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Original Article

Modeling factors predictive of functional improvement following acute stroke

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Abstract

Background: Predicting functional improvement at an early stage after stroke is critical to setting treatment goals and strategies. The aim of this study was to identify factors that can predict motor function improvement at 3 months and 6 months poststroke.

Methods: Forty-four patients with stroke were included in the study. We recorded age, interval between stroke onset and initiation of physical therapy, stroke type, history of diabetes or cardiovascular disease, functional status prior to stroke, cognition, motivation, walking ability, eating ability, hemineglect, sensory function, and brain lesion site as predictive factors. The Stroke Rehabilitation Assessment of Movement, Berg Balance Scale, Timed Up & Go Test, and the 6-Minute Walk Test were conducted upon intake and at 3 months and 6 months poststroke. Patients were assigned to a progressive group or a nonprogressive group based on their improvement in four functional measures. Variables for which there were significant group differences were used for stepwise discriminant analysis as determining factors and for setting the prediction model.

Results: Patient age, history of diabetes, functional status prior to stroke, and motivation were predictive factors of functional progress at 3 months poststroke. Motivation and functional status prior to stroke predicted functional progress at 6 months poststroke. By comparing the discriminant function values of the progressive and nonprogressive groups, functional improvement can be predicted.

Conclusion: Functional status prior to stroke and motivation are predictive of functional outcome at 3 months and 6 months poststroke. We have provided a formula that can be used to predict a patient's progress and then set treatment goals and programs accordingly.

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Keywords: functional improvement; prediction; stroke

1. Introduction

Cerebrovascular disease often leads to persistent disability in daily living activities. Patients and their families typically express concern about the potential for improvement of motor function. If the potential for improvement could be predicted early, strategies for best managing motor impairment could be developed, allowing for more cost effective care and benefiting patients and their families.

Age,[1−8] sex,[1,5,7−9] brain lesion site,[1,3,5,8] stroke type,[1,3,5,7,9] cognitive function,[7,8,10] functional status at admission,[4−7,11,12] stroke duration,[3,5,7] comorbidity,[7−9] hemineglect,[1,3,7] and aphasia[1,3,7] have all been considered as possible predictors of functional improvement in stroke patients. Regarding age, some studies suggest that it is not an important factor affecting functional progress[1,2,5−8] whereas others indicate that it is a significant predictor of functional improvement.[3,4] Sex,[1,5,7−9] brain lesion site,[1,3,5,8] stroke type,[1,3,5,7,9] and comorbidity[7−9] have consistently been found not to be important determinants of functional progress. Functional status at admission is a consistent, significant predictor of functional improvement.[4−7,11,12] However, conflicting findings have been reported for cognitive function,[7,8,10] stroke duration,[3,5,7] hemineglect,[1,3,7] and aphasia.[1,3,7]

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

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Most studies examining putative predictors of functional improvement in stroke patients are cross-sectional and measure functional outcomes only at the time of hospital discharge. This does not capture the real potential for improvement because a patient's recovery might last for 6 months or longer. In addition, most studies use the Functional Independence Measure (FIM) as a measurement tool. The FIM is reliable, valid, sensitive, and universal, but it can be problematic because ceiling effects in patients with mild disability can impede documentation of progress.

In the present study we sought to identify factors predictive of motor function improvement in stroke patients over an extended observational timeline spanning 6 months poststroke. We used four different functional measurement tools [Stroke Rehabilitation Assessment of Movement (STREAM), Berg Balance Scale (BBS), Timed Up & Go Test (TUG), and 6-Minute Walk Test (6MWT)] to avoid possible ceiling or floor effects, and we defined improvement in terms of clinical significance to document meaningful improvement. Our goal was to develop a prediction model for 3 months and 6 months poststroke.

