Psychometric Characteristics of the Barthel Activities of Daily Living Index in Stroke Patients

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Background and purpose: Although the Barthel activities of daily living (ADL) index (BI) is widely used to measure disability in Taiwan, the usage of the BI has not been scientifically justified. This study examined the reliability, validity, and responsiveness of the BI in a cohort of stroke patients who were followed for half a year after stroke.
Methods: One hundred and twenty-one patients were assessed using the BI at 14, 30, 90, and 180 days after stroke (DAS). Reliability of the BI was determined by estimation of inter-rater agreement and internal consistency. Validity of the BI was determined by examining convergent construct validity and predictive validity. Responsiveness was determined using effect size and *t*-statistics calculations.
Results: There was moderate to excellent agreement between raters for individual items (kappa value range, 0.53–0.94) and total score (ICC = 0.94). An excellent internal consistency was found within the BI at four DAS points (alpha value range, 0.89–0.92). The BI scores closely correlated with scores of the Fugl-Meyer motor assessment (measuring impairment) and the Berg balance scale (measuring balance) (Pearson's $r \geq 0.78$, $p < 0.0001$). The Frenchay activities index (measuring instrumental ADL) at 180 DAS showed moderate correlation with the BI scores obtained at 14, 30, and 90 DAS (Pearson's $r \geq 0.59$, $p < 0.0001$). The effect size *d*, standardized response mean, *t*-statistics, and *p*-values showed that the BI was moderately to highly responsive at each stage of stroke recovery except the late stage (90–180 DAS).
Conclusion: This study has demonstrated that the BI is a useful instrument with high inter-rater reliability, internal consistency, convergent and predictive validity, and adequate responsiveness in assessing ADL functions in stroke patients in Taiwan.

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Key words:
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Stroke is the most common cause of disability among the elderly [1]. Reducing the degree of disability is often a central aim of rehabilitation programs and other related interventions for patients who have suffered a stroke. In order to identify disabilities and manage their associated problems, both clinicians and researchers need a scientifically sound scale of disability.

An assessment tool should be scientifically sound in terms of three basic psychometric properties: reliability, validity, and responsiveness [2]. Reliability addresses the internal consistency of the scale items and the reproducibility of the scores when the scale is applied by the same rater (intra-rater reliability) or different raters (inter-rater reliability) [2]. Validity indicates whether the scale measures the concept that is to be measured [3]. In the absence of a gold standard, validity is established by assessing the degree to which the scale correlates with other measures measuring related entities (convergent construct validity) [2]. Predictive validity is expressed as the scale's ability to predict something it should theoretically be able to predict [3]. Responsiveness assesses the ability of the scale to detect meaningful clinical change over a short period of time [4].

The Barthel activities of daily living (ADL) index (BI) [5] is one standardized scale widely used by clinicians and researchers to assess disability [3]. It includes 10 fundamental items of ADL: feeding, grooming,

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bathing, dressing, bowel and bladder care, toilet use, ambulation, transfers, and stair climbing. The total score ranges from 0 to 20, with higher scores signifying better degrees of function. Although researchers in many populations have demonstrated the BI to be reliable [6, 7], valid [8, 9], and responsive [10, 11], no such study has been reported in the Taiwanese population.

In Taiwan, the BI is commonly used in stroke patients in both research and clinical settings. However, psychometric characteristics of the BI have not been systematically examined in Taiwan. Furthermore, several studies have reported that cultural factors influence the reliability and validity of the BI [12, 13]. The ADL tasks may be quite different between different cultures or lifestyles [14]. Thus, there is a need for further evaluation of the psychometric characteristics of the BI when it is used to evaluate stroke patients in Taiwan. The purpose of this study was to examine the reliability (including inter-rater reliability and internal consistency), validity (including convergent construct validity and predictive validity), and responsiveness of the BI administered to a cohort of stroke patients who were followed for half a year after stroke onset.

Patients and Methods

Subjects

Subjects were selected from stroke patients admitted to National Taiwan University Hospital between December 1, 1999, and September 30, 2000. Patients were included in the study if they met the following criteria: (i) diagnosis (International Classification of Diseases, Ninth Revision Clinical Modification [ICD-9-CM] codes) of cerebral hemorrhage (431), cerebral infarction (434), or other (430, 432, 433, 436, 437); (ii) first onset of stroke without other major diseases and the absence of a preexisting disability; (iii) stroke onset within 14 days prior to admission; (iv) ability to follow commands; (v) willingness to participate in this study; and (vi) residence in the greater Taipei area. The clinical diagnosis of stroke was confirmed by neuroimaging (computerized tomography or magnetic resonance imaging). Patients with a diagnosis of nonvascular accident-related subarachnoid hemorrhage, transient ischemic attack (ICD-9-CM code 435), or late effects of cerebrovascular disease (ICD-9-CM code 438) were excluded. Patients who suffered from another stroke or from other major diseases during the follow-up period were also excluded. Patients' demographic details and data on comorbidity were collected from their medical records.

