



Predicting Functional Recovery in Stroke Rehabilitation: The Role of Age and Stroke Subtype in Post-Acute Transitional Care

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Objective: This study investigated factors associated with improvement in activities of daily living (ADLs) among patients with stroke receiving post-acute care (PAC) in transitional inpatient care settings, highlighting age and stroke subtypes.

Methods: A retrospective cohort study reviewed records of 67 patients (aged 18 – 80 years) admitted to a transitional PAC ward from 2021 to 2023. Functional status was assessed at admission and discharge using the Barthel Index (BI), modified Rankin Scale (mRS), and Lawton Instrumental Activities of Daily Living (IADL) scale. Multiple linear regression identified functional gain predictors, adjusting for baseline severity and length of stay.

Results: During the PAC intervention, significant functional gains were observed across the BI, mRS, and Lawton IADL scales (all $p < 0.001$). Regression analysis revealed that stroke subtype (hemorrhagic) was a strong independent predictor of BI improvement ($B = 13.68$, $p = 0.001$), whereas younger age (< 65 years) significantly predicted both BI gain ($p = 0.038$) and mRS improvement ($p = 0.005$). Item-level analysis further indicated that younger patients achieved better recovery in high-mobility tasks, including bathing and stair climbing, whereas patients with hemorrhagic stroke exhibited greater improvement in transitional mobility and bowel control.

Conclusions: Younger age and hemorrhagic stroke subtypes were associated with greater functional recovery during PAC. These findings highlight the significance of individualized rehabilitation strategies tailored to patient demographics and stroke characteristics in transitional PAC programs.

Key words: stroke, post-acute care, barthel index, functional recovery, age

Introduction

Stroke remains a major global health challenge, affecting approximately 15 million individuals annually, with 5 million deaths and

5 million individuals experiencing long-term disability.¹ Measured in disability-adjusted life years, stroke is the second leading cause of death globally and the third leading cause of death and disability combined.² Stroke survivors frequently experience various disabilities, including motor,

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Received: December 18, 2025 Accepted: April 22, 2026

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speech, and cognitive impairments, with motor impairment being the most frequent, which results in motor function decline.³ Furthermore, approximately one-third of patients develop depression or anxiety disorders, negatively impacting social interactions and prognosis.⁴ Stroke poses substantial socioeconomic burden, with estimated global costs exceeding US\$721 billion annually, representing approximately 0.66% of the global gross domestic product.² A 2023 study in Taiwan reported that the average medical cost per patient in the first year following a stroke was US\$5,000, placing a considerable financial burden on families and society.⁵

In 1982,⁶ the concept of post-acute care (PAC) was first proposed and has evolved into structured programs bridging acute hospital care and return to home or community. Evidence shows PAC benefits patients with stroke by improving functional recovery and quality of life. Studies have demonstrated that PAC promotes neuroplasticity and improves motor function via individualized task-specific high-intensity interventions.⁷ Patients undergoing PAC exhibit improvement in physical activities and self-care across all Barthel Index (BI) items.^{8,9} The benefits of PAC vary according to stroke subtypes: patients with hemorrhagic stroke improve more in bowel control and transfers, whereas those with ischemic stroke improve in mobility and self-care.¹⁰ Age and baseline functions impact recovery, underscoring individualized care.¹¹ Furthermore, PAC integrates medical, nursing, rehabilitation, and psychosocial support to enhance cognition, reduce depression, and improve quality of life. PAC accelerates recovery, lowers caregiver burden, and reduces healthcare costs.^{12,13} Transitional PAC overcomes post-stroke residual deficits, consequently enhancing physical function, daily living, and cognition. However, older age, ischemic stroke, and low body mass index (BMI) predict slower recovery, fewer gains, and higher readmission or mortality rates.¹⁴

Despite recognition of PAC's benefits,

studies exploring which patient characteristics predict greater functional improvement in transitional care settings remain scarce. In particular, the impact of age and stroke subtypes on rehabilitation outcomes remains underexamined. Therefore, this study aimed to investigate how these factors affect functional gains among patients with stroke participating in an inpatient transitional PAC program.