2. Methods

2.1. Patients

Stroke patients were recruited from a university hospital in Taiwan. The inclusion criteria were: (1) hospitalized for stroke, which was diagnosed by computed tomography or magnetic resonance imaging; and (2) able to follow verbal commands or instructions. The exclusion criteria were: (1) recurrent stroke; (2) hospitalized for other diseases or rehabilitation; and (3) not able to complete the experimental procedures for any reason. A total of 53 patients out of 90 patients recruited met the inclusion criteria, gave informed consent, and participated in the study. This study was reviewed and approved by the Institutional Review Board of the National Yang-Ming University, Taipei, Taiwan.

2.2. Outcome measurements

STREAM is used to evaluate recovery of voluntary movement and basic mobility following stroke. It consists of 30 items divided into three subscales (upper limb movements, lower limb movements, and basic mobility) with a total score of 70 points.[13] STREAM has good inter- and intrarater reliability (correlation coefficients $\geq$ 0.96) and good internal consistency (Cronbach $\alpha \geq 0.98$).[14] Its correlation coefficients with the Fugl–Meyer Assessment scale and Barthel Index scale are 0.95 and 0.67, respectively, indicating good concurrent and convergent validity.[15] The smallest significant difference for the STREAM is 5.54[13]; therefore, a six-point increase from pretest to posttest is considered to be clinically significant improvement.

The BBS is the most widely used tool for assessing balance clinically. It contains 14 items related to functions of daily living, including dynamic and static balancing abilities as well as the ability to change positions. The total score is 56 points, with 0–4 points for each item. This scale has good inter- and intrarater reliability (correlation coefficient $\geq$ 0.97) and good internal consistency for stroke patients (Cronbach $\alpha \geq 0.97$).[16] With regard to its validity, it is highly correlated with motor function and performance in stroke patients.[17] The minimum important difference in the BBS is suggested to be six points.[18]

The TUG is used to evaluate basic functional mobility. Patients are seated in a chair, stand up, walk 3 m, turn around, return to the chair, and sit down. The time needed to complete these tasks is recorded. The TUG has good test–retest reliability, with an intraclass correlation coefficient of 0.96.[19] With regard to its validity, the coefficient of correlation with the Barthel Index scale is −0.78.[20] The 95% confidence interval value of the smallest real difference for the TUG test ranges between −3.75 seconds and 2.59 seconds[19]; thus, a reduction of 4 seconds or more in the time to complete the tasks is considered real progress.

The 6MWT is used to measure walking speed and endurance. Patients are instructed to walk back and forth at a self-selected pace along a 10-m walkway for 6 minutes and rests are taken as needed. The total distance traveled is recorded. The 6MWT has high test–retest reliability, with an intraclass correlation coefficient of 0.99.[19] The minimum important difference in the 6MWT is 19–22 m[21]; therefore, an increase of 22 m or more from a previous test is considered clinically significant improvement.

2.3. Experimental procedures

Basic data including sex, age, interval between stroke onset and initiation of physical therapy, stroke type (hemorrhagic or ischemic), history of diabetes, history of cardiovascular disease, functional status prior to stroke (independent or disabled), cognitive function (normal or mild, moderate, or severe dysfunction), motivation (good, ordinary, or poor), eating ability (independent or dependent), walking ability (independent or dependent), hemineglect, sensory function (normal or impaired), and brain lesion site (cerebral cortex, subcortical, or multiple) were collected from patients during an initial assessment. Functional status prior to stroke was classified as "independent" if the patient had been independent in activities of daily living according to the patient or family, and as "disabled" if the patient needed assistance with activities of daily living. Cognitive function was tested using a 10-item Short Portable Mental Status Questionnaire, in which: 0–2 incorrect answers indicates "normal function"; 3–4 incorrect answers indicates "mild dysfunction"; 5–7 incorrect answers indicates "moderate dysfunction"; and 8–10 incorrect answers indicates "severe dysfunction".[22] Motivation was classified as "good" if the patient actively engaged in activities; "ordinary" if the patient had to be urged to engage in activities; and "poor" if the patient was unwilling to engage in activities, according to the patient's family. Eating ability was classified as "independent" if the patient could feed himself or herself independently, and as "dependent" if the patient needed assistance. Walking ability was classified as "independent" if the patient could ambulate independently with or without assistive devices, and as "dependent" if the patient could ambulate only with assistance from others. Hemineglect was tested using the Symbol Cancellation Test and was indicated by asymmetrical symbol cancellation between two sides.[23] In terms of sensory function, proprioception (including motion sense and position sense) of the hip, knee, and ankle joints was assessed. Patients who responded correctly for all three joints were classified as having "normal" sensory function; otherwise, they were classified as "impaired".[24] Brain lesion site was categorized based on magnetic resonance imaging or computed tomography results.