Procedure

The condition of each subject was assessed using BI and other well-validated scales at 14, 30, 90, and 180 days after stroke (DAS). The study protocol was divided into two parts. The first part was an inter-rater reliability study. The BI evaluation was carried out on the same patient by two occupational therapists (A and B) at 14 DAS. Both assessments were made in a random order within a 24-hour time period. The 1-day period was established to minimize the effect of a possible spontaneous recovery, a confounding variable that could affect the results. Both occupational therapists voluntarily participated in this part of the study. They were blinded to the results of each other's assessments during the study period.

The second part of the protocol was a validity and responsiveness study. All subjects were evaluated with the BI as well as the Fugl-Meyer motor assessment (FM) [15] and the Berg balance scale (BBS) [16] at 14, 30, 90, and 180 DAS. The Frenchay activities index (FAI) was also used to assess the performance of instrumental activities of daily living (IADL) at 180 DAS [17]. All assessments for the validity and responsiveness study were made by occupational therapist A, who was blinded to the purpose of this study.

Instruments

The FM is probably the most widely known impairment scale used for the assessment of stroke [15]. It includes six subgroups: upper extremity motor function, lower extremity motor function, range of motion, pain, sensation, and balance [15]. The possible scores range from 0 to 226 points. The FM is reliable, valid, and sensitive to change [18–20].

The BBS was selected to measure balance [16]. It consists of 14 items measuring daily movements that are related to balance. Each item is graded from 0 to 4. The total scores range from 0 to 56 points. This instrument has high inter- and intra-rater reliability [16, 21] and good validity in patients with stroke [16, 22, 23].

The FAI was developed as a means of measuring IADL following stroke [17]. IADL consists of complex activities such as social interaction, domestic activities, work, and leisure [3]. FAI scores range from 0 to 45. The reliability and validity of the FAI have been confirmed [17, 24, 25].

Statistical analysis

Reliability

Inter-rater agreement on individual items of the BI was analyzed using the quadratic weighted kappa statistic. The weighted kappa score measures the agreement among raters adjusted for the amount of agreement expected by chance and the magnitude of disagreements [26]. A kappa value of more than 0.75 indicates

excellent agreement, 0.4 to 0.75 indicates fair to good agreement, and less than 0.4 indicates poor agreement [27].

Inter-rater reliability for the total score of the BI was analyzed using the intra-class correlation coefficient (ICC) statistic. The ICC was employed to examine the degree of agreement between repeated assessments by the two raters on the same patient. The ICC expresses measurement error and agreement as the relation between true variance and observed variance. Two-way ANOVA was employed to compute the variances needed to estimate the inter-rater reliability ICC values. The fixed effect of ICC Model 3 was used to compute the ICC value for inter-rater reliability [28]. An ICC value of more than 0.80 indicates high reliability [29]. The 95% confidence interval (95% CI) was calculated for each ICC to take sampling variation into account. A paired *t*-test was performed on the mean change between scores obtained on the two BI measurements to determine the presence of a systematic bias.

The internal consistency was examined using Cronbach's alpha coefficients. An alpha coefficient of greater than 0.70 is considered adequate for group comparison [30]. The alpha coefficients were calculated for the patients at 14, 30, 90, and 180 DAS.

Validity

Convergent construct validity was measured by examining the relationships between the total score of the BI with those of the FM and BBS at 14, 30, 90, and 180 DAS using the Pearson's product-moment correlation coefficient.

The predictive validity of the BI was assessed by examining the association between the results of the BI at three DAS points (14, 30, and 90 DAS) and that of the FAI at 180 DAS using the Pearson's product-moment correlation coefficient.

