, the OR for the cut-off of ≥ 15 s for the TUG (OR 0.84, 95% CI

0.31-2.27) is no longer statistically significant (p 0.728). The OR for the cut-off value of >12 s for the 10MWT decreases, but is still statistically significant.

When adding LOS, in addition to gender and age, to the GEE analyses, LOS (OR ranged from 1.033 to 1.050) was significant in all models. In addition, a lower OR was noted for each of the five measurement instruments. The SwePASS, with the highest OR (2.984, 95% CI 1.151-7.735), was the only measurement instrument that was able significantly to predict the risk of falling (p 0.024).

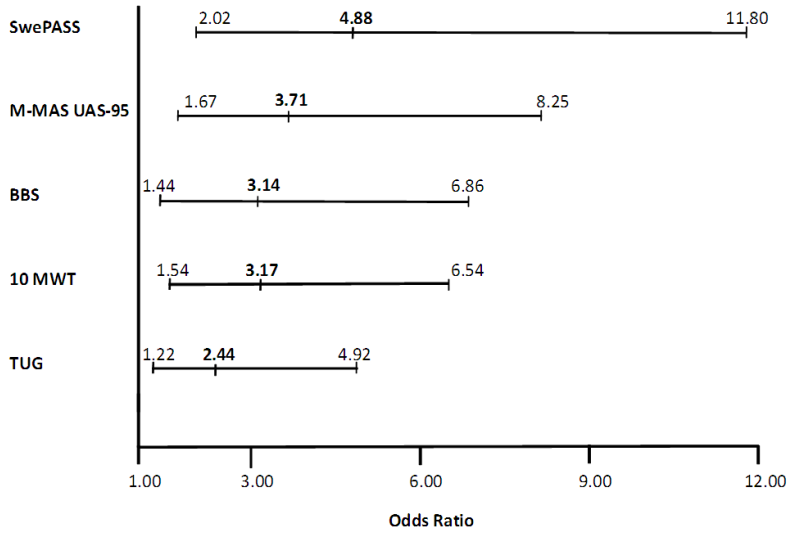
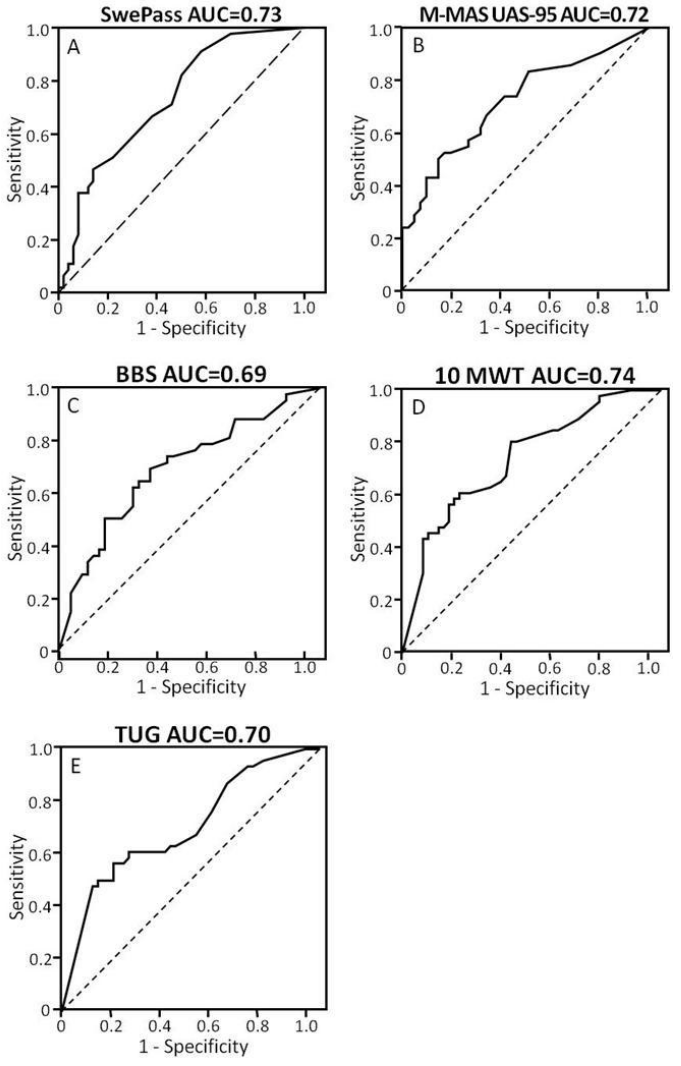


Figure 3. Odds ratio with 95% confidence interval for the risk of falling for each measurement instrument: the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS), the Modified Motor Assessment Scale (M-MAS UAS-95), the Berg Balance Scale (BBS), the 10 Metre Walking Test (10MWT) and the Timed Up & Go (TUG), according to Generalised Estimated Equations.

In Figures 4 A-E, the ROC curves, based on the sensitivity and 1-specificity, illustrate the ability to predict falling during the first year after stroke onset by using the SwePASS, the M-MAS UAS-95, the BBS, the 10MWT and the TUG.



Figures 4 A-E Area Under the Curve (AUC) for each measurement instrument used, the Modified Version of the Postural Assessment Scale for Stroke Patients (SwePASS), the Modified Motor Assessment Scale Uppsala Akademiska sjukhus-95 (M-MAS UAS-95), the Berg Balance Scale (BBS), the 10 Metre Walking Test (10MWT) and the Timed Up & Go (TUG).

Responsiveness of the SwePASS (Paper III)

Between 1st Week and Three Months

Of the 116 patients in Cohort II, 90 had been assessed at at least two consecutive follow-up assessments during the first year after stroke. Of these 90 patients, two did not participate in the assessments at baseline; four did not participate in the assessments at three months and a further 12 patients obtained a maximal SwePASS score at baseline. The responsiveness analysis from the 1st week to three months post stroke is therefore based on data from 72 patients.

From the 1st week to three months after stroke, increased SwePASS total scores were observed in 53 of the 72 patients (73.6%). Deterioration was found in seven patients (9.7%), while unchanged scores were found in 12 patients (16.7%).

For the different items, RP values ranged from 0.07 to 0.25. The largest systematic change in position was found for the total score (RP 0.31). Responsiveness, measured by the Relative Position, was established in nine of the 12 items and for the total score. The items were considered to be responsive if the RP for each item did not have any overlapping CIs compared with the corresponding reference value. The reference values are based on RP values from the intra-rater reliability study (Paper I).

Tables 7.1-7.12 show the results from the SwePASS assessments from the 1st week to three months, item by item.

The contingency tables, Tables 7.1-7.4, show an overwhelming agreement. Tables 7.5-7.12 show a clear change in position.

In all the items, apart from Item 8 and Item 9, a majority of the patients already at the baseline assessment obtained the highest score/category. In Item 8 and Item 9, only five and one of 72 patients obtained the highest score/category at baseline. In contrast, the results from Item 8 and Item 9 indicate a floor effect, with a majority of the patients obtaining the lowest score/category.

In Item 5, ‘Sitting to standing up’, 15 patients went from dependent (support from one person) to independent (without any help).

Moreover, in Item 8, from baseline to the follow-up assessment at three months post stroke, 34 patients remained unable to stand on the non-paretic leg, while 14 patients went from unable to able to stand on the non-paretic leg for a few seconds or longer.

For Item 9, 'Standing on paretic leg', the corresponding figures were 36 and 12 patients respectively.

In Item 10, 'Standing and picking up a shoe from the floor', 13 patients went from dependent (support from 1-2 people) to independent.

For both Item 11, 'Sitting down from standing up' and Item 12, 'Sitting on the edge of the bed to supine', 10 patients went from dependent (support from 1-2 people) to independent within the first three months after stroke onset.

Tables 7.1-7.12, representing Item 1 - Item 12, illustrate the paired distributions of assessments at baseline (x) and at three months after stroke (y) when classifying 72 individuals using the SwePASS with the categories (scores) 0, 1, 2 and 3. The diagonal, shown in grey, represents no change over time. Values above the diagonal indicate improvement, while values below point to deterioration. RP; Relative Position, 95% CI; 95% Confidence Interval, Responsive to change; yes or no is based on comparisons with reference values of RP and 95% CI from the intra-rater reliability study (Paper I).

Table 7.1 Supine to the affected lateral side (Item 1).

