ORIGINAL ARTICLE

The Impact of Timing and Dose of Rehabilitation Delivery on Functional Recovery of Stroke Patients

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Background: To investigate the impact of both timing and dose of rehabilitation delivery on the functional recovery of stroke patients.

Methods: From chart review, we included 76 patients who were admitted to a regional hospital for first-ever stroke, and who had received multidisciplinary rehabilitation programs including physical therapy (PT) and occupational therapy (OT) at the inpatient department, and continuous rehabilitation therapy at the outpatient department for at least 3 months. The collected data included age, sex, type of stroke (hemorrhage/infarction), onset of stroke, initial motor status by Brunnstrom's motor recovery stages, time to rehabilitation intervention (from onset of stroke), length of stay, existence of aphasia, craniotomy (yes/no), and total units of rehabilitation. Main outcome measures were serial Barthel Index (BI) at initial assessment, 1 month, 3 months, 6 months, and 1 year post-stroke.

Results: Age was inversely correlated with BI and BI improvement at 3 months and 6 months post-stroke. Rehabilitation intervention time from onset was negatively correlated with BI improvement at 1 month and 1 year, and with BI at 1 month, 3 months, 6 months, and 1 year post-stroke. The total units of inpatient PT and/or OT were positively correlated with BI improvement at 1 month, 3 months, and 6 months post-stroke. The total units of PT and/or OT were positively correlated with BI improvement at 3 months and 6 months post-stroke. And the initial BI was positively correlated with BI at 1 month, 3 months, and 6 months post-stroke. The total units of OT can significantly predict BI improvement at 3 months and 6 months post-stroke, while the initial BI capacity can significantly predict BI status at 1 month, 3 months, and 6 months post-stroke.

Conclusion: There is a dose-dependent effect of rehabilitation on functional improvement of stroke patients for the first 6 months post-stroke, and earlier delivery of rehabilitation has lasting effects on the functional recovery of stroke patients up to 1 year. [*J Chin Med Assoc* 2009;72(5):257–264]

Key Words: Barthel Index, dose, functional recovery, stroke rehabilitation, timing

Introduction

Early initiation of rehabilitation for stroke is the gold standard for post-stroke care worldwide,[1,2] but the influence of the timing and dose of rehabilitation delivery on the long-term functional recovery of stroke patients have yet to be addressed.[3,4] Current investigations of rehabilitation intervention are mostly focused on the first 6 months after stroke. Previous studies have reported that earlier intervention of inpatient rehabilitation improved activities of daily living (ADL) at discharge[5–7] and 6 months post-stroke.[8] It is uncertain if the effect of early rehabilitation intervention on stroke rehabilitation can last longer than 6 months. In 2005, Jette et al[9] found that higher rehabilitation intensity in skilled nursing facilities was associated with better functional improvement at discharge for stroke patients. However, they did not take into account the impact of after-discharge rehabilitation dose and duration. Delivery of timely and cost-effective stroke rehabilitation should be the goal of all 3 parties—medical professionals, patients, and payment policy makers.[10] To reach this goal, the essential question to be answered is: "In the long run, are therapies

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the earlier the better and/or the more the better?" This study was conducted to answer this question. We hypothesized that earlier intervention can improve stroke patients' long-term functional recovery, and that there is a "dose-dependent effect" of stroke rehabilitation. We also wanted to identify other predictors for the rehabilitation outcomes of patients with first-ever stroke.

Methods

Based on a retrospective review of medical charts, we included patients who were admitted to a regional hospital between February 2006 and February 2008 for first-ever stroke, and who had received multidisciplinary rehabilitation programs including physical therapy (PT) and occupational therapy (OT) at the inpatient department, and continuous rehabilitation therapy at the outpatient department for at least 3 months. The content of PT and OT were under the regulations of the *National Health Insurance Payment* for rehabilitation therapy, which consisted of 30-minute complicated therapies. The PT and OT items included both function-focus activities (e.g. ambulation training for PT, ADL training for OT) and impairment-focus activities (e.g. facilitation technique for PT, perceptual-motor training for OT). The units of PT and/or OT were defined as the total numbers of PT and/or OT attended within a certain period of time. We excluded stroke patients who were admitted under the diagnosis of recurrent stroke, those who were non-ambulatory prior to stroke, those with life expectancy <6 months due to malignancy, and those who had interrupted the rehabilitation.