Materials and Methods

Study design and participants

This retrospective study encompassed all adult patients (> 18 years) diagnosed with stroke, regardless of subtype (ischemic or hemorrhagic), who received PAC in a transitional care setting at a tertiary referral center from March 2021 to July 2023. Eligibility for PAC required stable vital signs and a modified Rankin Scale (mRS) score of 3 (moderate disability) or 4 (moderately severe disability).¹⁵

Demographic (age and sex), anthropometric (BMI), and clinical (length of hospital stays) data were collected from hospital electronic medical records. The exclusion criteria were as follows: (1) had a prior history of stroke, (2) participated in the PAC program for < 3 weeks, or (3) were aged > 80 years at the time of stroke. The Institutional Review Board of E-Da Hospital reviewed and approved the study protocol (approval no. EMRP-112-162).

Instrument and study parameters

In this study, functional recovery was evaluated using a multidimensional approach, incorporating global disability, basic activities of daily living (BADL), and instrumental activities of daily living (IADL).

mRS

The mRS was employed for assessing the degree of global disability and dependence of patients with stroke.¹⁶ Scores range from 0 (no symptoms) to 6 (dead). In this study, the mRS

served as a baseline inclusion criterion (with participants scoring 3 or 4) and an outcome measure for evaluating changes in overall functional independence.

BI

The BI is a 10-item scale assessing functional independence in activities, including fecal and urinary continence, grooming, toilet use, feeding, transfers, walking, dressing, stair climbing, and bathing. Scores range from 0 to 100, with lower scores signifying greater dependency. The BI is broadly employed for evaluating functional performance in patients with stroke¹⁷ and in older populations.¹⁸ It more effectively predicts physical function,¹⁹ independence in daily living,²⁰ length of hospital stays, and post-stroke mortality than other assessment tools.

Lawton IADL scale

The Lawton IADL scale was employed for assessing higher-level functional independence essential for community living. This scale evaluates eight complex activities: ability to use a telephone, shopping, food preparation, housekeeping, laundry, mode of transportation, responsibility for own medications, and ability to handle finances.²¹ Each item is scored on the basis of the level of assistance required, offering a comprehensive view of the patient's potential for successful transition back to the community.

PAC procedures

Our institute specializes in providing PAC for patients following acute stroke. All patients underwent comprehensive rehabilitative and nutritional assessments on the first day of admission. Transitional care services were tailored to each patient's physical and psychosocial requirements and comprised nursing care (wound care, disease management, and self-care training), medical care (pain and infection control, laboratory testing, and imaging), re-

habilitation, psychological support (emotional counseling and early intervention), and social support (assistance with financial and family-related issues).

The rehabilitation program encompassed 120-minute daily sessions conducted 5 days/week. To prevent patient fatigue and optimize engagement, the daily dose was divided into two 60-minute sessions (morning and afternoon). All patients received physical and occupational therapies as core interventions, with speech therapy incorporated for individuals with specific needs (e.g., aphasia or dysphagia). Although the session duration and frequency followed a standardized PAC protocol, the specific therapeutic exercises were tailored to address each patient's functional impairments.

Functional assessments, including the BI, mRS, and Lawton IADL scale, were systematically conducted at two time points: within 72 hours of admission (pre-test) and within 72 hours before discharge (post-test). This standardized protocol was designed to accurately capture the functional gains achieved during the transitional PAC program. The standard duration of PAC was 3 – 6 weeks, with possible extensions up to 12 weeks depending on the patient's clinical progress and rehabilitation needs.

Statistical analysis

Data were expressed as means (standard deviations). Analyses were performed using the Statistical Package for the Social Sciences (version 18; IBM). Descriptive statistics summarized demographic variables, including stroke subtypes (ischemic vs. hemorrhagic), age, sex, and comorbidities.