Y \ X	0	1	2	3	Total
3			6	60	66
2		1	4	1	6
1					0
0					0
Total	0	1	10	61	72

Value: RP: 0.07 95% CI: 0.001-0.140
Reference value: RP: 0.03 95% CI: 0.001-0.066
Responsive to change: No

Table 7.2 Supine to the non-affected side lateral (Item 2).

Y \ X	0	1	2	3	Total
3			7	58	65
2		2	4	1	7
1					0
0					0
Total	0	2	11	59	72

Value: RP: 0.09 95% CI 0.012-0.160
Reference value: RP: 0.01 95% CI -0.001-0.025
Responsive to change: No

Table 7.3 Supine to sitting up on the edge of bed (Item 3).

Y \ X	0	1	2	3	Total
3			7	59	66
2		2	4		6
1					0
0					0
Total	0	2	11	59	72

Value: RP: 0.10 95% CI 0.032-0.167
Reference value: RP: -0.01 95% CI -0.046-0.026
Responsive to change: Yes

Table 7.4 Sitting without support (Item 4).

Y \ X	0	1	2	3	Total
3	3	1	1	66	71
2					0
1					0
0	1				1
Total	4	1	1	66	72

Value: RP: 0.07 95% CI 0.011-0.127
Reference value: RP:-0.00 95% CI -0.023-0.021
Responsive to change: No

Table 7.5 Sitting to standing up (Item 5).

Y \ X	0	1	2	3	Total
3		2	15	49	66
2	1	1	1		3
1		3			3
0					0
Total	1	6	16	49	72

Value: RP: 0.23 95% CI 0.136-0.327
Reference value: RP: 0.02 95% CI -0.009-0.045
Responsive to change: Yes

Table 7.6 Standing with support (Item 6).

Y \ X	0	1	2	3	Total
3	1	2	6	58	67
2		1	1		2
1		3			3
0					0
Total	1	6	7	58	72

Value: RP: 0.12 95% CI 0.049-0.199
Reference value: RP: -0.01 95% CI -0.035-0.017
Responsive to change: Yes

Table 7.7 Standing without support (Item 7).

Y \ X	0	1	2	3	Total
3	5	1	9	47	62
2	2	1	1		4
1	1				1
0	5				5
Total	13	2	10	47	72

Value: RP: 0.21 95% CI 0.118-0.300
Reference value: RP: 0.03 95% CI 0.004-0.062
Responsive to change: Yes

Table 7.8 Standing on the non-paretic leg (Item 8).

Y \ X	0	1	2	3	Total
3	5	4	7	5	21
2	2	2			4
1	7	1	1	1	10
0	34	1	2		37
Total	48	8	10	6	72

Value: RP: 0.20 95% CI 0.092-0.301
Reference value: RP: 0.04 95% CI -0.000-0.089
Responsive to change: Yes

Table 7.9 Standing on the paretic leg (Item 9).

Y \ X	0	1	2	3	Total
3	7	6	5	1	19
2	2	2			4
1	3	4	1	1	9
0	36	2	1	1	40
Total	48	14	7	3	72

Value: RP: 0.18 95% CI 0.061-0.297
Reference value: RP: 0.02 95% CI -0.019-0.055
Responsive to change: Yes

Table 7.10 Standing, picking up a shoe from the floor (Item 10).

Y \ X	0	1	2	3	Total
3	5	2	11	46	64
2	1	2			3
1	3	1			4
0	1				1
Total	10	5	11	46	72

Value: RP: 0.25 95% CI 0.157-0.352
Reference value: RP: 0.00 95% CI -0.024-0.026
Responsive to change: Yes

Table 7.11 Sitting down from standing up (Item 11).

Y \ X	0	1	2	3	Total
3	1	1	9	55	66
2	1	2	1		4
1		2			2
0					0
Total	2	5	10	55	72

Value: RP: 0.16 95% CI 0.074-0.237
Reference value: RP: 0.02 95% CI -0.013-0.048
Responsive to change: Yes

Table 7.12 Sitting on the edge of bed to supine (Item 12).

Y \ X	0	1	2	3	Total
3	1	1	9	56	67
2		1	2		3
1		2			2
0					0
Total	1	4	11	56	72

Value: RP: 0.15 95% CI 0.070-0.234
Reference value: RP: -0.00 95% CI -0.032-0.030
Responsive to change: Yes

A systematic change in concentrations of scores was found for Item 9, 'Standing on the paretic leg' (RC -0.24, 95% CI -0.39 to -0.08), which indicates a shift towards more central scores on the scale. No other item shows any systematic change in concentration.

The Relative rank Variance (RV) is close to zero or zero (RV values between 0.000 and 0.002) for all items apart from for Item 8 (RV 0.04, 95% CI 0.00-0.072), Item 9 (RV 0.06, 95% CI 0.006-0.126) and the total score for the SwePASS (RV 0.13, 95% CI 0.034-0.232). This indicates heterogeneity in the ability (here: postural control) among the patients, at individual level.

Between those 28 patients who at discharge from the stroke unit were referred to training and those 44 patients who were not, there was no statistically significant difference in outcome.

Change in Postural Control over Time (Paper III)

From Three to Six Months

Of the 90 patients in Paper III, five did not participate in the assessments at three months, 13 did not participate in the assessments at six months and a further one patient had experienced a recurrent stroke. The analysis of change in postural control from three to six months after stroke (using the SwePASS score) is therefore based on data from 71 patients.

Improvements in postural control from three to six months after stroke, using the SwePASS score, were found in 35% of the patients, 17% had deteriorated and 48% were unchanged.

For the different items, RP values ranged from 0.00 to 0.10. The only significant systematic change in RP was noted in Item 8, 'Standing on the non-paretic leg', (RP 0.10, 95% CI 0.011-0.180) and for the total score (RP 0.09, 95% CI 0.030-0.152), which indicates a systematic change in position of score.

No statistically significant systematic changes in concentrations of scores (RC) could be found.

The Relative rank Variance (RV) is close to or zero for all items, which means negligible individual variability, except for Item 8 (RV 0.03, 95% CI 0.000-0.062), Item 9 (RV 0.02, 95% CI 0.000-0.033) and the SwePASS total score (RV 0.02, 95% CI 0.001-0.046).

From Six to Twelve Months

Of the 90 patients in Paper III, 13 did not participate in the assessments at six months, eight did not participate in the assessments at 12 months and a further four patients had experienced a recurrent stroke. The analysis of change in postural control from six to 12 months after stroke (using the SwePASS score) is therefore based on data from 65 patients.

Improvements in postural control from six to 12 months post stroke, using the SwePASS score, are shown in 19% of the patients, 26% deteriorated and 55% remained the same.

For the different items, RP values ranged from -0.07-0.02, with only the SwePASS total score (RP -0.07) being statistically significant, which means a systematic change in position, in the form of a deterioration (a reduced total sum).

No statistically significant systematic changes in concentrations of scores (RC) could be found.

The Relative rank Variance (RV) is close to or zero for all items, which means negligible individual variability, except for Item 9 and the SwePASS total score, both with RV 0.02, 95% CI 0.000-0.033.

Rasch Analysis of the SwePASS (Paper IV)

The Rasch analysis is based on data from 150 patients. The data were collected from all the three cohorts as follows; 15 patients from Cohort I, 114 patients from Cohort II and 21 patients from Cohort III (Figure 2). The median age was 76 years (min 34 and max 95 years). One hundred and thirty-eight patients (92%) had had an ischaemic stroke, while the remaining 12 patients (8%) had had a haemorrhagic stroke. The majority of all the patients (57%) were men. The SwePASS assessments were performed at a median of five days after stroke onset. The main findings are that the SwePASS shows an overall good fit to the Rasch model after adjustments for disordered thresholds and local dependence.

Analysis 1

Initial analysis showed good overall fit to the Rasch model with a non-significant chi-square value (x^2 34.78, DF 24, p 0.07), acceptable item (-0.41, SD 0.66) and person (-0.16, SD 0.20) fit residuals, high reliability (PSI 0.97), 3.33 percentage of positive t-test (PST) (95% CI -0.002-0.068). With a person separation index above the required value of 0.85, the SwePASS provides evidence that it is suitable for individual use However, further analysis of the items revealed disordered thresholds for four of the items: Item 4, Item 7, Item 8 and Item 10.