The collected data included age, sex, type of stroke (hemorrhage/infarction), onset of stroke, initial motor status according to Brunnstrom's motor recovery stage (BMRS), rehabilitation intervention from onset of stroke, length of stay (LOS), existence of aphasia, craniotomy (yes/no), total units of inpatient rehabilitation including PT and OT, and total units of outpatient rehabilitation including PT and OT at time interval of 1 month, 3 months, 6 months and 1 year, depending on the time when rehabilitation therapy was terminated either because of full functional recovery or self-withdrawal of patients.

The study protocol was approved by the hospital's institutional review board.

Main outcomes measures

For the ADL outcomes, we collected Barthel Index (BI), which is the most commonly used tool in Taiwan, from the medical records. As routine therapy, we scored BI for 2 qualifiers: performance and capacity, which are based on the qualifier used in the *WHO International Classification of Functioning, Disability and Health* activity checklist.[11] The former is the actual performance of stroke patients at their residence and recorded according to the patient or main caregivers' statement, the latter is the ability of stroke patients observed at rehabilitation treatment and recorded by therapists. We collected initial BI (performance/capacity) at first rehabilitation intervention as the baseline data. We also collected 1-month BI, 3-month BI, 6-month BI, and 1-year BI, which allowed for a variance of plus or minus 1 week from the specified data collection time. This caused some timely data to be missing from the review of charts.

We used BI discrepancy, which is the value of BI-capacity subtracted by BI-performance, as an indicator of contextual factors to be overcome for the best full functioning of ADL. In addition, we used the value of BI at 1 month subtracted by BI at first intervention as the improvement in ADL at 1 month, the value of BI at 3 months subtracted by BI at first intervention as the improvement in ADL functioning at 3 months, and so forth for 6 months and 1 year.

Statistical analysis

We used SPSS version 15.0 (SPSS Inc., Chicago, IL, USA) for Windows for data analysis. Pearson correlates were performed to establish the relationship between BI/BI improvement and all the independent variables including age, sex, stroke type, initial motor status by BMRS, rehabilitation intervention from onset of stroke, LOS, existence of aphasia, craniotomy (yes/no), total units of inpatient rehabilitation including PT and OT, total units of outpatient rehabilitation including PT and OT at time intervals of 1 month, 3 months, 6 months, and 1 year, and BI or BI improvement at 1 month, 3 months, 6 months, and 1 year post-stroke. Stepwise linear regression was used to build a predictive model for BI/BI improvement by the aforementioned independent variables.

Results

Descriptive statistics

There were 76 patients with first-ever stroke included in this study (Figure 1). They consisted of 39 men and 37 women; mean age was 59.9 ± 13.8 years. The mean initial BI in performance, capacity, and discrepancies were 21.4 ± 21.2, 29.1 ± 25.3, and 7.8 ± 9.0, respectively. The mean period of rehabilitation intervention

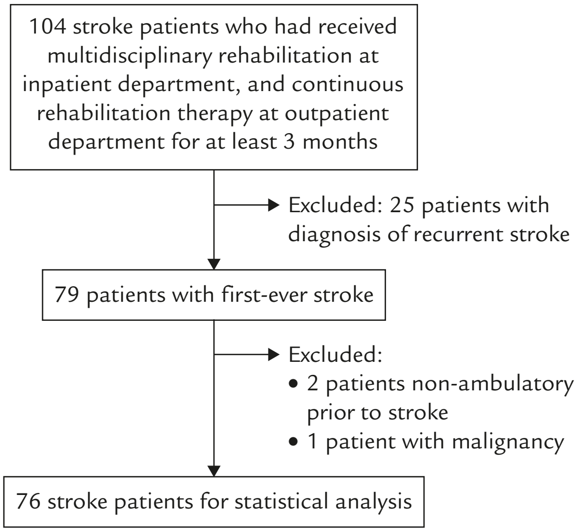

Figure 1. Patient inclusion/exclusion flowchart.

from stroke onset was 7.7 ± 4.6 days. The mean LOS was 14.8 ± 6.5 days (Table 1).

