

Measuring Physical Impairment and Disability With the Chedoke–McMaster Stroke Assessment

Carolyn Gowland, MHSc, PT; Paul Stratford, MSc, PT; Maureen Ward, MSc, OT;
Julie Moreland, BSc, PT; Wendy Torresin, MHSc, PT; Sandra Van Hullenaar, BSc, PT;
Julie Sanford, MSc, PT; Susan Barreca, BSc, PT;
Bernadette Vanspall, BSc, PT; and Nancy Plews, BSc, PT

Background and Purpose: The Chedoke–McMaster Stroke Assessment measures the physical impairments and disabilities that impact on the lives of individuals with stroke. This measure has three overall purposes: 1) to stage motor recovery to classify individuals in terms of clinical characteristics, 2) to predict rehabilitation outcomes, and 3) to measure clinically important change in physical function. This study was carried out to evaluate the ability of this measure to yield reliable and valid results.

Methods: Thirty-two subjects from a stroke rehabilitation treatment unit were assessed by research and treating physical therapists using multiple measures on multiple occasions. The measure's three purposes dictated the study objectives and design.

Results: Intrarater, interrater, and test–retest reliabilities of the impairment and disability inventories were estimated. Reliability coefficients for the total scores ranged from 0.97 to 0.99. Construct and concurrent validities were studied by examining the correlations between this and other measures. A priori hypothetical constructs stated that these correlations should exceed 0.60. These constructs were confirmed; the impairment inventory total score was found to correlate with the Fugl-Meyer Test ($r=0.95$, $p<0.001$) and the disability inventory with the Functional Independence Measure ($r=0.79$, $p<0.05$). Additional study hypotheses were also substantiated.

Conclusions: This study confirms that the Chedoke–McMaster Stroke Assessment yields both reliable and valid results. With the evaluation study now completed, the Chedoke–McMaster Stroke Assessment can be used with confidence as both a clinical and a research tool that can discriminate among subjects and evaluate patient outcomes. (*Stroke* 1993;24:58–63)

KEY WORDS • physical function • rehabilitation • stroke assessment

In stroke rehabilitation, as elsewhere in health care, properly constructed, valid, and reliable measures are needed to discriminate among subjects, to predict future states, and to evaluate patient outcomes or the effectiveness of interventions.¹ In the call for action of the National Symposium on Methodological Issues in Stroke Outcome Research, Basmajian² reinforced the need to discriminate among individuals with stroke. He pointed out that “rehabilitation professions must develop working models of *diagnostic classification* in order to evaluate and improve prognosis and treatment.” Stroke survivors do not make up a homogeneous group in terms of clinical characteristics and natural history.^{2,3} Earlier, Feinstein et al⁴ had noted that reliable and valid assessments that incorporate classifica-

tion of individuals into homogeneous subgroups foster logical prediction, treatment, and evaluation decisions.

The International Classification of Impairment, Disability, and Handicap provides a generally accepted framework for outcome evaluation. According to Smith,⁵ the targets of effective therapy are generally disability and handicap. It is these attributes as a direct reflection of a patient's functional level, not impairment, that should be measured to determine rehabilitation outcomes.

The Chedoke–McMaster Stroke Assessment (Chedoke Assessment) is a two-part measure made up of both a physical impairment inventory and a disability inventory. This new measure has two advantages. The impairment inventory can classify patients into homogeneous subgroups based on the stage of motor recovery, and the disability inventory measures change in disability (or inversely, physical function), not just impairment.

The purpose of the Chedoke Assessment's impairment inventory is to determine the presence and severity of common physical impairments to classify or stratify patients when planning and selecting interventions and evaluating their effectiveness. It has six dimensions, each measured on a 7-point scale. These dimensions include shoulder pain, postural control, the arm, the hand, the leg, and the foot. The 7-point scale

From the School of Occupational and Physical Therapy (C.G., P.S., M.W., J.M., W.T., J.S.), McMaster University; the Department of Physiotherapy (C.G., J.M., W.T., S.V.H., S.B., B.V., N.P.), Chedoke–McMaster Hospitals; and the Department of Rehabilitation Services (J.S.), St. Peter's Hospital, Hamilton, Canada.

Supported by grant 6606-3771-45, National Health Research and Developmental Program, Ottawa, Canada.