Figure 8 illustrates the distances and widths for the thresholds within and across the 12 items in the SwePASS.

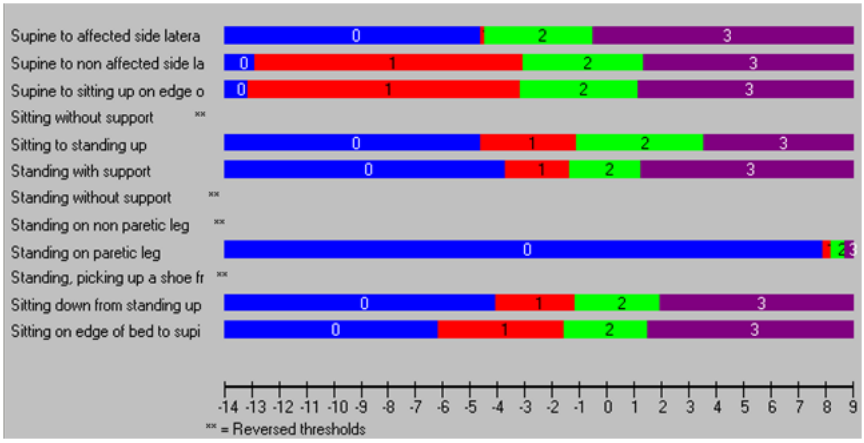


Figure 8. An illustration of the thresholds for the 12 items in the SwePASS. Disordered thresholds are shown for Item 4, Item 7, Item 8 and Item 10. For the other items, the variation within and between the thresholds varies.

The disordered thresholds for Item 4, 'Sitting without support', is demonstrated in Figure 9. In Item 4, it is more likely that a score of 0 will be obtained rather than a score of 1, even at the point where the probability of scoring 1 is at its peak.

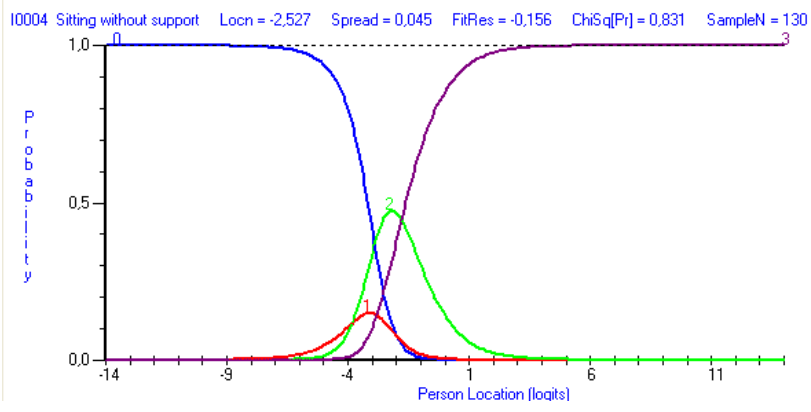


Figure 9. Category Probability Curve for the SwePASS Item 4 'Sitting without support'. The responses, shown as curves, do not fall in a logical progressive order.

Figure 10 gives an example of the ordered thresholds for Item 12 'Sitting on the edge of the bed to supine'. In Item 12, in contrast to Item 4, the curves are revealed in a logical progressive order. As a person's ability increases, so does the probability of obtaining the next score.

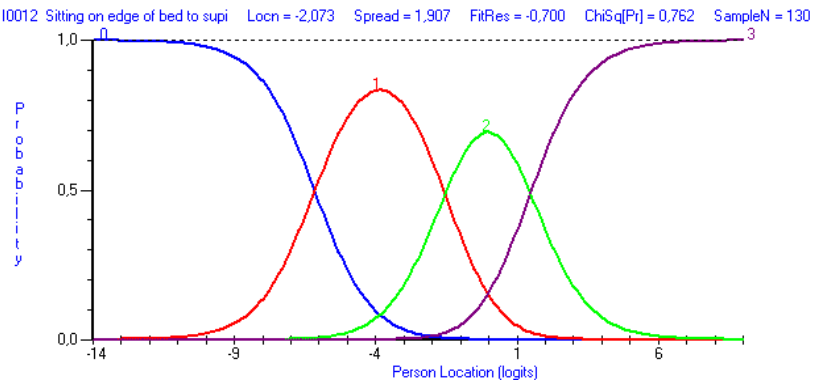


Figure 10. Category Probability Curve for the SwePASS Item 12, 'Sitting on the edge of the bed to supine'. The responses, shown as curves, fall in a logical progressive order.

Analysis 2 - Collapsing of Categories

Consequently, these items were rescored and collapsed from four to three categories. Response categories 1 and 2 were collapsed, giving the three response categories: 0, 1 and 2. Analysis with rescoring of items lead to a good overall fit to the Rasch model with a non-significant chi-square value (x^2 26.40, DF 24, p 0.33), acceptable item (-0.33, SD 0.51) and person (-0.14, SD 0.19) fit residuals, 3.33 percentage of positive t-test (PST) (95% CI -0.002-0.078), high reliability (PSI 0.97) and no remaining disorder of the thresholds. However, local dependency was found between the Item 6 'Standing with support' and Item 11 'Sitting down from standing up'.

Analysis 3 – Adjustment using a Testlet

Consequently, those items were combined into a testlet. After this adjustment, local dependence no longer remains, fit to the model is achieved (x^2 23.74, DF 22, p 0.36) with acceptable item fit -0.33 (SD 0.55) and person fit residuals -0.14 (SD 0.19). The reliability is only marginally reduced (PSI 0.96). Furthermore, positive *t*-tests of 3.33% (95% CI -0.002-0.078), below 5%, support unidimensionality.

Figure 11 illustrates the targeting graph, the person-item threshold distribution. The mean person ability value of 4.48 indicates that the sample as a whole is located at a higher level of postural control compared with the average for the items.

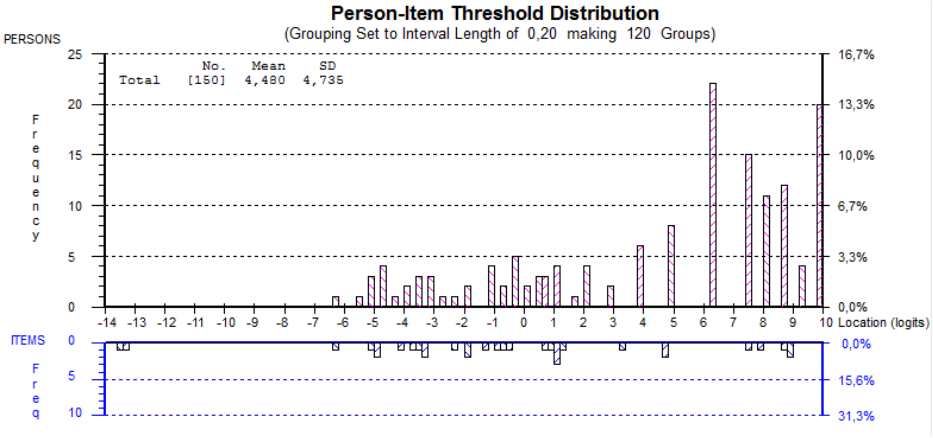


Figure 11. The final targeting graph illustrates the person-item threshold distribution of 35 thresholds, based on 10 items and one testlet of the SwePASS. The observations (n=150) are displayed on the logit scale, for persons at the upper graph and for items at the lower graph. Mean: Mean person ability value, SD: Standard Deviation.

According to the item location, defined in logits, Item 3, 'Supine to sitting up on the edge of the bed', is the least demanding and Item 9, 'Standing on paretic leg', is the most difficult item.

DISCUSSION

Main Findings

The main findings in this thesis are that the Modified Postural Assessment Scale for Stroke Patients (SwePASS) proved to be a reliable measurement instrument, with a moderate ability to identify those patients at risk of falling during the first year after stroke and of being responsive to change in the acute stage after stroke. Furthermore, the SwePASS appears to be a unidimensional measurement instrument. In addition, postural control evaluated using the SwePASS shows an improvement during the first six months after stroke onset. Taken as a whole, the measurement properties demonstrated that the SwePASS could be considered for use in rehabilitation, when assessing postural control in patients after stroke.