Univariate correlates to BI at 1 month, 3 months, 6 months, and 1 year from stroke onset

Rehabilitation intervention time from onset, existence of aphasia, LOS, and having had craniotomy were negatively correlated with BI at 1 month ($p < 0.05$). Infarction-type stroke, BMRS-proximal upper limb, distal upper limb, and lower limb, and initial BI including performance, capacity, and discrepancy were positively correlated with BI at 1 month ($p < 0.05$).

Age and rehabilitation intervention time from onset were negatively correlated with BI at 3 months ($p < 0.05$). BMRS-proximal upper limb, distal upper limb, and lower limb, and initial BI including performance, capacity, and discrepancy were positively correlated with BI at 3 months ($p < 0.05$).

Age, existence of aphasia, and rehabilitation intervention time from onset were negatively correlated with BI at 6 months ($p < 0.05$). BMRS-proximal upper limb, distal upper limb, and lower limb, and initial BI including performance, capacity and discrepancy, and total units of OT at 6 months were positively correlated with BI at 6 months ($p < 0.05$).

Rehabilitation intervention time from onset was negatively correlated with BI at 1 year ($p < 0.05$) (Table 2).

Univariate correlates to BI improvement at 1 month, 3 months, 6 months, and 1 year from stroke onset

Rehabilitation intervention time from onset was negatively correlated with BI improvement at 1 month ($p < 0.05$). Initial BI-discrepancy, total units of inpatient OT, total units of inpatient PT plus OT, and total units of OT at 1 month were positively correlated with BI improvement at 1 month ($p < 0.05$).

Age and infarction-type stroke were negatively correlated with BI improvement at 3 months ($p < 0.05$). LOS, total units of inpatient PT, inpatient OT, inpatient PT plus OT, PT at 3 months, OT at 3 months, and PT plus OT at 3 months were positively correlated with BI improvement at 3 months ($p < 0.05$).

Age was negatively correlated with BI improvement at 6 months ($p < 0.05$). Total units of inpatient OT, inpatient PT plus OT, PT at 6 months, OT at 6 months, and PT plus OT at 6 months were positively correlated with BI improvement at 6 months ($p < 0.05$).

Rehabilitation intervention time from onset was negatively correlated with BI improvement at 1 year ($p < 0.05$) (Table 2).

Predictors of BI at 1 month, 3 months, 6 months, and 1 year post-stroke by stepwise linear regression analysis

The significant predictors for BI at 1 month post-stroke were initial BI capacity and earlier rehabilitation intervention (adjusted $r^2 = 0.723$). The significant predictors for BI at 3 months were initial BI capacity, total units of OT at 3 months, younger age, earlier rehabilitation intervention, hemorrhagic-type stroke, BMRS-proximal upper limb, and LOS (adjusted $r^2 = 0.744$). The significant predictors for BI at 6 months were initial BI capacity, younger age, earlier rehabilitation intervention, BMRS-proximal upper limb, total units of inpatient PT, hemorrhagic-type stroke, and total units of PT plus OT at 6 months (adjusted $r^2 = 0.735$). The significant predictors for BI at 1 year were earlier rehabilitation intervention and hemorrhagic-type stroke (adjusted $r^2 = 0.601$) (Table 3).

Predictors of BI improvement at 1 month, 3 months, 6 months, and 1 year post-stroke by stepwise linear regression analysis

The significant predictors for BI improvement at 1 month were initial BI discrepancy and total units of OT at 1 month (adjusted $r^2 = 0.135$). The significant predictors for BI improvement at 3 months were total units of OT at 3 months, hemorrhagic-type stroke, earlier rehabilitation intervention, younger age, initial BI performance and discrepancy (adjusted $r^2 = 0.529$). The significant predictors for BI improvement at 6 months were total units of OT at 6 months, younger age, BMRS-proximal upper limb, lower initial BI performance, earlier rehabilitation intervention time, and total units of inpatient PT (adjusted $r^2 = 0.589$).