Responsiveness

Responsiveness was examined at four stages after stroke, ie, early stage (14–30 DAS), middle stage (30–90 DAS), late stage (90–180 DAS), and overall stage (14–180 DAS). Because there is no consensus on how best to assess the responsiveness to change of scales [31], four approaches were employed in this study. First, effect size *d* was defined as the observed change divided by the standard deviation of the baseline score. That is, effect size *d* was calculated by dividing the mean change scores by the standard deviation of the baseline (eg, BI at 14 DAS) score in the same subjects. Second, standardized response mean (SRM), another kind of effect size, was calculated by dividing the average change between initial (eg, BI at 14 DAS) and follow-up (eg, BI at 30 DAS) measurements by the standard deviation of the change score. Cohen suggested that an effect size of more than 0.8 is large, 0.5 to 0.8 is moderate, and 0.2 to 0.5 is small [26]. Third, paired *t*-tests were used to determine the statistical significance of these change scores. Fourth, the patient's impairment recovery (change in FM score) during the overall stage (14–180 DAS) was chosen as an external criterion. The relationship between the changes in score of the BI and FM was examined using Pearson's correlation coefficient.

If the original data violated the normality assumption, data transformations were used to normalize the variables. SPSS for Windows 10.0 software was used for all data management and analysis.

Results

A total of 126 patients met the criteria for inclusion and were invited to participate in the study. Five patients declined the invitation. The baseline characteristics of the 121 subjects who enrolled in the study are shown in Table 1. Fourteen subjects were lost to follow-up or removed from the cohort at 30 DAS, and 31 patients were lost to follow-up or removed at 90 DAS. Sixty-eight patients remained in the cohort at 180 DAS.

The distributions of the BI total scores at each stage of stroke recovery are presented in the Figure. The floor and ceiling effect, the percentages of the sample scoring the minimum and maximum possible scores, respectively, reflect the extent that scores cluster at the bottom and top of the scale range. Floor and ceiling effects exceeding 20% are considered to be significant [11]. The BI, as expected, showed significant ceiling effects at 90 and 180 DAS, 37% and 56%, respectively. Square transformation was then used to improve the distributions of the original data. Data analyses were performed on both the original data and transformed data for the validity and responsiveness study. Because similar results were obtained, the original data were used.

Table 1. Baseline characteristics of study patients (n = 121)

Gender	Male/female	65/56
Age	Mean, years (SD)	69.2 (11.2)
Diagnosis	Cerebral hemorrhage	32 (26.4%)
	Cerebral infarction	72 (60.0%)
	Others	17 (14.6%)
Side of hemiplegia	Right/left	55/66
BI (14 DAS)	Mean (SD)	7.6 (6.1)
FM (14 DAS)	Mean (SD)	155.5 (46.5)
BBS (14 DAS)	Mean (SD)	5.9 (4.8)

SD = standard deviation; BI = Barthel activities of daily living index; DAS = days after stroke; FM = Fugl-Meyer motor assessment; BBS = Berg balance scale.