Study Design

A prospective longitudinal cohort observational study design was chosen in order to study the measurement properties of the SwePASS in a consecutive and unselected population of patients with stroke. A cohort study can be defined as 'an investigation in which the researcher follows (observes) a group, termed the cohort, over time to measure the incidence of a particular outcome' (169).The longitudinal aspects were required with respect to the assessment of the reliability, the ability to predict the risk of falling, the responsiveness and the change in postural control over time. The time points for the follow-up at three months post stroke was chosen in the light of several studies showing that most of the recovery occurs within the first three months after stroke onset (263-265). In many publications, the six-month period after stroke onset is regarded as the acute phase and the next phase is therefore known as the chronic phase. It therefore seemed appropriate to have the time point for follow-up at six months post stroke. Finally, the 12-month assessment was chosen in order to evaluate the chronic phase after stroke and because this is a time point commonly studied in the stroke literature. However, there might be a risk of influences by other medical conditions, the longer the follow-up. Our aim of consecutive enrolment

could not be realised for practical reasons. Since the SwePASS is a clinical scale, the most adequate solution was to evaluate its measurement properties in a clinical setting. It is consequently, necessary to reflect on problems it may involve.

Sample Size

A power calculation requires advanced guesswork to arrive at the changes that are needed. Beyond that the SwePASS is a new clinical measurement instrument; E Svensson's method is also fairly new. When this study started, the size of systematic change in position was not known, as we had no previous values to use as a basis for the difference we could expect to find. A power calculation prior to study entry was therefore not made. Nevertheless, it would have been an advantage to have larger sample sizes in the inter-rater reliability study and in the Rasch analysis. In the inter-rater reliability study, as many as in the intra-rater study might have been satisfactory. For Rasch analysis, Linacre proposed a sample size of 250 for accurate estimation and appropriate degree of precision, regardless of targeting of persons to the scale. When subjects are well targeted to the scale, the sample size can be much smaller, 108 for perfect targeting (266). However, based on the results, the current population sizes appear to be excellent in the assessment of intra-rater reliability and responsiveness.

Disturbing Factors

Generally speaking, there is a potential disturbing factor problem for the people who agree to participate in a study. The lack of registration of any incidence of neglect and visual field loss may also be confounding. Another possible disturbing factor is age. Cognition is an aspect that has been shown to affect postural control after stroke. Unfortunately, no cognitive test was performed on the patients in the POSTGOT study. The fact that the fear of falling has been reported both as a consequence of falls (97) and as a marker of underlying pathology (58) raise the question of causal effect. Is the fear of falling both an outcome and a causal factor?

It would have been interesting if the studies had included evaluations of the individual's perspective of the risk of falling.

Moreover, expectancies may also exert effects on the data (164). Observers or raters who expect behavioural change may be more likely to find it (171).

The restriction of choosing of first-ever stroke was one way to reduce the disturbing factor. Another way was to adjust for age in the logistic regression model (Paper II). In order to blind the raters, particularly for the intra-rater reliability study, there was no access to the previous test protocol.

Selection of Population

One major issue when it comes to selection problems is whether the population is representative. The study was designed in order to include patients that were representative of acute stroke patients in Sweden. Patients with first-ever stroke admitted to and treated at the stroke unit at Sahlgrenska University Hospital, Östra, in Göteborg, Sweden, were selected. The decision to include patients from a stroke unit was made with the expectation of collecting a representative sample of the typical stroke population, as most stroke patients in Sweden are already admitted to stroke units in the acute phase, as well as during rehabilitation (128, 129). The choice of first-ever stroke was made in order to create a more homogeneous group. Even so, patients with stroke, regardless of first-ever stroke or not, are a heterogeneous group. There are differences in terms of the location of lesions, degrees of impairment, disabilities and other diseases that might influence outcome and recovery potential. In addition, in Paper I, the interpretation or the conclusion of the results would have been more beneficial if the SwePASS had been tested in a more heterogeneous group than first-ever stroke. A high level of reliability in a population representing a wide variety of individuals with stroke would have been even better to rely on. In addition, if a more selected population, with a known decline in postural control as the inclusion criterion, had been assessed, a more targeted population would have been obtained and

this would have been valuable in Paper IV, in the Rasch analysis of the SwePASS.

One way to describe the population was by classifying it into haemorrhagic stroke and ischaemic stroke. Another way was to classify subtypes for ischaemic stroke according to Trial of Org 10172 in Acute Stroke Treatment (TOAST) criteria (267).

For the greater part of the inclusion time, there was no obvious selection problem for the current population, as a population representative for all three stroke units, Mölndal, Sahlgrenska and Östra, at Sahlgrenska University Hospital. Nowadays, the patients at the stroke units at Sahlgrenska University Hospital may be selected, by thrombolysis given at Sahlgrenska but not at Östra or Mölndal. This fact could have made its mark on possible selection bias in Paper IV, where 21 of the 150 patients were enrolled in the spring of 2012. Patients, potential candidates for thrombolysis, might differ by being in the middle of the scale for body function, with a great deal to gain and little to lose from thrombolysis. Moreover, the responsible physician did not medically approve patients with more severe stroke symptoms to participate in the study. It would have been interesting, however, although this was perhaps not possible for ethical reasons, to include patients with severe neurological sequelae.

To summarise, with regard to the convenient enrolment and the established inclusion and exclusion criteria, we believe that the studied population is representative of patients at the stroke units in Göteborg and in Sweden.

Follow-Up

In longitudinal studies, it is essential to optimise the follow-up rate. The more severely ill the patients are, the more difficult the follow-up. In the current study, the follow-up rate was relatively low. This might have affected the results. The reason for the low follow-up rate is that many patients had physical disabilities after their stroke and had difficulties coming to the centre for the assessments. Based on the fact that the most severely disabled patients did not complete the study, the rate of patients who fell might have been underestimated. It would have been

an advantage if we had had the opportunity to visit the patients at home or at their nursing home for follow-up visits.

The 20 patients who did not participate in any follow-up differ by higher age and longer length of stay, compared with those patients who came to at least one follow-up. Consequently, based on the results of the fall prediction study (Paper II), with higher age and longer length of stay in those patients who fell compared with those who did not, there might be an underestimation of falls in the study.

Moreover, it would have been interesting if we had performed more frequent follow-ups during the first three months after stroke with the emphasis on falls and recovery.

Performance-Based Measurements

Excluding the use of structured questions, only *performance-based* measurement instruments have been used. Performance measurements, in comparison to self-reporting, have been shown to be more reliable and to reduce the effects of impaired hearing and cognition on a person's ability to understand and answer a question (177).

The *selection* of the clinical scales, the M-MAS UAS-95 and the BBS was based on common clinical practice at the time, when most of the data were collected. One expressed disadvantage in relation to using the BBS, is that the BBS does not include important aspects of dynamic balance control (268) that reflect balance challenges during activities of daily living. Compared with the definition of dynamic balance (18), neither SwePASS refers to all the aspects described.

During the last three years, the M-MAS UAS-99 version appears to be dominant, at least at the stroke units at the Sahlgrenska University Hospital, where the M-MAS UAS-99 is recommended in the local guidelines and also where the studies were performed. However, at the time for the studies in this thesis, the M-MAS UAS-99 was not used as routine, nor had it been published whether the scale was reliable, valid and responsive to change, why it was not selected.

The TUG and the 10MWT, measurement instruments given continuous data, were added as they reflect walking, dynamic balance and contain several everyday procedures (standing up, walking and turning) that require postural control.

Measurement Error Problems

Reliability, validity, responsiveness, sensitivity, specificity and recall biases are all examples of factors underlying the measurement error problem. To avoid problems with measurement error, it is essential to use reliable instruments that measure what they are intended to measure, and that are also sensitive enough to pick up a true change. The clinical scales and tests used in the papers have all been shown to possess these measurement properties. However, with regard to ordinal data, the choice of method used, ICC, when assessing the measurement properties of the BBS and the PASS is questionable but used by some, for example (192, 213, 240). When ordinal scales are mathematically analysed as interval data, the results may be misleading. (269).

To minimise or prevent problems with measurement error, i.e. *measurement bias*, a written manual for the assessment procedures, including manuals for the scales and tests, was used. Moreover, pre-training with the assessors was performed. Even so, there is a risk of observer drift, which refers to 'the tendency of observers to change the many ways in which they apply the definitions of behaviour over time' (164).