All patients completed the STREAM and BBS assessments. Patients who were able to walk independently were assessed using the TUG Test. The 6MWT was used with patients who were able to complete it. Patients were given an initial assessment when first seen in the rehabilitation department and were assessed again at 3 months and 6 months poststroke. If the difference in any of the four outcomes measures between the initial assessment and 3-month poststroke assessment, or between the initial assessment and 6-month poststroke assessment, met the minimum important difference or smallest real difference as described earlier, a true improvement in motor function was determined. Based on these outcomes patients were assigned to two groups: the progressive group, which showed true improvement in at least one outcome measure, and the nonprogressive group, which showed true improvement in none of the outcome measures. We also recorded frequency of physical and occupational therapy 3 months and 6 months poststroke.

2.4. Data analysis

The data were analyzed using the SPSS version 12.0 (SPSS Inc., Chicago, IL, USA).

We used independent samples t tests to compare age, interval between stroke onset and initiation of physical therapy, and frequency of physical and occupational therapy in the progressive and nonprogressive groups. Chi-square tests were used to compare nominal variables (sex, stroke type, history of diabetes, history of cardiovascular disease, functional status prior to stroke, cognitive function, motivation, eating ability, walking ability, hemineglect, sensory function, and brain lesion site) between the two groups. In cases in which the expected numbers were below five in the cross-tables, Fisher's exact test was substituted for the Chi-square test. Statistical significance was set at $p < 0.05$.

Variables for which there were significant group differences were put into stepwise discriminant analysis to identify variables with discriminant ability. The discriminant function was established as the prediction model to predict potential for improvement of motor function at 3 months and 6 months poststroke.

3. Results

Fifty-three stroke patients were enrolled in this study. Of these, 44 completed the second and third assessments, and nine were dropped from the study because they declined to continue ($n = 4$), moved to another city ($n = 2$), experienced problems with traveling ($n = 1$), became ill ($n = 1$), or died ($n = 1$; Fig. 1). The mean age of the 44 participants (24 men and 20 women) was 68.7 years (range, 33–88 years). The mean duration from stroke onset to initiation of physical therapy was 10.4 days (range, 2–34 days). Ten participants had suffered ischemic stroke, and 34 suffered hemorrhagic stroke. Thirty-seven participants had a subcortical lesion, four had a cortical lesion, and three had multiple lesions. Table 1 presents the demographic and basic information of the participants. The results of the four outcome measurements are presented in Table 2.

3.1. Initial assessment to 3-month poststroke assessment

Thirty-five patients (79.5%) were assigned to the progressive group and nine (20.5%) were assigned to the nonprogressive group. The groups differed significantly in age ($p = 0.011$), history of diabetes ($p = 0.021$), history of cardiovascular disease ($p = 0.041$), functional status prior to stroke ($p = 0.038$), cognitive function ($p = 0.044$), motivation ($p = 0.003$), eating ability ($p = 0.003$), and sensory function ($p = 0.018$; Table 1).