Address for correspondence: C. Gowland, Chedoke–McMaster Hospitals, Chedoke Campus Building 74, Room 19, Box 2000, Station A, Hamilton, Ontario, Canada L8N 3Z5.

Received July 16, 1992; final revision received September 3, 1992; accepted September 23, 1992.

corresponds to seven stages of motor recovery (with the exception of shoulder pain, which has a unique scale based on severity). Twitchell⁶ first observed and described the motor recovery sequence following stroke. He noted that recovery follows a predictable, stepwise course and that, although a patient may reach a plateau at any step along the recovery sequence, no steps are skipped and the order that the patient passes through the steps is never altered. Based on Twitchell's work, Brunnstrom⁷ identified and defined six recovery stages and described how the hemiplegic arm and leg progress through these stages. However, she did not establish the reliability or validity of the recovery stages. Unlike the physical performance test of Fugl-Meyer et al (Fugl-Meyer Test),^{8–16} which measures similar impairments, the Chedoke Assessment retains the concept of stages of motor recovery. Brunnstrom's definitions of the stages were revised (Appendix 1), and test items for staging the arm and leg were modified. Four dimensions were added (shoulder pain, postural control, the hand, and the foot), and items for determining the stage of each were identified. The maximum total score for the impairment inventory is 42 (i.e., there are six dimensions, each scored on a 7-point scale). The definitions of stages of motor impairment and the specific test items have been previously published.¹⁷

The purpose of the Chedoke Assessment's disability inventory (Appendix 2) is to measure clinically important change in physical disability (apart from the arm). This inventory is designed to be used in conjunction with the Uniform Data System for Medical Rehabilitation (UDS), which includes the Functional Independence Measure (FIM).¹⁸ The disability inventory consists of a gross motor function index and a walking index. The measurement of these attributes is considered important for the evaluation of outcome and for the determination of effectiveness of therapeutic interventions. The inventory has a maximum total score of 100 (70 from the gross motor function index, which has 10 items, and 30 from the walking index, with five items). With the exception of item 15, each item is scored on the same 7-point scale as the FIM. To score item 15, the 2-minute walking test¹⁹ is used to assess the gait efficiency of ambulating patients. If the distance in meters walked within 2 minutes is age and sex appropriate, a 2-point bonus is assigned.

A manual describing the development and evaluation of the Chedoke Assessment, with detailed instructions on administration, scoring, and interpretation, is available from the authors. It includes treatment guidelines²⁰ that describe how assessment data can be used to select appropriate treatment goals and treatment protocols.

The remainder of this paper describes the study recently completed to determine the reliability and validity of each of the two inventories of the Chedoke Assessment.

Subjects and Methods

Subjects were drawn from the inpatient and day-hospital population admitted to the stroke unit of Chedoke–McMaster Rehabilitation Centre, a regional tertiary-care institution. Over 9 months, consecutive admissions with a diagnosis of completed stroke were recruited if informed consent could be obtained. In accordance with institutional guidelines, if a patient was

TABLE 1. Characteristics of Study Patients

Characteristic	Mean	Range
Age (years)	64	18–86
Time after onset (weeks)	9	2–36
Hospital stay (weeks)*	10	3–25
Fugl-Meyer Test score	153	78–217
Impairment inventory score	22	10–34
Functional Independence Measure score	81	27–121
Disability inventory score	51	18–97

*Calculated at discharge.

unable to give informed written consent to participate due to language or cognitive impairments, the closest family member was approached to give consent. A total of 32 subjects (18 women and 14 men) were included. Fourteen subjects had a hemiplegia involving the right side, 14 had the left side involved, and four had bilateral involvement. Mean and range of the subjects' age, weeks after onset, length of hospital stay, and impairment and disability are summarized in Tables 1 and 2. Based on International Classification of Diseases–9 Codes, three subjects had a principal diagnosis of intracerebral hemorrhage, two of basilar artery occlusion, three of occlusion or stenosis of precerebral arteries, four of occlusion of cerebral arteries, two of acute but ill-defined cerebrovascular disease, four of late effects of cerebrovascular disease, 13 of spastic hemiplegia, and one of quadriplegia with brain stem infarction. Concurrent neurological deficits included hemianopsia in seven subjects, sensory involvement in 23, and seizure disorders in five. The majority of subjects were vigilant, with three classified as lethargic and three others as attentive. Many subjects had some degree of cardiac pathology; this included such disorders as congestive heart failure, atrial fibrillation, myocardial infarction, angina, or cardiomyopathy. Comorbidity was common; three subjects had diabetes, three had congestive obstructive pulmonary disease, and two had osteoarthritis of the knees. During the rehabilitation stay five subjects were diagnosed with a urinary tract infection. Discharge data were available from 29 subjects; during the course of the study two subjects died and one withdrew due to illness.