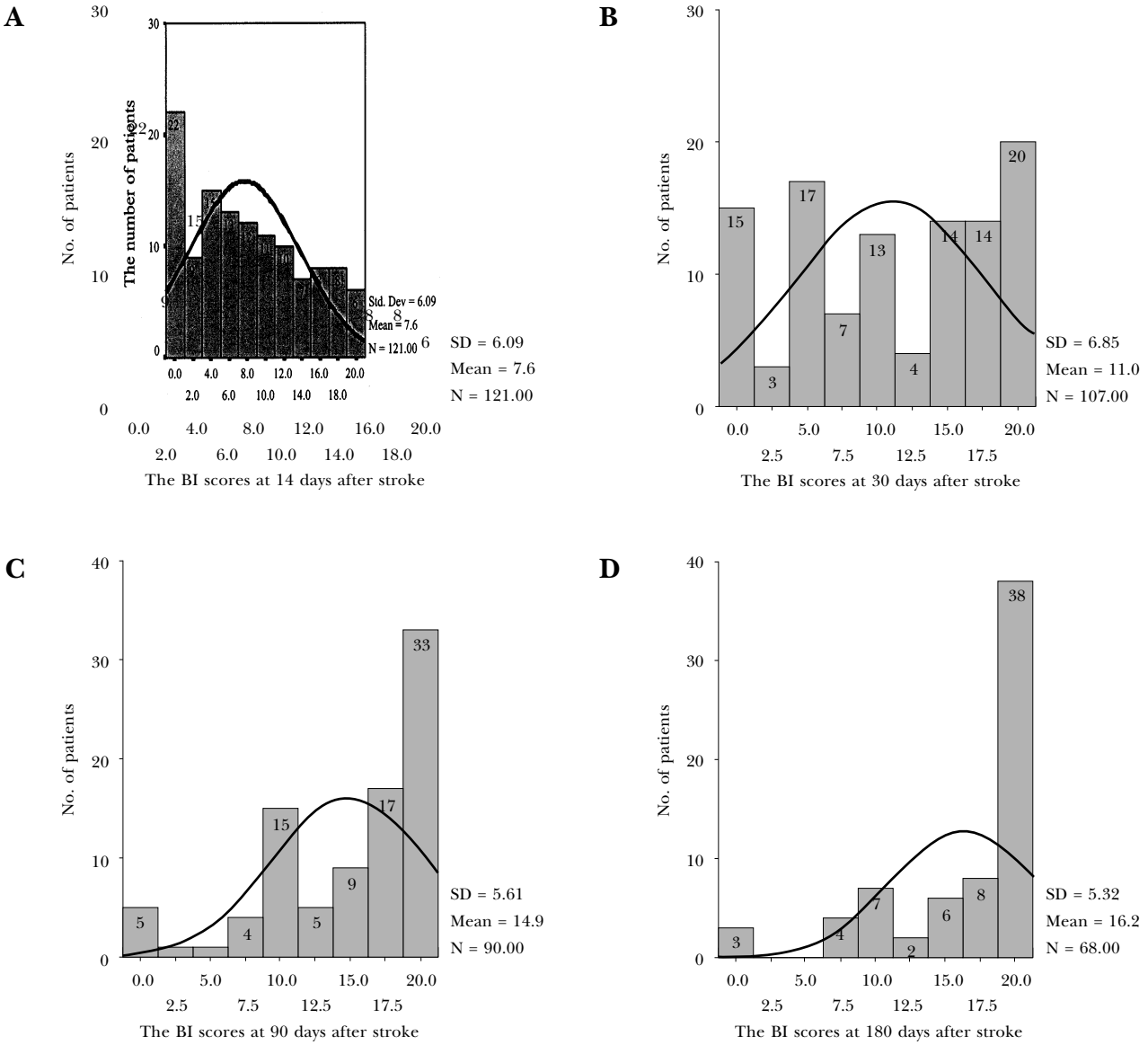

Figure. *Histogram with normal curve superimposed over the distribution of total scores of the Barthel index (BI) at 14 , 30, 90 , and 180 days (A, B, C and D, respectively) after stroke. SD = standard deviation.*

Reliability

In the assessment of inter-rater reliability on individual items, weighted kappa statistics for each of the 10 items ranged from 0.53 to 0.94 (median, 0.72), indicating moderate to excellent agreement. The items 'bathing' and 'dressing' were the only two items that showed moderate agreement.

In the assessment of inter-rater reliability of the total score, the ICC was 0.94 (95% CI: 0.91–0.96, $p < 0.0001$), indicating very high inter-rater agreement. Furthermore, BI scores from the two raters at 14 DAS showed no systematic bias (mean change score = 0.07, $SD = 2$, $p = 0.743$).

The Cronbach's alphas ranged from 0.89 to 0.92 at the four DAS points, indicating excellent internal consistency.

Validity

The results for convergent construct validity and predictive validity are shown in Table 2. The BI scores were highly correlated with the BBS and FM scores at each stage of stroke recovery, indicating good convergent construct validity (Pearson's $r \geq 0.78$, $p < 0.0001$). The BI scores at 14, 30, and 90 DAS correlated moderately with the FAI scores at 180 DAS (Pearson's $r \geq 0.59$, $p < 0.0001$). The results showed the predictive validity of the BI was well within acceptable ranges.

Table 2. Convergent construct validity and predictive validity of the Barthel index (BI) as measured using the Pearson's product moment correlation coefficient

	Construct validity		Predictive validity
	BI *vs* FM	BI *vs* BBS	(BI predicting FAI)*
14 DAS	0.8	0.89	0.59
30 DAS	0.81	0.94	0.66
90 DAS	0.78	0.9	0.63
180 DAS	0.8	0.91	–

FM = Fugl-Meyer motor assessment; BBS = Berg balance scale; FAI = Frenchay activities index; DAS = days after stroke. * The FAI was administered at 180 days after stroke onset.

Responsiveness

The responsiveness of the BI is partly listed in Table 3. The effect size *d*, SRM, *t*-statistics, and *p*-values showed that the BI was moderately to highly responsive at each stage of stroke recovery except, as expected, the late stage (90–180 DAS), where it showed low responsiveness. Furthermore, the relationship between the change in score of the BI and FM during the overall stage was moderate (Pearson's $r = 0.54$, $p < 0.001$). These results indicate that the BI is sensitive to change over time.

Discussion

The patient's function in ADL is one of the more important indicators of recovery in stroke patients. A psychometrically sound ADL scale that meets both practical and research needs provides valuable information for both clinicians and researchers. Our study was the first to comprehensively investigate the psychometric characteristics of the BI when applied to stroke patients in Taiwan.