The eight variables with significant group differences were put into the stepwise discriminant analysis. Motivation, functional status prior to stroke, history of diabetes, and age were selected based on the results of the stepwise discriminant analysis. In the progressive group, Fisher's linear discriminant function coefficient for age was 0.483, for history of diabetes was 4.884, for functional status prior to stroke was 32.065, and for motivation was 2.698. The constant was −34.740. The derived linear discriminant function in the progressive group was $Y_{progress,\ 3m} = -34.740 + 0.483 \times \text{age} + 4.884 \times \text{history of diabetes} + 32.065 \times \text{functional status prior to stroke} + 2.698 \times \text{motivation}$. Y indicates the discriminant value. In the nonprogressive group, Fisher's linear discriminant function coefficient for age was 0.576, for history of diabetes was 7.595, for functional status prior to stroke was 39.904, and for motivation was 4.837. The constant was −56.661. The derived linear discriminant function in the nonprogressive group was $Y_{nonprogress,\ 3m} = -56.661 + 0.576 \times \text{age} + 7.595 \times \text{history of diabetes} + 39.904 \times \text{functional status prior to stroke} + 4.837 \times \text{motivation}$ (Table 3). When all observation values were reclassified and verified by this derived linear discriminant function, 38 of 44 participants were predicted correctly. The correct distinction rate was 86.4% (Table 4).

3.2. Initial assessment to 6-month poststroke assessment

Only one of nine patients in the nonprogressive group at 3 months showed clinically significant progress at 6 months, and thus was assigned to the progressive group 6 months poststroke. Therefore, a total of 36 patients (81.8%) were assigned to the progressive group and eight patients (18.2%) were assigned to the nonprogressive group. There were significant differences in age ($p = 0.013$), history of diabetes ($p = 0.048$), functional status prior to stroke