The Chedoke Assessment's three purposes dictated the evaluation study's objectives and design. The five objectives used to determine the reliability and validity of the measure and the design for each are as follows.

TABLE 2. Physical Impairments of Study Patients

Dimension	Recovery stage on admission						
	1	2	3	4	5	6	7
Shoulder pain	2	3	0	6	12	7	2
Postural control	0	8	1	17	5	1	0
Arm	1	12	10	4	4	1	0
Hand	1	14	5	4	6	2	0
Leg	0	5	9	8	6	4	0
Foot	3	10	7	4	5	3	0

Values are number of patients.

Objective 1

This was to evaluate the interrater and intrarater reliabilities of the impairment inventory. To meet this objective, patients were assessed concurrently by both a treating and a research physical therapist during the first week of admission. Random assignment was used to determine who would handle the patient during the assessment. The assessment was videotaped, and the treating therapist scored the videotape after a minimum interval of 2 weeks.

Three research physical therapists and three treating physical therapists gathered the study data. The research therapists had no prior knowledge of the patients in the study and little familiarity with the Chedoke Assessment. Before the study subjects were tested, the therapists read and discussed the administration guidelines. Areas of possible disagreement in interpretation of patient performance were identified, discussed, and resolved. Each therapist then tested one patient, following which further discrepancies were explored. The experience of the treating therapists with the Chedoke Assessment ranged from 4 months to 5 years.

For Objectives 1 and 2, the point estimates of acceptable reliability were set a priori at a Type 2,1 intraclass correlation coefficient (ICC)²¹ of at least 0.90 for the total score of the two inventories and at least 0.80 for each of the six impairment dimensions and two disability indexes. We also stipulated that the lower 95% confidence level of the ICC should be greater than 0.80 for the inventory total scores for the measure to be clinically useful.

Objective 2

This was to determine the interrater and test-retest reliabilities of the disability inventory. Because this inventory is designed to discriminate among patients at a given point in time and to assess change in a patient's function, it was important to assess the amount of variability that a patient would show in a "stable" state. Patients were assessed concurrently by both the treating and research therapists on admission and again within 5 days. Random assignment was used to determine who would handle the patient during the assessment. Handling was alternated on subsequent assessments of the same patient.

Objective 3

This was to determine the Chedoke Assessment's construct validity. To do this we hypothesized that specific impairments and disabilities would have the highest correlations with similar attributes on other measures and that these correlations would be significantly greater than 0.60. For example, impairment scores were compared with similar impairment subscores on the Fugl-Meyer Test of physical performance⁸ (i.e., postural control with balance; the sum of arm and hand with the sum of shoulder, elbow, forearm, wrist, and hand; the sum of leg and foot with the sum of hip, knee, foot, and ankle; and shoulder pain with upper limb joint pain), and disability scores were compared with similar disability subscores on the FIM (i.e., the gross motor function index with the mobility subscore, and the walking index with the locomotion subscore).

To meet this objective, additional measures were required. During the admission week the Fugl-Meyer Test was administered by the research therapist and the FIM by members of the stroke team. Before gathering data we established the ability of these raters to reliably use the Fugl-Meyer Test. Interrater reliability with a small sample of patients ($n=12$) was found to be acceptable, with ICC=0.96. Team members had recently been trained and tested in the use of the FIM.

Objective 4

This was to determine the Chedoke Assessment's concurrent validity with criterion measures. Again, the measures selected for comparison were the Fugl-Meyer Test and the FIM. Although these measures have some scales similar to the Chedoke Assessment, as shown by the hypothesized constructs tested in Objective 3, neither assesses only similar attributes. Our a priori hypothesis was that the magnitude of the correlations of the total scores would be significantly greater than 0.60. It was thought that this would adequately express a positive correlation. The design was similar to that required for Objective 3.