Data relating to fall history were collected by asking structured questions about any fall since the last follow-up visit. Although used by others (53), the retrospective data collection method can be a sign of bias. More specifically, it can cause *recall bias* or lack of precision. Although the beliefs that events like a fall stand out from the rest of the phenomena of everyday life, there is no guarantee that this is the case. The effect of cognitive influences may also have played a role in the reporting of falls. Furthermore, not gathering information about falls every week or month as expressed (92) may have led to an underestimation of the risk of falling. A diary for the registration of falls might have reduced the risk of recall bias.

The test result throughout the study was always based on the patients' first attempt, regardless of what was said in the manuals. The choice of this methodology can be discussed. Clinical experience indicates that patients in the acute phase after stroke onset are easily fatigued. In the literature, post-stroke fatigue is reported to occur in 39% two years after stroke (270). When several tests were carried out after one another on the same occasion, the purpose was to reduce bias related to fatigue, by reducing the number of trials. There might be bias of underestimation, if several attempts are required for the patient to perform optimally. Or the opposite, there might be bias in top performance, if no pre-training in the form of several attempts was needed. Randomisation of the order in which the tests were performed, however, could have solved this problem.

The indications of no DIF using the SwePASS, revealed in the Rasch analysis, also indicate that there were no item bias. Namely, patients with equal levels of postural control responded in a similar manner to an individual item.

Methodological factors may influence the clinical interpretation of walk performance (271). In the thesis, the 10 MWT was based on a standing start and speed was calculated based on manual timekeeping over a distance of 10 metres. It has been stated that, to increase reliability, at least three gait cycles are needed to certify that overall average speed is measured (185) If there were some universal walk-test methodology, this would probably improve comparisons between different groups and studies.

Rating variability may be caused by inconsistent performance as a result of stroke. The use of the interview approach, when asking about any fall, may have benefits. The interview may give the rater an opportunity to add complementary questions or elucidations related to the observation of the patients' reactions and behaviours (168). Based on the fact, reported from Riks-Stroke (130), that in 2001-2009, nearly a third of the patients responded to the three-month questionnaire without any assistance, the choice of interview approach when collecting data regarding falls also appears retrospectively to have been a good choice.

As described in the introduction, reported falls may be associated with or influenced by many factors, such as environmental factors, recall methods and socio-cultural differences. The focus in this thesis was restricted, however. In the regression model, age, gender and length of stay (LOS) were included. In the model, LOS is strongly correlated to the risk of falling. This finding was not surprising. First, length of stay correlates strongly with more severe stroke (272, 273). Second, the physician's decision, in cooperation with the patient, his/her family and the rest of the team, is based on the results of assessments of function and activity and participation, including activities of daily living and assessments of postural control as well as a clinical estimation of the patient's ability to manage at home.

The follow-ups were performed during the time interval ± two weeks in relation to the target time, just as in the study by Andersson *et al*. (85), which might have had an effect on the results.

Confounding Factors

Age can be a confounder, as well as a disturbing factor (previously discussed). The median age in the 114 patients in the intra-rater reliability study (74 years) was two years lower than the mean age presented in the Swedish quality register for stroke patients (274) for 2003 (128). In addition to age there are far more confounding factors that need to be discussed. In Paper I, acute illness, which may change the patient's health status from one day to the next or even within a few hours or less, may be a confounding factor. Despite this, high intra-rater reliability for the SwePASS was demonstrated. This strengthens the confidence in the results. In Paper II, cognition, visual neglect, other diseases, medication and social conditions are potential confounding factors and no check (or registration) was made for them. Perhaps there is a difference in fall outcome when living alone, without any relative/close person who can recall the use of walking aids. Potential confounding factors in Paper III were the type and amount of physical activity or physical exercise during the follow-up period. For Paper IV, the skewed population, regarding capacity in postural control versus difficulty in the items, can be mentioned (discussed in more detail under Selection Problems).

Reliability

The results point to high reliability of the SwePASS, especially within the same physiotherapist. However, in the inter-rater reliability study, with only 15 patients, the power is low and there is a high risk of Type II error, i.e. the study population is too small to detect a true difference.

In each item of the SwePASS in the intra-rater reliability study, PA was clearly over 70%, which is considered satisfactory (171). In the inter-rater reliability study, all items, but Item 8, showed satisfactory PA values. However, the criterion for sufficient agreement also depends on the number of observed responses coded and the rate and variability of the observed abilities (171) .

The statistical method described by E Svensson (163, 180) was chosen because no loss of data occurs; compared with some of the classical methods that are applicable to ordinal data, but require the dichotomisation of the data. E Svensson's method also present results at both the group level (Relative Position and Relative Concentration) and at the individual level (Relative rank Variance). Parameters of reliability are recommended to be presented with 95% CI (2). The 95% CIs are in the software for E Svensson's method and are automatically available.

The Rasch analysis presented a Person Separation Index (PSI) above 0.85 for the SwePASS. A PSI, internal consistency (a concept of reliability), above 0.85, indicates that the SwePASS can be used at the individual level. This information is of great value to the clinician, as in the rehabilitation there is a wish to use the measurement instruments at individual level.

The previously presented definition of reliability, 'the degree to which the measurement is free from measurement error', can be discussed.

Prediction of the Risk of Falling

The definition of a fall, the ability to perform a test and the predictive values need to be commented on in more detail.

In this longitudinal cohort study, the registered end-point was whether the patient had fallen. The *definition of a fall* was set prospectively, as an

event in which the person unintentionally found himself or herself below sitting level or on the ground.

The question of whether a single *fall* corresponds to a greater risk of falling, or whether *multiple falls* are a better end-point has been discussed. The choice of which to use was not obvious. However, as one fall can make a difference to the patient, a single fall was chosen. In the initial article by Berg and colleagues (199), the cut-off level was based on a prediction of multiple falls. The cut-off score of ≤42 on the BBS for falls (Paper II) is slightly lower than that previously presented (92, 108, 199, 275). In another study, a cut-off score of ≤ 29 for risk of falling was used (276). The dissimilarities could be explained by differences in the definition of fall, by different selections of study population, acute or chronic stroke, environmental and cultural factors and the way the dichotomisation is performed.

The optimal cut-off for each measurement instrument used in the thesis was chosen in order to compare the different measurement instruments with one another. When comparing the optimal BBS cut-off (score ≤ 42) with the predetermined cut-off (score < 45), the results from the sample in the thesis show a lower sensitivity and a higher specificity for the predetermined cut-off. The use of either cut-off results in similar values.

Recently, in a large prospective study, of stroke patients, Tilson and colleagues (78) identified the same cut-off score of ≤ 42 for the BBS as the optimal score, as in the current study. The cut-off score in Tilson's study was for multiple falls, however. Despite similarities in the longitudinal design, with follow-up up to 12 months post stroke, there are some disparities with regard to the selection of the patients. Tilson *et al.* included younger patients, community dwelling, 45 days after stroke onset, who were able to walk 10 feet without support from more than one person at a self-selected walking speed slower than 0.8 m/s and with the ability to follow a three-step command. Furthermore, their patients participated in an intervention study of the impact of walking recovery and interventions on falls. The majority of all falls, 55.4%, occurred three to five months after stroke. The cognitive ability and activity (steps/day) were recorded. As in the current study, they had fewer women than men.

In several prior studies have examined impaired postural control, in patients who were wheelchair users were excluded (89, 277, 278) as *unable to perform a test.* In our study, we included all patients in the analysis. Patients in wheelchairs, who were unable to perform the 10MWT, turned out to be those with the highest risk of falling (OR 6.06 95% CI 2.66-13.84). The result is interesting for people involved in stroke rehabilitation. The approximate 20% who were unable to perform the 10MWT during the first week after stroke are similar to the 15% reported to be unable to walk at admission in the Copenhagen Stroke Study (279).

If the individuals who were unable to perform the TUG are excluded and separated from those who perform TUG ≥ 15 s, the OR decreases remarkably to a non-statistically significant OR value of 0.84. This cut-off value therefore appears to be less valid/useless when the patients who are unable to perform the TUG are excluded. In a recent study, despite being based on frail individuals aged 65 and older, a TUG cut-off of ≥ 12 s produced low values of correctly identified risk of falling at the six- and 12-month follow-ups, 40.6% and 50% respectively, based on sensitivity and specificity (280). In a systematic review from 2011 (281), it was found that more research is required to establish the TUG predictive validity for falls, especially in frail elderly people.