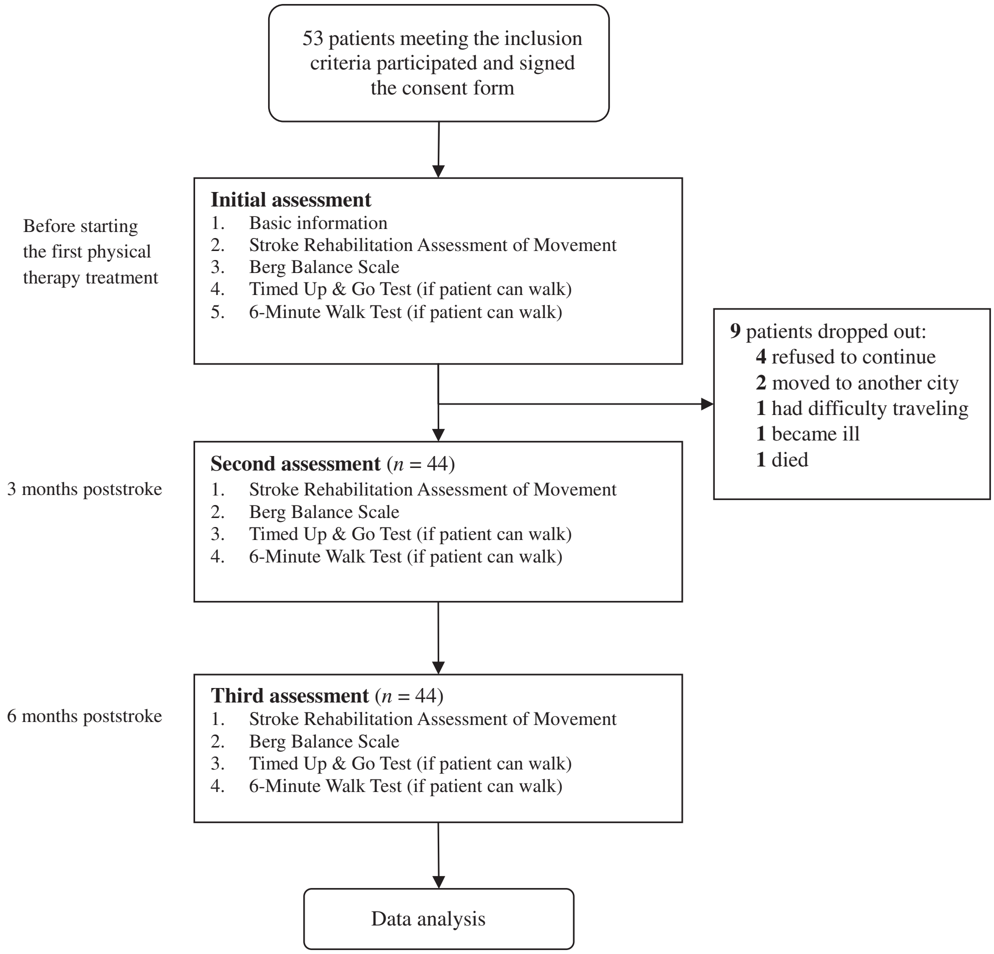

Fig. 1. Study protocol.

($p = 0.03$), motivation ($p = 0.004$), eating ability ($p = 0.014$), hemineglect ($p = 0.048$), and sensory function ($p = 0.009$; Table 1).

The seven variables with significant differences were put into the stepwise discriminant analysis. Only motivation and functional status prior to stroke were selected. In the progressive group, the Fisher's linear discriminant function coefficient for functional status prior to stroke was 28.712 and for motivation was 4.273. The constant was −17.346. The derived linear discriminant function in the progressive group was $Y_{\text{progress, 6m}} = -17.346 + 28.712 \times$ functional status prior to stroke $+ 4.273 \times$ motivation. Y indicates the discriminant value. In the nonprogressive group, the Fisher's linear discriminant function coefficient for functional status prior stroke was 36.129 and for motivation was 6.772. The constant was −31.480. The derived linear discriminant function in the nonprogressive group was $Y_{\text{nonprogress, 6m}} = -31.480 + 36.129 \times$ functional status prior to stroke $+ 6.772 \times$ motivation (Table 3). When all observation values were reclassified and verified by this calculation, 39/44 patients were predicted correctly. The correct distinction rate was 88.6 % (Table 4).

4. Discussion

We used clinically significant differences to document factors predicting functional improvement at 3 months and 6 months poststroke. According to our results, motivation, functional status prior to stroke, history of diabetes, and age are predictive of motor function improvement 3 months poststroke. The correct distinction rate was 86.4%. We also noted that motivation and functional independence prior to stroke might be predicting factors for motor function improvement at 6 months poststroke. The correct distinction rate was 88.6%.

To our knowledge, no other studies have examined the influence of motivation on functional progress in stroke patients. In this study, we divided motivation into three levels: "good", "ordinary", and "poor". We found that more motivated patients had a higher likelihood of being assigned to the progressive group.

We found that functional status prior to stroke is an important predictive factor of functional progress at 3 months and 6 months poststroke. Of the 44 patients in this study, only two were disabled prior to stroke and both were assigned to the

Table 1
Demographic information of the participants ($n = 44$).