Objective 5

This was to evaluate responsiveness (i.e., ability of the disability inventory to detect minimal clinically important change). To accomplish this objective we tested the change that took place between admission and discharge, hypothesizing that it would be both statistically significant and greater than the change noted in the FIM. Both the disability inventory and the FIM were administered on both admission and discharge. Treating therapists took responsibility for these measures.

Data Analysis

All data entry and statistical analyses were done using SPSS/PC+ Version 3.1 software. To determine interrater, intrarater, and test-retest reliabilities, separate analysis of variance tables were generated and Type 2,1 ICCs and their respective 95% confidence limits were calculated.²¹ Type 2 ICC allows for the examination of systematic differences due to rater or time. Validity coefficients for the impairment inventory were derived by correlating the impairment scores with the Fugl-Meyer Test scores and for the disability inventory by correlating the disability scores with the FIM scores.²² To test the Objective 4 hypothesis Fisher's Z transformation was applied to the correlation coefficients.²² Responsiveness coefficients were derived for the disability inventory and the FIM by performing a repeated-measures analysis of variance that contrasted admission and discharge scores. The responsiveness coefficient is defined as the proportion of variance due to change (time) divided by the variance due to change (time) plus error.²³ The relative efficiency was also calculated by dividing the Chedoke Assessment F value for change by the FIM F value for change. This is equivalent to comparing the t^2 statistic described by Liang et al.²⁴

Results

Table 3 summarizes the intrarater, interrater, and test-retest ICCs and their 95% confidence limits for the total score and dimensions of the impairment inventory

TABLE 3. Reliabilities of Chedoke-McMaster Stroke Assessment ($n=32$)

Inventory	Intrarater		Interrater		Test-retest	
	ICC	95% CI	ICC	95% CI	ICC	95% CI
Impairment						
Shoulder pain	0.96	0.92–0.98	0.95	0.91–0.98	—	—
Postural control	0.96	0.93–0.98	0.92	0.84–0.96	—	—
Arm	0.95	0.89–0.97	0.88	0.76–0.94	—	—
Hand	0.93	0.85–0.96	0.93	0.84–0.96	—	—
Leg	0.98	0.96–0.99	0.85	0.73–0.93	—	—
Foot	0.94	0.87–0.97	0.96	0.91–0.98	—	—
Total score	0.98	0.95–0.99	0.97	0.94–0.98	—	—
Disability						
Gross motor function	—	—	0.98	0.97–0.99	0.96	0.93–0.98
Walking	—	—	0.98	0.95–0.99	0.98	0.96–0.99
Total score	—	—	0.99	0.98–1.00	0.98	0.95–0.99

ICC, intraclass correlation coefficient; CI, confidence interval.

and for the total score and indexes of the disability inventory (Objectives 1 and 2). The ICCs for the total scores ranged from 0.97 to 0.99 (minimum set a priori at 0.90) and for the dimensions and indexes from 0.85 to 0.98 (minimum set a priori at 0.80). The lower 95% confidence level of the ICCs for the total scores ranged from 0.94 to 0.98 (lowest acceptable value set a priori at 0.80). All values were higher than the minimum acceptable levels set a priori, and no systematic differences between either raters or occasions were found.

Table 4 displays the correlation matrix used to examine the construct and concurrent validities of the Chedoke Assessment (Objectives 3 and 4). Postural control correlated better with balance on the Fugl-Meyer Test ($r=0.84$, $p<0.01$) than with any other dimension on

either this test or the FIM; the sum of the arm and hand correlated best with the sum of the shoulder, elbow, forearm, wrist, and hand ($r=0.95$, $p<0.001$); the sum of the leg and foot correlated best with the sum of the hip, knee, foot, and ankle ($r=0.93$, $p<0.001$); and shoulder pain correlated best with upper limb joint pain ($r=0.76$, $p<0.01$). In the disability inventory, the gross motor function index correlated better with the mobility subscore on the FIM ($r=0.90$, $p<0.001$) than with any other dimension on either this test or the Fugl-Meyer Test, and the walking index correlated best with the FIM locomotion subscore ($r=0.85$, $p<0.01$). The concurrent validity of the Chedoke Assessment is supported; the total score of the impairment inventory correlates with that of the Fugl-Meyer Test ($r=0.95$, $p<0.001$) and the