In a review from 2008, Gates and colleagues (282) presented four factors needed to provide sound evidence for the use and accuracy of screening instruments in order to predict the risk of falling among older adults. First, they suggested that the studies should be based on a clinically relevant population. Second, the population should be of a sufficiently large size. Third, the follow-up should be conducted with a sufficient duration. Fourth, the final factor was the use of reliable screening tests. The POSTGOT study meets these requirements and shows that all the scales, the SwePASS, M-MAS UAS-95, BBS and the tests, the 10MWT and TUG are moderate predictors of falls during the first year after stroke. Based on the confidence intervals, no scale or test was better than any other.

The diagnostic value is in the positive predictive value (PPV) and the negative predictive value (NPV). The predictive value of a test depends on the prevalence of the condition in the population. For a given

sensitivity and specificity, the NPV will decrease as the prevalence increases and vice versa. None of the tests was ideal. A positive predictive value of 60%, as for the SwePASS, implies that four of ten patients classified as 'individuals with a risk of falling' will not fall during the first year after stroke. A negative predictive value of 76%, as for the SwePASS and 10MWT, means that one of four patients classified as 'individuals with no risk of falling' will fall during the first year. In relation to the low negative predictive values and the low values of specificity, the clinical usefulness of the cut-off scores or seconds used in the study is limited.

Recovery

Considering that the largest improvements take place early after stroke, it would have been interesting to have more measurements during the first three months post stroke.

The statement that postural control shows an improvement the first six months in patients after a first event of stroke is further supported in Paper IV, where the SwePASS gives good indications of being a unidimensional scale.

Recovery may be influenced by the amount and content of physical training, motivation and engagement of the patient his/her and family. Unfortunately, this was not registered during the follow-up.

Floor and Ceiling Effect

The presence of *floor effect* refers to when data cannot take on a value lower than a particular number or a measurement phenomenon in which an instrument is unable to detect declines in scores for the participants of interest. Another existing definition is 'if more than 15% of the patients achieve the lowest possible score' (193). In the current study, a floor effect was found in Item 7, Item 8, Item 9 and Item 10 in the SwePASS. In the original PASS (1), a floor effect was also seen, although on day 30 after stroke onset, in Item 8 (43% obtained a score of 0) and in Item 9 (67% obtained a score of 0). Other features of floor effect have previously been discussed.

Opposite to the floor effect, there is the *ceiling effect*. A ceiling effect refers to when data cannot take a higher value than a particular number or a measurement phenomenon in which an instrument is unable to detect gains in scores for the participants of interest. Another existing definition is 'when more than 15% of the patients achieve the highest possible score' (193). In the current study, a ceiling effect was found in all 12 items. The occurrence of ceiling effect can be a reason why true change in a measurement instrument cannot be detected (2).

Both floor and ceiling effect, which refers to interpretability, can affect the responsiveness, depending on how improvement is defined, by increasing or lowering the score (2). Floor and ceiling effects can occur when applying measurements to another population than the population for which the measurement was originally developed. Roughly speaking, the target population in this thesis, patients with stroke, is the same as in the study by Benaim and colleagues (1). However, the population differs regarding time since stroke with respect to time for the first assessments (1st week versus 30 days). The differences could be explained by differences in subgroups of stroke, but this is difficult to compare when the available data relating to this are limited (1). At the three-month follow-up, 28% of the patients had received 36/36 scores using the SwePASS. The corresponding figure, 36/36 scores using the PASS, at the assessments at 90 days after stroke, was 38% (1).

Responsiveness

When it comes to the aim of detecting changes over time, *responsiveness* is important. In Paper III it is shown that the SwePASS is responsive to change, but on one condition. Responsiveness applies to the subjects who do not obtain the highest score for the SwePASS at baseline. That fact that the previously discussed ceiling effect affects responsiveness is evident in Paper III. Using the SwePASS, a score of 36 implies no room for improvement in postural control. The higher ceiling effect with a longer time since stroke onset indicates that the SwePASS has a reduced ability to distinguish changes in postural control after the first three months post stroke. Consequently, the SwePASS might not be the first choice for patients who have high postural capacity. Also

Benaim and colleagues (1) have shown that the PASS is less suitable after three months, with 38% of the patients obtaining the maximum score.

When selecting items for creating the SFPASS, the criteria were based on the highest internal consistency and the greatest responsiveness, which were met by the following items: 'Supine to sitting up on the edge of the table', 'Sitting to standing up', 'Standing on non-paretic leg', 'Standing up to sitting down' and 'Sitting on the edge of the table to supine' (196). The mentioned items match Item 3, Item 5, Item 9, Item 11 and Item 12, all of which demonstrated responsiveness in the thesis.

Considerations Regarding Ordinal Data

Measuring and evaluating are essential in rehabilitation. The process might be challenging, in every case using ordinal scales. In ordinal scales, the numbers given to categories/items are just symbols, understood to demonstrate the latent construct that is intended to represent a rank order not a numerical value. Even though we do not know how far apart the categories are and that a summation of the item scores is not recommended (283), summation nonetheless are done. In addition, patients and physiotherapists might be led to believe that differences in scores are linear and the amount of change is the same, regardless of the level of dependence of the patient. The fact that ordinal data are still widely used in statistical calculations, such as means, should be of increasing concern to the rehabilitation community (269).

With respect to the nature of ordinal data, E Svensson's method and the Rasch analysis were used. The benefits of using E Svensson's method have been previously discussed (under reliability).

The use of Rasch analysis and Rasch-derived instruments, equally in the analysis of data from ordinal scales in outcome research and in the development and evaluation of instruments, is encouraged (269). Rasch analysis presents a way to transform ordinal scales into interval scales when data fit the model. In an interval scale, there are equal values for equal differences, regardless of location and the summation of scores is possible. In order to add the item scores to produce a valid total score, which can be used as a valid indicator of the person ability measured by

the scale, evidence of internal construct validity (unidimensionality, item invariance and local independence) is needed. However, to carry out a transformation of the ordinal scales in the SwePASS to an interval scale, a larger population than the 150 in this thesis is required. Nevertheless, it should be noted that there is a disadvantage when it comes to using sum scores. A sum score is more useful with movement in the centre of the scale, where the raw scores are often comparable with the logits, compared with movement across the margins of the range. At the margins, the sum score might be less useful in the form of understatement of the real metric increase in raw score.

When deciding on the number of categories in a measurement instrument, the choice is also based on how many categories that are relevant and how many degrees of the latent characteristic that can be distinguished by the clinician or the patients. If the categories can be ordered soundly, there is a greater chance that they will fit the Rasch model. The scoring may be affected by different factors, such as factors in the surroundings, the interpretation of the manual and previous experience of assessing patients. Despite indications of a good fit to the Rasch model, the Rasch analysis of the SwePASS showed disordered thresholds. In general, disordered thresholds can be caused by incomprehensible items, the use of terms with multiple meanings, unspecified items and two or more questions per item (2). For those items that showed disordered thresholds, a closer look, including a hypothesis for the reasons, and a scoring content analysis are needed.

For Item 4, the category probability curves illustrate that the probability for the patients to obtain category 1 is very low, even when the curve has its peak. One hypothesis is the use of the word ‘slight’ in the definition for scoring 1. This kind of unspecified item might have multiple meanings for different observers and might therefore lead to the disorder.

In Item 7, the disordered thresholds can be explained by the definitions of category 1, 2 and 3. The use of ‘or’ and ‘and’ in these definitions means that two questions per item category are involved.

In Item 8, a score of 1 is not used at all. This is perhaps not surprising, since the time frame is poorly defined, with a range from a few seconds to ten seconds for score 1-3.

In Item 10, it may be difficult to figure out the change in capacity between 'cannot perform the activity' to 'perform the activity with help from two persons'. The difference between the categories is perhaps not so great.

The disordered thresholds involve two issues. First, disordered thresholds should be interpreted as a violation of measurement. If the categories do not work in a consistent manner, the results of evaluation may not show true changes. This may lead to problems in outcome studies, as well as in clinical evaluations. Second, disordered thresholds require some form of solution. A reduction in the number of categories might be the solution. Beyond bringing order to scale, this solution, a reduction in categories, might have further issues (284). First, a reduction in threshold provides less scope for a nuanced evaluation, which reduces the opportunity to detect changes. Second, the reduction in the categories may result in a shorter time to perform the test. Moreover, the time available to familiarise oneself with a new instrument may pass more rapidly. Third, the communication in the clinical situation might be enhanced.