Table 3. Responsiveness of the Barthel index (BI) at different stages after stroke onset

	Mean change score	Effect size, *d*	SRM	*t*-statistics
14–30 DAS (n = 107)	2.61	0.56	0.85	8.83*
30–90 DAS (n = 90)	3.56	0.53	0.87	8.19*
90–180 DAS (n = 68)	0.26	0.11	0.28	2.28†
14–180 DAS (n = 68)	7	1.27	1.5	12.37*

SRM = standardized response mean; DAS = days after stroke. *$p < 0.0001$; †$p = 0.026$.

In this study, reliability of the BI was examined in terms of inter-rater reliability and internal consistency. The weighted kappa statistics indicated moderate to high agreement between raters in each item, and the ICC showed excellent agreement between raters for the total score. These findings are similar to those of previous studies [6, 32]. It was noted that two items, 'bathing' and 'dressing', showed only moderate inter-rater agreement. Specific training on scoring these two items is needed for BI users, although excellent inter-rater agreement was achieved for the total score. Our results also showed excellent internal consistency in the BI, which means that the 10 items in the BI are homogeneous in measuring patients' ADL function. Brown et al found a similar result [33]. These results suggest that the BI is a reliable scale.

Regarding the convergent construct validity of the BI, our results showed a high degree of correlation between BI scale and the BBS and FM scales at each stage of stroke recovery. These results indicated that balance and severity of stroke impairment are related to ADL function in stroke patients; this is similar to other researchers' findings that motor loss and sitting balance correlate with BI score [8, 34, 35]. These results indicate that physical function in stroke patients may influence their ADL functions and that the convergent construct validity of the BI is well supported.

As patients' BI scores at three earlier DAS points moderately correlated with the FAI scores at 180 DAS, these results reflected that the basic ADL function at the early stages of stroke recovery is an indicator of the IADL function of stroke patients. Other studies produced similar findings, such as that the BI scores obtained at early stages of stroke recovery can predict independent living in community, length of inpatient stay, vocational status, and mortality [32, 36, 37]. The predictive validity of the BI is further confirmed by our study.

A scale with excellent responsiveness can inform health professionals about clinically significant improvement in patients. In this study, the BI was found to be highly responsive during the early stage of stroke. Some other researchers have recently found similar results [10, 11]. The low responsiveness at the later stages of recovery may be due to the plateau of the improvement in ADL function in stroke patients. The plateau of the BI at 180 DAS has also been reported in other studies [10, 34].

The BI showed ceiling effects at 90 and 180 DAS that were similar to those found in previous studies [11, 38]. These results may indicate that the BI does not evaluate across the entire continuum of disability for patients with stroke. Actually, the BI evaluates only self-care and mobility, so it is not adequate for assessing the full impact of stroke-related disability. Other disability scales, such as the FAI,

which measures social function and more complex ADL than the BI, should be used in addition to the BI when comprehensive stroke disabilities are assessed [39, 40].

The BI and the functional independence measure (FIM) are arguably the most widely used scales of disability both in stroke research and clinical work. The FIM was developed to be a more comprehensive and responsive scale of disability than the BI, as the FIM contains more test items and has more scoring levels. Interestingly, a recent study reported that the BI and the FIM showed a similar responsiveness in rehabilitation inpatients with moderate to severe stroke and multiple sclerosis, suggesting that the FIM has no advantage over the BI in evaluating change [11]. The similar levels of responsiveness of the BI and FIM have important implications for both clinicians and researchers. Further study is needed in order to develop a comprehensive comparison of the psychometric characteristics of the BI and FIM.

There are three limitations of this study that might concern readers. First, there are several scoring guidelines for the BI. We adopted the scoring guidelines that had been examined and suggested by Wade and Collin [41]. Therefore, the results from this study should be interpreted with caution when other scoring guidelines are used. Second, the intra-rater and concurrent validity of the BI were not examined in this study. Although we found high inter-rater reliability and high convergent construct validity and predictive validity, further investigation of the intra-rater reliability and concurrent validity of the BI in Taiwan might be needed. The third limitation that might concern readers is that the sample size in this study was not large enough for us to further analyze the data according to the type of stroke. As the type of stroke could affect the results of this measure, further studies with larger sample sizes are needed to analyze these effects on the psychometric characteristics of the BI.

The results of this study indicate that the BI is reliable, valid, and sensitive to change when applied to stroke patients in Taiwan. The BI is suggested for use in measuring ADL function in stroke patients for both clinicians and researchers.

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