TABLE 4. Correlation Matrix Examining Construct and Concurrent Validities of Chedoke-McMaster Stroke Assessment by Comparing It to Fugl-Meyer Test and Functional Independence Measure ($n=32$)

Chedoke Assessment	Fugl-Meyer Test					Functional Independence Measure		
	Balance	Shoulder, elbow, forearm, wrist, and hand	Hip, knee, foot, and ankle	Upper limb joint pain	Total score	Mobility subscore	Locomotion subscore	Total score
Impairment inventory								
Postural control	0.84*	0.53	0.65	0.46	0.69	0.74	0.66	0.73
Arm and hand	0.46	0.95†	0.76	0.49	0.89	0.40	0.46	0.36
Leg and foot	0.68	0.79	0.93†	0.56	0.87	0.58	0.53	0.58
Shoulder pain	0.38	0.49	0.59	0.76*	0.66	0.40	0.36	0.36
Total score	0.67	0.88	0.90	0.65	0.95†	0.59	0.57	0.57
Disability inventory								
Gross motor function	0.88	0.49	0.67	0.40	0.65	0.90†	0.85	0.81
Walking	0.68	0.40	0.41	0.31	0.49	0.83	0.85*	0.64
Total score	0.85	0.46	0.61	0.38	0.62	0.91	0.89	0.79‡

$p>0.60$ (one-tailed) of numbers on diagonal based on Fisher's Z transformation.

* $p<0.01$, † $p<0.001$, ‡ $p<0.05$.

TABLE 5. Ability of Chedoke–McMaster Stroke Assessment to Detect Change in Physical Disability Compared With Functional Independence Measure ($n=32$)

Measure	Variance ratio	<i>F</i>
Chedoke Assessment (disability inventory)	0.53	37.25*
Functional Independence Measure	0.39	19.40*

Variance ratio, variance due to change/(variance due to change+error).

* $p<0.001$ (one-tailed).

total score of the disability inventory with that of the FIM ($r=0.79$, $p<0.05$). Both values significantly exceed 0.60, the minimum acceptable level established a priori.

Table 5 displays the variance ratios and *F* values used to determine the ability of the disability inventory to detect significant change (Objective 5). The Chedoke Assessment was found to be considerably more responsive to change than the FIM; specifically, the relative efficiency was 1.92 times greater.

Discussion

This study confirms that the Chedoke Assessment yields both reliable and valid results as determined by the objectives set for this purpose. The reliability is gratifyingly high considering that the subject sample included consecutive admissions (ICCs can be inflated if the variance due to patients is increased by oversampling subjects scoring at the high and low ends of the scale).²³

Because the overall correlation with the Fugl-Meyer Test is high ($r=0.95$), one may question introducing a newer measure; however, the Chedoke Assessment has two advantages. It measures change in disability (or inversely, physical function), not just impairment, and the impairment inventory can classify patients into homogeneous subgroups based on the stage of motor recovery. For many years, Brunnstrom stages of recovery have been used in rehabilitation settings as a meaningful way to describe a patient's impairments. What has been missing is the standardization of these stages and the evaluation of their reliability and validity.

Using an earlier version of the Chedoke Assessment, the predictive properties of the measure in the rehabilitation setting were investigated. We established that the stage of recovery of various impairments provides valid and significant prognostic indicators for outcomes.²⁵ The outcomes considered were activities of daily living; recovery of the arm, leg, and postural control; and gross motor function, gait, and shoulder pain. Using this classification scheme, predictive equations were developed to guide therapists in setting goals when the estimation of discharge potential is an important consideration.²⁵ For example, on admission of a patient to rehabilitation, an equation that considers the stage of recovery of the arm and leg and the weeks after stroke can predict the stage of recovery of the arm at discharge; 81% of the variance in outcome can be explained by this equation. However, predictive validity of the current version has not been examined, nor has the current version been studied to determine its ability to predict functional outcome earlier than 3 weeks after stroke.