Clinical variable	Basic information ($n = 44$)		Differences between two groups 3 mo poststroke			Differences between two groups 6 mo poststroke		
	Distribution	Range	Progressive group ($n = 35$)	Nonprogressive group ($n = 9$)	p	Progressive group ($n = 36$)	Nonprogressive group ($n = 8$)	p
Age (y)	68.7 (13.3)	33−88	66.2 (13.1)	78.6 (9.5)	0.011*	66.4 (12.9)	79.1 (10.1)	0.013*
Interval between stroke onset and initiation of physical therapy (d)	10.4 (6.2)	2−34	9.8 (5.5)	12.6 (8.4)	0.240	9.8 (5.4)	12.9 (8.9)	0.210
Sex (female/male)	24/20		20/15	4/5	0.710	21/15	3/5	0.436
Stroke type (ischemic/hemorrhagic)	10/34		8/27	2/7	1.00	9/27	1/7	0.659
History of diabetes (yes/no)	18/26		11/24	7/2	0.021*	12/24	6/2	0.048*
History of cardiovascular disease (yes/no)	31/13		22/13	9/0	0.041*	23/13	8/0	0.082
Functional status prior to stroke (independent/disabled)	42/2		35/0	7/2	0.038*	36/0	6/2	0.030*
Cognitive function (normal/mild dysfunction/moderate dysfunction/ severe dysfunction)	28/7/5/4		25/5/2/3	3/2/3/1	0.044*	25/5/3/3	3/2/2/1	0.165
Motivation (good/ordinary/poor)	28/12/4		26/8/1	2/4/3	0.003*	26/9/1	2/3/3	0.004*
Eating ability (independent/dependent)	25/19		24/11	1/8	0.003*	24/12	1/7	0.014*
Walking ability (independent/dependent)	11/33		10/25ssss	1/8	0.411	10/26	1/7	0.656
Hemineglect (normal/hemineglect/ untestable)	30/6/8		26/3/6	4/3/2	0.118	27/3/6	3/3/2	0.048*
Sensory function (normal/impaired)	34/10		30/5	4/5	0.018*	31/5	3/5	0.009*
Brain lesion site (cerebral cortex/subcortical/ multiple)	4/37/3		3/30/2	1/7/1	0.607	3/31/2	1/6/1	0.376
Frequency of physical therapy within 3 mo of stroke (times)	27.4 (19.6)	3−67	27.7 (18.8)	26 (23.9)	0.815			
Frequency of occupational therapy within 3 mo of stroke (times)	25.3 (18.9)	2−63	25.2 (17.9)	25.9 (23.9)	0.921			
Frequency of physical therapy within 6 mo of stroke (times)	44.9 (36.8)	3−133				42.9 (34.5)	54.3 (47.2)	0.436
Frequency of occupational therapy within 6 months of stroke (times)	40.2 (35.3)	2−128				37.1 (32.1)	54.1 (47.3)	0.223

Data are presented as mean (standard deviation) or frequency.
* $p < 0.05$.

nonprogressive group. It is possible that disability prior to stroke may affect potential for progress after stroke. However, additional studies would be necessary to confirm this proposition.

Our findings with regard to age are not consistent with those of previous studies. Many studies have concluded that age is not an important factor in functional progress following stroke.[1,2,5−8] It has been suggested that age is not related to functional progress when confounding factors are controlled, even though older patients tend to receive lower scores on the FIM. In our study the nonprogressive group was significantly older than the progressive group. In other words, older patients were more likely to be assigned to the nonprogressive group 3 months poststroke. The difference between our results and those of others may be related to differing definitions of functional improvement. However, we also found that age was no longer an important predictive factor for functional improvement at 6 months poststroke. The influence of history of diabetes was similar to that of age.

Using stepwise discriminant analysis, we found that walking ability, eating ability, and sensory function were not important predictors of functional progress. Liaw et al[8] found that eating ability and walking ability were predictive of improvement in the FIM score at 3 months poststroke. Lin et al[7] suggest that sensory impairment is an important predictor of functional progress in stroke patients during their hospitalization. In that study, FIM was the only outcome measurement, whereas in our study we used STREAM, BBS, TUG, and 6MWT to measure all aspects of motor function that are of concern to physical therapists, and we used clinical significance as an indicator of progress. When predicting functional improvement in stroke patients, the above-mentioned studies are useful if the goal is to predict progress in daily living function, whereas our study is useful if the goal is to predict clinically significant progress in motor function in the first 6 months poststroke.

We expected that frequency of physical or occupational therapy would be predictive of functional progress; however, we found no significant differences between the progressive and nonprogressive groups in this measure. Patients in the nonprogressive group received as many treatments as patients in the progressive group. However, in this study, the treatment programs and durations of physical and occupational therapy were not controlled. Therefore, only the frequency of physical therapy and occupational therapy may not be able to predict the functional improvement.

Table 2
The results of the four outcome measurements.