Table 1. Descriptive statistics for patient characteristics, serial Barthel Index and units of rehabilitation at different time points

	n (%)	Mean ± SD	Minimum	Maximum
Sex				
Female	39 (51.3)			
Male	37 (48.7)			
Stroke type				
Hemorrhage	26 (34.2)			
Infarction	50 (65.8)			
Aphasia				
Yes	19 (25.0)			
No	57 (75.0)			
Craniotomy				
Yes	19 (25.0)			
No	57 (75.0)			
Initial BI				
Performance	76	21.4 ± 21.2	0	80
Capacity	76	29.1 ± 25.3	0	90
Discrepancy	76	7.8 ± 9.0	0	40
Age (yr)	76	60.0 ± 13.9	28	84
REH intervention from onset (d)	76	7.7 ± 4.6	0	27
Length of stay (d)	76	14.8 ± 6.5	5	33
BI at 1 mo post-stroke	73	38.2 ± 27.7	0	100
BI at 3 mo post-stroke	62	64.0 ± 29.0	0	100
BI at 6 mo post-stroke	47	68.1 ± 29.1	0	100
BI at 1 yr post-stroke	21	64.5 ± 30.1	0	95
BMRS				
Proximal upper limb	76	2.6 ± 1.4	1	5
Distal upper limb	76	2.4 ± 1.5	1	5
Lower limb	76	3.0 ± 1.6	1	5
Inpatient				
PT#	76	4.8 ± 2.8	1	16
OT#	76	3.3 ± 2.2	1	13
1 mo post-stroke				
PT#	76	9.6 ± 3.3	3	20
OT#	76	7.8 ± 2.6	1	13
3 mo post-stroke				
PT#	76	26.4 ± 8.7	7	55
OT#	76	23.9 ± 6.5	7	37
6 mo post-stroke				
PT#	48	51.2 ± 13.8	28	105
OT#	48	47.7 ± 11.2	29	69
1 yr post-stroke				
PT#	21	105.0 ± 26.3	55	153
OT#	21	96.2 ± 26.0	51	135

SD = standard deviation; BI = Barthel Index; REH = rehabilitation; BMRS = Brunnstrom's motor recovery stages; PT# = units of physical therapy; OT# = units of occupational therapy.

The significant predictors for BI improvement at 1 year were earlier rehabilitation intervention, hemorrhagic-type stroke, and lower initial BI performance (adjusted $r^2 = 0.552$) (Table 4).

Discussion

This study found that earlier rehabilitation intervention in acute stroke care was correlated with better

Table 2. Correlation coefficient between potential predictors and Barthel Index/Barthel Index improvement

	BI				BI improvement			
	1 mo (*n* = 73)	3 mo (*n* = 62)	6 mo (*n* = 47)	1 yr (*n* = 21)	1 mo (*n* = 73)	3 mo (*n* = 62)	6 mo (*n* = 47)	1 yr (*n* = 21)
	r	*r*	*r*	*r*	*r*	*r*	*r*	*r*
Age	–0.16	–0.39*	–0.44*	–0.41	–0.15	–0.33*	–0.41*	–0.43
Male	0.09	0.13	0.07	–0.05	0.02	0.04	0.05	0.03
Infarction-type stroke	0.27†	–0.03	0.03	–0.13	0.01	–0.34*	–0.29	–0.246
Craniotomy	–0.32*	–0.16	–0.27	–0.24	–0.09	0.08	0.05	–0.07
Aphasia	–0.31*	–0.19	–0.41*	–0.31	–0.04	0.08	–0.11	–0.24
REH intervention	–0.52‡	–0.51‡	–0.56‡	–0.67*	–0.27†	–0.19	–0.27	–0.47†
Length of stay	–0.4‡	–0.19	–0.26	–0.14	–0.03	0.27†	0.21	0.13
BMRS								
Proximal upper limb	0.43‡	0.44‡	0.42*	0.36	0.14	0.12	0.21	0.36
Distal upper limb	0.45‡	0.45‡	0.37*	0.21	0.14	0.11	0.13	0.18
Lower limb	0.52‡	0.52‡	0.54‡	0.39	0.09	0.08	0.17	0.32
Initial BI								
Performance	0.84‡	0.63‡	0.5‡	0.29	0.12	–0.17	–0.21	–0.15
Capacity	0.84‡	0.67‡	0.56‡	0.3	0.22	–0.06	–0.09	–0.11
Discrepancy	0.4‡	0.37*	0.37*	0.2	0.32*	0.23	0.27	0.03
Inpatient								
PT#	–0.14	–0.07	0.1	0.14	0.17	0.3†	0.41*	0.32
OT#	0.007	0.05	0.07	0.23	0.25†	0.31†	0.308†	0.3
PT# + OT#	–0.09	–0.02	0.09	0.2	0.24†	0.33*	0.39*	0.34
1 mo post-stroke								
PT#	0.05				0.16			
OT#	0.23				0.26†			
PT# + OT#	0.14				0.23			
3 mo post-stroke								
PT#		0.008				0.3†		
OT#		0.2				0.41‡		
PT# + OT#		0.08				0.36*		
6 mo post-stroke								
PT#			0.11				0.31†	
OT#			0.36*				0.47‡	
PT# + OT#			0.24				0.41*	
1 yr post-stroke								
PT#				0.18				0.19
OT#				0.35				0.33
PT# + OT#				0.27				0.27