As indicated earlier, the Chedoke Assessment is designed to be used in conjunction with the UDS and the FIM. We chose the same scoring key as the FIM for the disability inventory to provide a consistent model for conceptualizing the degree of independence of the patient, or inversely, the degree of burden on the caregiver. The disability inventory, as demonstrated by the validation of the relative responsiveness of the Chedoke Assessment and the FIM, is meant to be more responsive to change in the physical domain, which is assessed only summarily in the FIM. The disability inventory provides additional information needed to plan a therapeutic intervention that stresses functional activity. Because change in disability is the principal outcome of interest, we designed the disability inventory specifically to pick up small but important change in patient function.

Although the Chedoke Assessment has been used for many years in the clinical setting, the understanding of its properties was far from complete. This study addresses some of the obvious concerns about the measure's reliability and validity.

In conclusion, the study reported here further evaluates a measure of physical impairment and disability that can be used for classifying patients according to their stage of recovery, for predicting probable rehabilitation outcomes, and for evaluating the effectiveness of interventions aimed at improving the physical function of individuals with stroke.

At a time when health care costs are of major concern to health care providers, the availability of a valid outcome measure suitable for use in both clinical and research settings should be greeted enthusiastically. The Chedoke Assessment offers such a measure as part of a comprehensive assessment and treatment package; the Assessment is accompanied by a clinical data base and predictive equations suitable for judging the prognosis of an individual patient while in intensive rehabilitation.

Appendix 1 Definitions of Stages of Motor Impairment

Stage 1. Flaccid paralysis is present. Phasic stretch reflexes are absent or hypoactive. Active movement cannot be elicited reflexly with a facilitatory stimulus or volitionally.

Stage 2. Spasticity is present and is felt as a resistance to passive movement. No voluntary movement is present, but a facilitatory stimulus will elicit primitive movement patterns reflexly. These primitive patterns are the stereotyped flexion and extension synergies.

Stage 3. Spasticity is marked. The primitive synergistic movement patterns can be elicited voluntarily, but are obligatory. In most cases, the flexion synergy dominates the arm, the extension synergy the leg. There are strong and weak components within each synergy.

Stage 4. Spasticity decreases. Synergy patterns can be reversed if movement takes place in the weaker synergy first. Movements combining antagonistic synergies can be performed when the prime movers are the strong components of the synergy.

Stage 5. Spasticity wanes, but it is evident with rapid movement and at the extremes of range. Synergy patterns can be reversed even if the movement takes place in the stronger synergy first. Movements utilizing the weak components of both synergies acting as prime movers can be performed. Most movements become environmentally specific.

Stage 6. Coordination and patterns of movement are near normal. Spasticity as demonstrated by resistance to passive

movement is no longer present. A great variety of environmentally specific patterns of movement are now possible. Abnormal patterns of movement with faulty timing emerge when rapid or complex actions are requested.

Stage 7. Normal. A "normal" variety of rapid, age-appropriate complex movement patterns are possible with normal timing, coordination, strength, and endurance. There is no evidence of functional impairment compared with the normal side. There is a "normal" sensory-perceptual-motor system.

Appendix 2 Chedoke-McMaster Stroke Assessment Disability Inventory

Gross Motor Function Index

1. Supine to side lying on strong side
2. Supine to side lying on weak side
3. Side lying to long sitting through strong side
4. Side lying to sitting on side of the bed through strong side
5. Side lying to sitting on side of the bed through weak side
6. Standing
7. Transfer to and from bed toward strong side
8. Transfer to and from bed toward weak side
9. Transfer up and down from floor and chair
10. Transfer up and down from floor and standing

Walking Index

11. Walking indoors
12. Walking outdoors, over rough ground, ramps, and curbs
13. Walking outdoors several blocks
14. Stairs
15. Age- and sex-appropriate walking distance (in meters) for 2 minutes (2-point bonus)

Scoring key from the Functional Independence Measure, Uniform Data System For Medical Rehabilitation, State University of New York at Buffalo

Independence (no helper)

7. Complete independence (timely, safely)
6. Modified independence (device)

Modified dependence (helper)

5. Supervision
4. Minimal assist (subject=75%)
3. Moderate assist (subject=50%)

Complete dependence (helper)