Considerations in Relations to Items

In the SwePASS, some modifications were made compared with the original PASS. A decision was made to change the expressions 'much' and 'little', which might have 'multiple meanings' for the rators and should therefore be avoided (2). Instead, we used the expressions; 'help from two persons' and 'help from one person'.

Despite the definition of arm movements in the SwePASS, Item 7 appears to be less successful. In item 7, the words 'and' and 'or' point to 'several-in-one question', which are not recommended. The optimal is one question for each item (2).

The fact that the assessment of standing on the non-paretic leg, Item 8, is included in the SwePASS is positive. Based on a longitudinal study in

the field of stroke rehabilitation (285), it has been suggested that the non-paretic leg plays a role in functional improvements in gait more related to compensatory mechanisms than to recovery.

Both Item 8 and Item 9, the items that include standing on one leg, present notable results in several outcomes. In the intra-rater reliability study, they showed both the lowest kappa and percentage agreement values. Item 8 showed the highest Relative Position (RP), even if it was non-significant. In the inter-rater reliability study, Item 9 showed the highest RP, even if it was non-significant, and the highest RV, even if it was very small. In relation to the distribution of scores, Item 8 and Item 9 also possess the highest values for floor effect.

Taken together, Item 8 and Item 9 appear to be the two least reliable items in the SwePASS, but, at the same time they show RV in the responsiveness study. The reasons for this may lie in the interpretation of the manual but also in the nature of the task, which may be affected by anxiety/fear and training effect in those that are unaccustomed to standing on one leg, which is not an everyday activity for everyone. The performance, standing on one leg, can also be affected by spontaneous improvement and recovery.

Gender Differences

In the Rasch analysis, there was no differential item functioning (DIF) regarding gender (or age and localisation for stroke lesion), which indicates that the SwePASS can be used and works out equally, regardless of gender (or age and localisation for stroke lesion). Nor did gender fall out in the analysis using GEE. The sample sizes in the studies are, however, small, and from this thesis, it is not possible actually to rule out the existence of a gender difference in the usefulness of the SwePASS in recovery after stroke or in the risk of falling after stroke.

Ethical and Clinical Considerations

Current research, with frequent assessments, where postural control is challenged, might in itself imply a significant risk of falling for the patients. No falls or near falls occurred with testing, however.

The percentage, 48%, for at least one fall during the first year after stroke is higher than the 33% reported for community-dwelling individuals, older than 65 years, during one year (46). This confirms that falls after stroke are common. In overall terms, the risk of falling is an important ethical dilemma for everyone that works with rehabilitation, who together with the patient, often strives for greater autonomy at transfers and a higher degree of mobility. Interventions for postural control must be carefully challenging.

With the aim of predicting the risk of falling, the cost of misclassifying of a patient, using a measurement instrument, may be serious in two ways. There is a risk of either missing a patient with an appropriate fall risk, or incorrectly imposing a fall hazard on a patient who has none. In this context, we should remember that the risk of falling is multifaceted and that more parameters can be used than the result produced by clinical measurement instruments, to form a solid assessment of the risk of falling.

The average time to perform the SwePASS was only eight minutes. Together with the high reliability, the moderate validity and the responsiveness, this makes the SwePASS a quick and easy measurement that is useful in clinical settings.

Limitations

The sample sizes in the inter-rater reliability study and in the Rasch analysis are a clear limitation and these results should therefore not be interpreted as anything more than indications.

Another limitation is the number of raters in the intra-rater reliability and the prediction study. One of the independent raters became ill and had to be replaced by two others.

At the time of inclusion, a global rating scale was not routinely used of at the stroke units in Göteborg (Sweden). A global rating scale, such as the National Institutes of Health Stroke Scale (NIHSS) (286), might have increased the opportunity for comparisons with other populations.

Not using diaries for the registration of falls might be a limitation.

Further limitations are the long interval between baseline and the first follow-up (three months) and the number of missing data in the follow-ups.

Strengths

It is a strength that the study was performed in a clinical setting, more or less in the routine care of patients at a stroke unit (not in a perfectly controlled situation), in which the scale was intended to be applied in the future.

Another strength is the fact that the results are based on a range of common clinical measurement instruments, scales and tests and that an identification of the risk of falling early after stroke was validated by a longitudinal follow-up of stated falls.

Clear instructions, manuals and pre-training in how to perform the assessments were practiced prior to study involvement with the aim of minimising the risk of bias through multiple rater effects. Together with the fact that the same procedure was followed on all the assessment occasions, this is a strength.

Appropriate techniques by using E Svensson statistical method and Rasch analysis, are used in the analyses of the ordinal data.

CONCLUSIONS

The thesis has contributed with some new knowledge.

- The SwePASS demonstrates high intra-rater reliability and also indicates high inter-rater reliability.

- The SwePASS provides a valid cut-off score, which moderately can predict the risk of falling during the first year after a first event of stroke. In comparison with the Modified Motor Assessment Scale UAS-95, the Berg Balance Scale, the 10 Metre Walking Test and the Timed Up & Go, no statistically significant difference is found, indicating that no scale or test is superior to another.

- The SwePASS is responsive to change (another aspect of validity).

- The SwePASS indicates to be a unidimensional scale, with satisfying internal construct validity.

- The SwePASS appears to be usable at individual level, with satisfying internal consistency reliability.

- The SwePASS indicates to be used regardless of gender, age and localisation of stroke lesion (left or right brain).

- Postural control shows an improvement during the first six months in patients after a first event of stroke, when evaluated using the SwePASS.

- The SwePASS is easy to handle and quick to administer in a clinical setting.

- The measurement properties show that the SwePASS could be considered for use in rehabilitation when assessing postural control in patients after stroke.

- These results should be confirmed in a large multicenter study.

CLINICAL IMPLICATIONS

- The SwePASS is feasible for use in clinical settings to provide reliable information about the risk of falling after stroke when dichotomised and used with the cut-off value.

- The SwePASS is also practical for use in the clinic to follow changes in postural control over time when used item by item.

- This far, as the SwePASS has not yet been tested with a sufficiently large population or in an adequately well-targeted population, the scale should not be used as a sum score.

- SwePASS appears to be applicable at individual level and to be suitable for all stroke patients, regardless of gender, age or the localisation of stroke lesion.

- This thesis may have contributed to the development of evidence-based practice in stroke care and rehabilitation, by acting as a model for the way new measurement instruments could be assessed before implementation in a clinical setting. Few other scales for postural control have been assessed this thoroughly. This thesis might add a piece to the jigsaw puzzle of the evidence in clinical outcome measurements.

FUTURE PERSPECTIVES

This thesis has raised some issues that could be studied in more detail.

- An inter-rater reliability study of the SwePASS with a larger population, to evaluate whether the results indicated in this thesis can be confirmed.

- Comparisons between the original PASS and the SwePASS (English version), to analyse the significance of the modifications made to the SwePASS.

- Analysing and dealing with possible thresholds and local dependence using Rasch analysis of the SwePASS with a larger population with more impaired postural control. A sufficient sample size will enable a transformation of sum score to Rasch values (logit). A transformation table, allowing the use of the original raw scores, will be of value in everyday clinical practice.

- Qualitative research with the emphasis on the patient's experience of postural control.