Functional recovery was assessed by comparing scores at admission and discharge. To analyze changes in the BI, mRS, and Lawton IADL scale, paired t-tests were employed.

To identify independent predictors of functional gains (defined as the change in scores from admission to discharge for the BI

and IADL scale), multiple linear regression analyses were performed. The models included functional gain as the dependent variable. Age, stroke subtypes, and sex were the independent variables entered into the models. The admission mRS score and the onset-to-PAC interval were included as covariates to adjust for baseline clinical severity and potential temporal confounding. A p -value of < 0.05 was considered statistically significant.

Results

Baseline characteristics and comorbidities

As shown in Table 1, the analysis included 67 patients with acute stroke, comprising 36 (53.7%) with ischemic stroke and 31 (46.2%) with hemorrhagic stroke. The median age of the participants was 61.8 (interquartile range [IQR], 55.0 – 70.0) years, and most participants were male (70.1%). The mean BMI was 24.7 (IQR, 22.0 – 27.0) kg/m². Hypertension was the most frequent comorbidity (98.5%), followed by diabetes mellitus (41.7%), hyperlipidemia (28.3%), arrhythmia (14.9%), cardiovascular disease (7.4%), kidney disease (5.9%), and urinary tract infection (4.4%).

Functional outcomes following PAC intervention

As exhibited in Table 2, all functional measures demonstrated highly significant improvement from admission to discharge following the PAC program ($n = 67$, all $p < 0.001$). The mean mRS score significantly decreased by 1.03 ± 0.85 points ($t = 9.891$, $p < 0.001$),

Table 1. Baseline demographic and clinical characteristics of participants ($n = 67$).

Variable	Number of participants (%)
Stroke subtype	
Ischemia (%)	36 (53.7)
Hemorrhage (%)	31 (46.2)
Demographic profile	
Age, mean (IQR, year)	61.8 (55.0 – 70.0)
Sex, male (%)	47 (70.1)
BMI, mean (IQR, kg/m ²)	24.7 (22.0 – 27.0)
Comorbidity profile (%)	
Hypertension	66 (98.5)
Diabetes mellitus	28 (41.7)
Hyperlipidemia	19 (28.3)
Arrhythmia	10 (14.9)
Cardiovascular disease	5 (7.4)
Kidney disease	4 (5.9)
Urinary tract infection	3 (4.4)

IQR: interquartile range; BMI: body mass index.

indicating substantially reduced global disability levels and increased overall independence. The total BI score demonstrated a remarkable increase, with a mean improvement of 31.57 ± 5.94 points ($t = -16.214$, $p < 0.001$). This gain reflects a considerable enhancement in patients' ability to perform basic self-care tasks. Moreover, the IADL score significantly improved by 1.76 ± 1.22 points ($t = -11.820$, $p < 0.001$), demonstrating that patients gained higher-level functional skills necessary for community reintegration.

Predictors of functional gains following PAC intervention: multiple linear regression analysis

As shown in Table 3, three multiple linear regression models were constructed to investigate factors associated with functional recovery

Table 2. Functional outcomes at admission and discharge ($n = 67$).

Assessment tool	Admission (pre-PAC)	Discharge (post-PAC)	Mean difference (95% CI)	t -value	p -value
mRS	3.84 ± 0.37	2.81 ± 0.97	$1.03 (0.82 - 1.24)$	9.891	$< 0.001^{***}$
Barthel Index	39.10 ± 19.98	70.67 ± 21.62	$31.57 (27.68 - 35.45)$	-16.214	$< 0.001^{***}$
Lawton IADL	1.81 ± 1.77	3.57 ± 2.08	$1.76 (1.46 - 2.06)$	-11.820	$< 0.001^{***}$

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

PAC: post-acute care; CI: confidence interval; mRS: modified Rankin Scale; IADL: instrumental activities of daily living.