2. Maximal assist (subject=25%)
1. Total assist (subject=0%)

References

1. Kirshner B, Guyatt G: A methodological framework for assessing health indices. *J Chronic Dis* 1985;38:27-36
2. Basmajian JV: The call for action. *Stroke* 1990;21(suppl II):II-3
3. Gresham GE: Past achievements and new directions in stroke outcome research. *Stroke* 1990;21(suppl II):II-1-II-2
4. Feinstein AR, Josephy BR, Wells CK: Scientific and clinical problems in indexes of functional disability. *Ann Intern Med* 1986;105:413-420
5. Smith DS: Outcome studies in stroke rehabilitation: The South Australian Stroke Study. *Stroke* 1990;21(suppl II):II-56-II-58
6. Twitchell TE: The restoration of motor function following hemiplegia in man. *Brain* 1951;74:443-480
7. Brunnstrom S: *Movement Therapy in Hemiplegia: A Neurophysiological Approach*. New York, Harper & Row Publishers, Inc, 1970
8. Fugl-Meyer AR, Jaasko L, Leyman I, Olsson S, Stegling S: The post-stroke hemiplegic patient. I: A method for evaluation of physical performance. *Scand J Rehabil Med* 1975;7:13-31
9. Wood-Dauphinee SL, Williams JL, Shapiro SH: Examining outcome measures in a clinical study of stroke. *Stroke* 1990;21:731-739
10. Duncan PW, Badke MB: *Stroke Rehabilitation: The Recovery of Motor Control*. Chicago, Year Book Medical Publishers, Inc, 1987
11. Duncan PW, Propst M, Nelson SG: Reliability of the Fugl-Meyer assessment of sensorimotor recovery following cerebrovascular accident. *Phys Ther* 1983;63:1606-1610
12. Berglund K, Fugl-Meyer AR: Upper extremity function in hemiplegia. *Scand J Rehabil Med* 1986;18:155-157
13. deWeerd JWG, Harrison MA: Measuring recovery of arm-hand function in stroke patients: A comparison of the Brunnstrom-Fugl-Meyer Test and the Action Research Arm Test. *Physiother Can* 1985;37:65-69
14. Dettmann MA, Linder MT, Sepic SB: Relationships among walking performance, postural stability and functional assessments of the hemiplegic patient. *Am J Phys Med* 1987;66:77-90
15. Lindmark B, Hamrin E: Evaluation of functional capacity after stroke as a basis for active intervention: Validation of a modified chart for motor capacity assessment. *Scand J Rehabil Med* 1988;20:111-115
16. Lindmark B, Hamrin E: Evaluation of functional capacity after stroke as a basis for active intervention: Presentation of a modified chart for motor capacity assessment and its reliability. *Scand J Rehabil Med* 1988;20:103-109
17. Gowland C: Staging motor impairment after stroke. *Stroke* 1990;21(suppl II):II-19-II-21
18. Data Management Service of the Uniform Data System for Medical Rehabilitation and the Centre for Functional Assessment Research: *Guide for Use of the Uniform Data Set for Medical Rehabilitation*, ed 3. Buffalo, NY, State University of New York at Buffalo, 1990
19. Butland RJA, Pang J, Gross ER, Woodcock AA, Geddes DM: Two-, six-, and 12-minute walking tests in respiratory disease. *BMJ* 1982;284:1607-1608
20. Gowland C, Torresin W, VanHullenaar S, Best L: Therapeutic exercise for stroke patients, in Basmajian JV, Wolf SL (eds): *Therapeutic Exercise*. Baltimore, Md, Williams & Wilkins Co, 1990, pp 207-229
21. Shrout PE, Fleiss JL: Intraclass correlation coefficients: Uses in assessing rater reliability. *Psychol Bull* 1979;420-428
22. Kleinbaum DG, Kupper LL: *Applied Regression Analysis and Other Multivariable Methods*. Boston, Duxbury Press, 1978, pp 78-80, 158-159
23. Streiner DL, Norman GR: *Health Measurement Scales: A Practical Guide to Their Development and Use*. New York, Oxford University Press, 1989, p 84
24. Liang MH, Larson MG, Cullen KE, Schwartz JA: Comparative measurement efficiency and sensitivity of five health instruments for arthritis research. *Arthritis Rheum* 1985;28:542-547
25. Gowland C: Predicting sensorimotor recovery following stroke rehabilitation. *Physiother Can* 1984;36:313-320