Outcome measurement		Total distribution	3 mo poststroke		6 mo post stroke	
			Progressive group ($n = 35$)	Nonprogressive group ($n = 9$)	Progressive group ($n = 36$)	Nonprogressive group ($n = 8$)
STREAM	Initial assessment ($n = 44$)	37.9 ± 24.3 ($n = 44$)	43.0 ± 21.7 ($n = 35$)	17.9 ± 24.8 ($n = 9$)	43.4 ± 21.5 ($n = 36$)	13.0 ± 21.3 ($n = 8$)
	Second assessment ($n = 44$)	50.6 ± 24.8 ($n = 44$)	58.8 ± 17.1 ($n = 35$)	18.9 ± 25.1 ($n = 9$)	58.7 ± 16.9 ($n = 36$)	14.3 ± 22.3 ($n = 8$)
	Third assessment ($n = 44$)	52.4 ± 25.5 ($n = 44$)	60.9 ± 16.6 ($n = 35$)	19.2 ± 27.5 ($n = 9$)	61.1 ± 16.4 ($n = 36$)	13.4 ± 22.7 ($n = 8$)
BBS	Initial assessment ($n = 44$)	21.3 ± 20.6 ($n = 44$)	24.5 ± 20.5 ($n = 35$)	8.4 ± 16.6 ($n = 9$)	24.5 ± 20.2 ($n = 36$)	6.6 ± 16.8 ($n = 8$)
	Second assessment ($n = 44$)	36.6 ± 21.3 ($n = 44$)	43.7 ± 15.8 ($n = 35$)	9.0 ± 17.0 ($n = 9$)	43.2 ± 15.9 ($n = 36$)	7.0 ± 17.0 ($n = 8$)
	Third assessment ($n = 44$)	39.0 ± 21.0 ($n = 44$)	46.2 ± 14.4 ($n = 35$)	11.0 ± 19.5 ($n = 9$)	46.1 ± 14.2 ($n = 36$)	7.4 ± 17.3 ($n = 8$)
TUG (s)	Initial assessment ($n = 23$)	43.5 ± 37.5 ($n = 23$)	44.7 ± 38.9 ($n = 21$)	30.9 ± 20.4 ($n = 2$)	44.7 ± 37.9 ($n = 22$)	16.5 ($n = 1$)
	Second assessment ($n = 34$)	22.5 ± 19.6 ($n = 34$)	22.1 ± 19.8 ($n = 32$)	28.5 ± 19.1 ($n = 2$)	22.7 ± 19.8 ($n = 33$)	15.0 ($n = 1$)
	Third assessment ($n = 34$)	18.6 ± 14.7 ($n = 34$)	18.7 ± 15.1 ($n = 32$)	17.6 ± 5.0 ($n = 2$)	18.7 ± 14.9 ($n = 33$)	14.0 ($n = 1$)
6MWT (m)	Initial assessment ($n = 23$)	149.8 ± 124.4 ($n = 23$)	147.2 ± 129.3 ($n = 21$)	177.5 ± 67.2 ($n = 2$)	146.4 ± 126.2 ($n = 22$)	225 ($n = 1$)
	Second assessment ($n = 34$)	214.1 ± 128.9 ($n = 34$)	218.8 ± 130.2 ($n = 32$)	138.0 ± 103.2 ($n = 2$)	214.2 ± 130.9 ($n = 33$)	211 ($n = 1$)
	Third assessment ($n = 34$)	242.5 ± 127.9 ($n = 34$)	246.3 ± 130.6 ($n = 32$)	180.5 ± 54.4 ($n = 2$)	243.2 ± 129.8 ($n = 33$)	219 ($n = 1$)

Data are presented as mean ± standard deviation.
6MWT = 6-Minute Walk Test; BBS = Berg Balance Scale; STREAM = Stroke Rehabilitation Assessment of Movement; TUG = Timed Up & Go Test.

Many studies report that the National Institutes of Health stroke scale is a good indicator of stroke outcome,[25–27] but whether it is also a good predictor of motor function improvement is still unclear. The severity of stroke patients in our study was not explored. It is better to include acute stroke severity scale, the National Institutes of Health stroke scale, for analysis in future studies.