$^*p < 0.01$; $^\dagger p < 0.05$; $^\ddagger p < 0.001$. BI = Barthel Index; r = correlation coefficient; REH = rehabilitation; BMRS = Brunnstrom's motor recovery stages; PT# = units of physical therapy; OT# = units of occupational therapy.

functioning of daily activities at 1 month, 3 months, 6 months, and 1 year post-stroke, as well as greater improvement of daily activities at 1 month and 1 year post-stroke. It was also a significant predictor of BI and BI improvement at 3 months, 6 months, and 1 year post-stroke. These results reiterate the importance of early initiation of stroke rehabilitation and demonstrate the lasting effects of early intervention up to 1 year post-stroke.

Table 3. Multivariate analysis by stepwise linear regression for predictors of Barthel Index at various time points

Variables	β	SE
BI at 1 mo (*n* = 73)		
Initial BI-capacity	0.83	0.1*
REH intervention from onset	–0.94	0.4†
BI at 3 mo (*n* = 62)		
Initial BI-capacity	0.58	0.1*
OT# at 3 mo	0.87	0.3*
Age	–0.67	0.2*
REH intervention from onset	–2.45	0.5*
Infarction-type stroke	–13.19	5.6†
BMRS-proximal upper limb	3.62	1.6†
Length of stay	0.78	0.4†
BI at 6 mo (*n* = 47)		
Initial BI-capacity	0.58	0.1*
Age	–0.62	0.2*
REH intervention from onset	–2.49	0.7*
BMRS-proximal upper limb	7.14	1.9‡
Inpatient PT#	2.01	0.9†
Infarction-type stroke	–15.05	6.3†
PT# + OT# at 6 mo	0.24	0.1†
BI at 1 yr (*n* = 21)		
REH intervention from onset	–4.98	0.9*
Infarction-type stroke	–29.01	9.3*

**p* < 0.01; †*p* < 0.05; ‡*p* < 0.001. *SE = standard error; BI = Barthel Index; REH = rehabilitation; OT# = units of occupational therapy; BMRS = Brunnstrom's motor recovery stages; PT# = units of physical therapy.*

Table 4. Multivariate analysis by stepwise linear regression for predictors of Barthel Index improvement at various time points

Variables	β	SE
BI improvement at 1 mo (*n* = 73)		
Initial BI-discrepancy	0.51	0.2*
OT# at 1 mo	1.39	0.6†
BI improvement at 3 mo (*n* = 62)		
OT# at 3 mo	0.75	0.3†
Infarction-type stroke	–20.38	5.2*
REH intervention from onset	–2.44	0.5*
Age	–0.61	0.2*
Initial BI-performance	–0.40	0.1‡
Initial BI-discrepancy	0.70	0.2*
BI improvement at 6 mo (*n* = 47)		
OT# at 6 mo	0.53	0.3†
Age	–0.80	0.2*
BMRS-proximal upper limb	8.28	2.1*
Initial BI-performance	–0.56	0.2‡
REH intervention from onset	–1.87	0.7†
Inpatient PT#	2.21	1.0†
BI improvement at 1 yr (*n* = 21)		
REH intervention from onset	–5.05	1.0*
Infarction-type stroke	–28.91	9.6*
Initial BI-performance	–1.06	0.4†

**p* < 0.01; †*p* < 0.05; ‡*p* < 0.00. *SE = standard error; BI = Barthel Index; OT# = units of occupational therapy; REH = rehabilitation; BMRS = Brunnstrom's motor recovery stages; PT# = units of physical therapy.*

Regarding the dose-dependent effect of rehabilitation on the functional recovery of stroke patients, this study showed that the total units of rehabilitation correlated well with BI improvement at 1, 3 and 6 months from stroke onset but not at 1 year from onset, which suggests that there is a dose-dependent effect of rehabilitation within the first 6 months from stroke onset. This finding is compatible with the concept of "golden periods" of stroke rehabilitation for 6 months from onset, implying the virtue of rehabilitation training effect, possibly by directed practice or relearning process, on improvement of functional activities. Moreover, this correlation was stronger for OT than for PT on BI improvement during 1–6 months and 3-month BI status. It coincides with the research of Bode et al[12] in 2004, which demonstrated that greater than expected gains in self-care were predicted by more intensive function-focused OT. This result reflects the task-specific training effects of OT on daily activity performance.