Table 3. Multiple linear regression analysis of factors associated with functional recovery gains ($n = 67$).

Predictors	Unstandardized coefficients		Standardized coefficients	<i>t</i>	<i>p</i>	<i>R</i> ²	Adjusted <i>R</i> ²	<i>F</i>
	<i>B</i>	<i>SE</i>	β					
Model 1 BI gain								
(Constant)	32.54	19.36	-	1.68	0.098	0.29	0.23	<i>F</i> = 5.03
Stroke subtype	13.68	3.95	0.41	3.46	0.001**			<i>P</i> = 0.001
Age group	-8.31	3.91	-0.25	-2.13	0.038*			
Baseline mRS	2.39	5.13	0.05	0.47	0.643			
Sex	-3.62	3.66	-0.11	-0.99	0.327			
PAC length of stay	0.00	0.09	0.00	-0.02	0.983			
Model 2 mRS improvement								
(Constant)	2.87	1.05	-	2.75	0.008	0.21	0.15	<i>F</i> = 3.27
Stroke subtype	0.31	0.21	0.18	1.44	0.154			<i>P</i> = 0.011
Age group	-0.62	0.21	-0.36	-2.92	0.005**			
Baseline mRS	-0.27	0.28	-0.12	-0.96	0.343			
Sex	-0.11	0.20	-0.06	-0.53	0.596			
PAC length of stay	0.00	0.01	-0.01	-0.08	0.935			
Model 3 IADL gain								
(Constant)	-1.17	1.66	-	-0.71	0.481	0.03	-0.04	<i>F</i> = 0.43
Stroke subtype	0.13	0.34	0.05	0.39	0.699			<i>P</i> = 0.824
Age group	0.15	0.33	0.06	0.44	0.663			
Baseline mRS	-0.36	0.44	-0.11	-0.81	0.421			
Sex	0.10	0.31	0.04	0.33	0.746			
PAC length of stay	0.01	0.01	0.15	1.21	0.233			

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

PAC: post-acute care; BI: Barthel Index; mRS: modified Rankin Scale; IADL: instrumental activities of daily living; SE: standard error.

outcomes, including BI gain, mRS improvement, and IADL gain. Stroke subtypes, age groups, baseline mRS scores, sex, and PAC length of stay (LOS) were the independent variables entered into the models.

In Model 1 (BI gain), the stroke subtype and age group were identified as statistically significant predictors. Stroke subtypes were positively associated with BI gain ($B = 13.68$, standard error (SE) = 3.95, $p = 0.001$). Patients with hemorrhagic stroke demonstrated greater improvement in BI scores than those with ischemic stroke, suggesting better recovery in BADL during rehabilitation. Age groups were negatively associated with BI gain ($B = -8.31$, $SE = 3.91$, $p = 0.038$), indicating that patients aged ≥ 65 years exhibited smaller improvement in BI scores than younger patients. Baseline mRS, sex, and PAC LOS were not significant predictors. The model explained 23% of the variance in BI gain ($R^2 = 0.29$, adjusted $R^2 = 0.23$).

In Model 2 (mRS improvement), age groups were the only significant predictor ($B = -0.62$, $SE = 0.21$, $p = 0.005$). Older patients demonstrated less improvement in disability status than younger patients. Stroke subtypes, baseline mRS, sex, and PAC LOS were not significantly associated with mRS improvement. The model explained 15% of the variance ($R^2 = 0.21$, adjusted $R^2 = 0.15$).

In Model 3 (IADL gain), none of the predictors reached statistical significance. Stroke subtypes, age groups, baseline mRS, sex, and PAC LOS were not associated with IADL improvement. The model showed very limited explanatory power ($R^2 = 0.03$, adjusted $R^2 = -0.04$), indicating that the variables included in this model were inadequate to explain variation in IADL recovery.