SAMMANFATTNING PÅ SVENSKA

Stroke innebär en skada på någon eller flera av hjärnans funktioner. En vanlig konsekvens av detta är nedsatt postural kontroll, vilket kan leda till ökad risk för fall. Förutom risk för skada, kan ett fall även leda till att patienten oroar sig för nya fall, vilket kan leda till inaktivitet och nedsatt livskvalitet. Syftet med avhandlingen var att utvärdera mätegenskaperna hos en ny klinisk ordinalskala som bedömer postural kontroll hos patienter med stroke, Den modifierade svenska versionen av Postural Assessment Scale for Stroke Patients (SwePASS). Mer specifikt avsågs utvärdering av skalans tillförlitlighet, giltighet, förmåga att prediktera fall och mäta förändring av postural kontroll över tid, samt att följa förändring av postural kontroll upp till 12 månader efter stroke. Ytterligare syfte var att få svar på om skalan mäter en dimension och kan användas för bedömning på individnivå samt om skalans delmoment kan summeras till en totalsumma. Totalt ingick 152 patienter med förstagångsstroke i avhandlingen, varav 116 följdes upp med mätningar av postural kontroll och frågor om fall efter tre, sex och 12 månader. SwePASS visar hög tillförlitlighet och förmåga att mäta förändring över tid. SwePASS, som använts under den första veckan efter stroke, kan i viss mån identifiera patienter med risk att falla under det första året efter stroke. Postural kontroll, bedömd med SwePASS, visar en förbättring under de första sex månaderna efter strokeinsjuknandet. Raschanalys indikerar att SwePASS mäter en dimension, fungerar som ett globalt mått på postural kontroll och kan användas på individnivå hos patienter med stroke. Ytterligare studier, med fler patienter, behövs för att bekräfta aktuella resultat. Sammanfattningsvis, resultaten av SwePASS-skalans mätegenskaper indikerar att skalan är användbar i klinisk verksamhet för patienter som drabbats av stroke.

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The Swedish Version of PASS, SwePASS

Item	Scale	Item	Scale
1. Supine to affected side lateral		**7. Standing without support**	
Cannot perform the activity	0	Cannot stand without support	0
Can perform the activity with support from 2 persons	1	Can stand without support for 10 s or leans heavily on 1 leg	1
Can perform the activity with support from 1 person	2	Can stand without support for more than 1 minute or stands slightly asymmetrically	2
Can perform the activity without any help	3	Can stand without support for more than 1 minute and at the same time draw hand/s from forehead to neck (like pulling your fingers through your hair) alternating with arm/s hanging parallel to the trunk to avoid tiredness	3
2. Supine to non-affected side lateral		8. Standing on non-paretic leg	
Cannot perform the activity	0	Cannot stand on the non-paretic leg	0
Can perform the activity with support from 2 persons	1	Can stand on the non-paretic leg for a few seconds	1
Can perform the activity with support from 1 person	2	Can stand on the non-paretic leg for more than 5 seconds	2
Can perform the activity without any help	3	Can stand on the non-paretic leg for more than 10 seconds	3
3. Supine to sitting up on edge of bed		9. Standing on paretic leg	
Cannot perform the activity	0	Cannot stand on the paretic leg	0
Can perform the activity with support from 2 persons	1	Can stand on the paretic leg for a few seconds	1
Can perform the activity with support from 1 person	2	Can stand on the paretic leg for more than 5 seconds	2
Can perform the activity without any help	3	Can stand on the paretic leg for more than 10 seconds	3
4. Sitting without support		10. Standing, picking up a shoe from the floor	
Cannot sit	0	Cannot perform the activity	0
Can sit with slight support, for example with 1 hand	1	Can perform the activity with support from 2 persons	1
Can sit for more than 10 s without support	2	Can perform the activity with support from 1 person	2
Can sit for 5 min without support	3	Can perform the activity without any help	3
5. Sitting to standing up		11. Sitting down from standing up	
Cannot perform the activity	0	Cannot perform the activity	0
Can perform the activity with support from 2 persons	1	Can perform the activity with support from 2 persons	1
Can perform the activity with support from 1 person	2	Can perform the activity with support from 1 person	2
Can perform the activity without any help	3	Can perform the activity without any help	3
6. Standing with support		12. Sitting on edge of bed to supine	
Cannot stand, even with support	0	Cannot perform the activity	0
Can stand with strong support from 2 persons	1	Can perform the activity with support from 2 persons	1
Can stand with moderate support from 1 person	2	Can perform the activity with support from 1 person	2
Can stand with support of only 1 hand	3	Can perform the activity without any help	3

Corrected version 2012-11-01

Only one attempt per item is allowed. Ensure that the patient meets the criteria for the scores below, as well as the criterion for the registered score.

A stopwatch is used in items 4 and 7-9, where the patient should maintain a position within a specific time. Item 4 should be performed with the patient´s feet supported on the floor. In items 1-3, 5-6 and 10-12, the patient´s postural balance/control should be scored according to different degrees of support.

The SwePASS, developed by Carina Persson, Maria Edvinsson, Katharina Stibrant Sunnerhagen and Ulla Svantesson, published in *J Rehab Med* 2011; 00: 00, is a synthesis of the original French version and the published English version of the Postural Assessment Scale for Stroke Patients by Benaim C, Pérennou DA, Villy J, Rousseaux M, Pelissier JP. *Stroke* 1999; 30: 1862-1868. Correspondence address: Carina Persson,

Appendix 1

The Swedish Version of PASS, SwePASS

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Den svenska versionen av PASS, SwePASS

Moment	Skalsteg	Moment	Skalsteg
1. Ryggliggande till sidliggande på afficierad sida		**7. Stående utan stöd**	
Kan inte utföra aktiviteten	0	Kan inte stå utan stöd	0
Kan utföra aktiviteten med två personers hjälp	1	Kan stå utan stöd i 10 sekunder eller belastar det ena benet kraftigt	1
Kan utföra aktiviteten med en persons hjälp	2	Kan stå utan stöd i en minut eller står lätt asymetriskt	2
Kan utföra aktiviteten utan hjälp	3	Står utan stöd i över en minut och utför samtidigt armrörelser över skuldernivå; hand/händer i rörelse från panna till nacke	3
2. Ryggliggande till sidliggande på icke afficierad sida		**8. Stående på icke afficierat ben**	
Kan inte utföra aktiviteten	0	Klarar inte att utföra aktiviteten	0
Kan utföra aktiviteten med två personers hjälp	1	Klarar att stå i upp till 5 sekunder	1
Kan utföra aktiviteten med en persons hjälp	2	Klarar att stå mer än 5 sekunder	2
Kan utföra aktiviteten utan hjälp	3	Klarar att stå mer än 10 sekunder	3
3. Ryggliggande till sängkantsittande åt icke afficierad sida		**9. Stående på afficierat ben**	
Kan inte utföra aktiviteten	0	Klarar inte att utföra aktiviteten	0
Kan utföra aktiviteten med två personers hjälp	1	Klarar att stå i upp till 5 sekunder	1
Kan utföra aktiviteten med en persons hjälp	2	Klarar att stå mer än 5 sekunder	2
Kan utföra aktiv			3
4. Sängkantsit			
Klarar inte att si			0
Klarar att sitta n			1
Klarar att sitta u			2
Klarar att sitta u			3
5. Sängkantsit			
Kan inte utföra a			0
Kan utföra aktiviteten med två personers hjälp	1	Kan utföra aktiviteten med två personers hjälp	1
Kan utföra aktiviteten med en persons hjälp	2	Kan utföra aktiviteten med en persons hjälp	2
Kan utföra aktiviteten utan hjälp	3	Kan utföra aktiviteten utan hjälp	3
6. Stående med stöd		**12. Sängkantsittande till ryggliggande**	
Kan inte stå med stöd	0	Kan inte utföra aktiviteten	0
Kan stå med två personers stöd	1	Kan utföra aktiviteten med två personers hjälp	1
Kan stå med en persons stöd	2	Kan utföra aktiviteten med en persons hjälp	2
Kan stå med enbart lätt stöd från en hand	3	Kan utföra aktiviteten utan hjälp	3

Utrustning: tidtagarur och sko/toffel. Informera patienten om att bedömningen baseras på hans/hennes första försök vid varje delmoment. Använd tidtagarur vid delmoment 4 och 7-9 för bedömning av förmåga att kunna bibehålla en position viss tid enligt kriterier. I delmoment 1-3, 5-6 och 10-12 bedöms postural kontroll enligt olika kriterier för hjälp/stöd (verbal, taktil eller tillsyn). Den svenska versionen av PASS (SwePASS), framtagen av Carina Persson, Maria Edvinsson, Katharina Stibrant Sunnerhagen och Ulla Svantesson och publicerad i *Journal of NeuroEngineering and Rehabilitation* 2011 **8**:57, är en modifierad syntes av den franska originalversionen och den publicerade engelska versionen av Benaim C, Pérennou DA, Villy J, Rousseaux M, Pelissier JP publicerad i *Stroke* 1999, 30: 1862-1868.

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