Also, we can see that the strongest predictor for BI performance at 3 and 6 months is the initial BI capacity, whereas for BI improvement it is the total units of OT. The former indicates that initial functional capability can predict final functional status, which was shown by Pettersen et al[13] in 2002. The latter reveals the true value of rehabilitation in improving ADL functioning despite stroke patients' original daily activity performance. From the prospective view of care providers, the initial functional ability of stroke patients cannot be changed as it has already occurred, but the timing and frequency of rehabilitation delivery to facilitate functional improvements can be worked on. Our results show that intense rehabilitation delivery during the golden period does in fact hasten the functional gain of stroke patients. Therefore, it is of paramount importance to enhance the functional recovery of stroke patients within the first 6 months by intense rehabilitation, so that stroke patients can regain their performance of daily activities earlier.

This study also demonstrated the negative impact of age on functional recovery of stroke patients, which was previously shown by Pan et al[14] and Tur et al.[15] As to the impact of initial motor impairment, we can see that better baseline BMRS of the proximal upper limb can significantly predict greater BI at 3 and 6 months post-stroke and BI improvement at 6 months. This result is similar to that of the study of Lin et al[16] in 2000, which revealed that arm motor recovery stage could significantly predict rehabilitation efficiency and effectiveness. Since most of the measurement items used in the BI are related to self-care abilities, which to a large extent rely on upper limb motor control, BMRS of the upper limb is more influential than BMRS of the lower limb on the recovery of ADL performance.

It should be noted that the patient population of the initial evaluation data was not the same at 6 months or 1 year. Once rehabilitation was terminated because of full functional gain of the patient or due to self-withdrawal of the patient, the collection of BI data was no longer available. Since the aim of our research was to determine the efficacy of rehabilitation on the functional recovery of stroke patients, only data from patients who underwent continuous rehabilitation at our department were collected. Thus, we lack the BI data of patients who did not receive rehabilitation or interrupted rehabilitation for comparison. Moreover, we only included patients who had been discharged after receiving inpatient multidisciplinary rehabilitation, and who had received at least 3 months of rehabilitation after stroke. The patient population of our research tended to be in the so-called "middle band" of stroke patients:[17] those who were conscious at initial assessment, who had significant hemiparesis or hemiplegia, and who were discharged after intensive inpatient comprehensive rehabilitation. We did not, however, define the inclusion of patients based on the "middle band" criteria.

BI, a tool for measuring basic ADL, is one of the most frequently used outcome measures for stroke patients worldwide.[18,19] It has the advantages of good reliability and validity and being practical to communicate among medical professionals, but it has also been criticized for its insensitivity to small functional changes and the ceiling effect.[20] For some of our stroke patients who have already reached the plateau of basic ADL but are still undergoing rehabilitation for other reasons (e.g. for instrumental ADL), the rehabilitation effectiveness cannot be reflected by the BI. This is the major limitation of our study. In addition, we did not obtain BI information prior to stroke for the individual, and thus did not take the premorbid functional status into account, which can also influence the result of functional recovery. This is the second limitation of our study.

In conclusion, this is the first study in Taiwan to demonstrate the dose-dependent effect of rehabilitation on long-term functional improvement of stroke patients. We also showed that earlier delivery of rehabilitation has long-lasting effects on the functional recovery of stroke patients up to 1 year. In a future study, we will collect more information on stroke patients to further define the subtypes of stroke related to functional recovery patterns and to determine the best dose of rehabilitation delivery at the different stages of stroke for the most efficient functional recovery.

Acknowledgments

The authors would like to thank Ms Chin-Luan Chiu for assistance with data collection, Professor Shan-Tair Wang and Professor How-Ran Guo for assistance with statistical analysis, and Mr Shawn Lajeunesse for assistance in editing the English portion of this paper.

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