We used stepwise discriminant analysis to identify variables with discriminant ability, and to establish the predictive potential of the discriminant variables for improvement of motor function at 3 months and 6 months poststroke. The discriminant value can be calculated manually. When a patient is first seen in the rehabilitation department, his or her scores on the predicting factor measures can be put into the linear discriminant function formula to calculate the discriminant value of each group ($Y_{progress}$ and $Y_{nonprogress}$). If $Y_{progress} > Y_{nonprogress}$, the prediction is that the patient will exhibit clinically significant improvement in at least one of the four measures. Using this metric we achieved an impressive correct distinction rate (86.4% and 88.6% for 3 months and 6 months poststroke, respectively), indicating that the potential for motor function improvement at 3 months poststroke can be predicted based on age, history of diabetes, functional status prior to stroke, and motivation, and the potential for motor function improvement at 6 months poststroke can be predicted by functional status prior to stroke and motivation. We used the coefficients of a standardized typical discriminant function to weigh the influence of the variables. Our results indicate that the most influential variable at 3 months poststroke is functional status prior to stroke (0.620), followed by history of diabetes (0.519), motivation (0.508), and age (0.477; Table 2). At 6 months poststroke, the most influential variable is motivation (0.744), followed by functional status prior to stroke (0.710; Table 2). Among these predictive factors, motivation is the only one that can be enhanced; hence, it is imperative to develop strategies to improve patient motivation poststroke.

4.1. Limitations of the study

Due to the limited number of participants in the study, we were not able to analyze further the four outcome measurements individually. Therefore, we were able to predict only the likelihood of improvement in at least one of the four outcome measurements at 3 months and 6 months poststroke, and not the likelihood of improvement in the outcome measurements individually. Furthermore, because the heterogeneity of stroke disease and our participants were only selected from a university hospital, and the types of stroke in this study are uneven (10 ischemic stroke, 34 hemorrhagic stroke), it is possible that our results may not be generalizable to all stroke patients. The small enrollment patient number and the largely different patient number between progressive and nonprogressive groups are the weaknesses of our study. It is likely that the test items for the three visits are too sophisticated to recruit patients. Finally, the lack of stroke severity at admission for analysis should be noted. Future study should address the above-

Table 3
Discriminant function coefficients for 3 months and 6 months poststroke.

	Variable	Typical discriminant function coefficients	Fisher's linear discriminant function coefficients	
		Standardized coefficients	Progressive group	Nonprogressive group
3 mo poststroke	Age	0.477	0.483	0.576
	History of diabetes (yes: 1; no: 0)	0.519	4.884	7.595
	Functional status prior to stroke (independent: 1; disabled: 2)	0.620	32.065	39.904
	Motivation (good: 1; ordinary: 2; poor: 3)	0.508	2.698	4.837
	Constant		−34.740	−56.661
6 mo poststroke	Functional status prior to stroke (independent: 1; disabled: 2)	0.710	28.712	36.129
	Motivation (good: 1; ordinary: 2; poor: 3)	0.744	4.273	6.772
	Constant		−17.346	−31.480

Table 4
Results analysis for 3 months and 6 months poststroke.

		Group	Predicted group assignment		Total	Correct distinction rate
			Nonprogressive group	Progressive group		
3 mo poststroke	Actual group	Nonprogressive group	6 (66.7)	3 (33.3)	9 (100)	86.4% = (6 + 32)/44
		Progressive group	3 (8.6)	32 (91.4)	35 (100)	
6 mo poststroke	Actual group	Nonprogressive group	4 (50)	4 (50)	8 (100)	88.6% = (4 + 35)/44
		Progressive group	1 (2.8)s	35 (97.2)	36 (100)	

Data are presented as *n* (%) unless otherwise indicated.

mentioned limitations for further validation and clinical applications.

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