Overall, the findings suggest that age is the most consistent factor associated with functional recovery, with older patients dem-

onstrating less improvement in BI and mRS outcomes. Stroke subtypes were highly associated only with BI gain, with patients with hemorrhagic stroke exhibiting greater improvement in BADL function. By contrast, other factors not included in the present models, including cognitive function, social support, or environmental factors, may influence IADL recovery.

Item-level analysis of the BI

Although the regression models confirmed age and stroke subtypes as independent predictors of overall recovery, total BI scores may mask specific patterns of functional gain. To offer more targeted clinical insights for rehabilitation planning, an item-level analysis was conducted to identify which specific daily activities contributed most to the recovery differences observed between subgroups.

Comparison of improvements by age stratification

In the age-stratified analysis (Table 4), patients aged < 65 years achieved significantly greater improvement in mobility-intensive and self-care tasks, particularly in bathing (2.7 ± 2.5 vs. 0.7 ± 1.8 , $p < 0.001$), climbing stairs (4.5 ± 3.3 vs. 2.5 ± 2.9 , $p < 0.05$), and dressing/undressing (2.9 ± 3.5 vs. 1.0 ± 2.3 , $p < 0.05$). No other sub-items showed significant age-related differences, suggesting that gains in complex

motor skills primarily caused superior recovery in younger patients.

Influence of stroke subtype on functional recovery

When analyzed by stroke subtype (Table 5), patients with hemorrhagic stroke exhibited distinct advantages in transitional movements and physiological regulation. Significant gains were noted in transfer from a wheelchair to bed (5.8 ± 4.3 vs. 4.0 ± 2.8 , $p < 0.05$) and bowel control (1.7 ± 2.4 vs. 0.4 ± 1.8 , $p < 0.05$). Furthermore, near-significant trends favoring the hemorrhagic group were noted for ability to walk ($p = 0.057$), feeding ($p = 0.063$), and bladder control ($p = 0.071$). These findings suggest that hemorrhagic stroke survivors can possess a higher potential for regaining autonomic and transitional functions during the PAC phase.

Discussion

The results of this study noted substantial functional improvements in patients' BI, mRS, and IADL scores during systemic PAC intervention. These findings align with previous research, indicating that intensive task-specific rehabilitation training during the subacute phase can facilitate neuroplasticity and functional recovery.^{7,22,23} By simultaneously evaluating the

Table 4. Comparison of item-level Barthel Index functional gains between age groups.

Item	Age < 65 years Mean (SD)	Age ≥ 65 years Mean (SD)	<i>p</i>
Feeding	2.3 (3.0)	2.5 (3.8)	0.827
Grooming	1.3 (2.2)	1.2 (2.6)	0.754
Toileting	3.9 (2.9)	2.9 (2.5)	0.142
Bathing	2.7 (2.5)	0.7 (1.8)	< 0.001**
Dressing/undressing	2.9 (3.5)	1.0 (2.3)	< 0.05*
Bowel control	0.7 (1.7)	1.5 (2.7)	0.150
Bladder control	4.2 (3.2)	3.1 (2.9)	0.132
Ability to walk	7.9 (5.2)	6.3 (4.3)	0.205
Climbing stairs	4.5 (3.3)	2.5 (2.9)	< 0.05*
Transfer from a wheelchair to bed	5.2 (3.2)	4.0 (4.2)	0.153

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

SD: standard deviation.

Table 5. Comparison of item-level Barthel Index functional gains between stroke subtypes.

Item	Hemorrhage Mean (SD)	Ischemia Mean (SD)	<i>p</i>
Feeding	3.2 (4.0)	1.6 (2.4)	0.063
Grooming	1.6 (2.4)	0.9 (2.3)	0.271
Toileting	3.8 (2.8)	3.1 (2.7)	0.320
Bathing	2.1 (2.5)	1.8 (2.4)	0.632
Dressing/undressing	4.1 (3.4)	3.4 (2.8)	0.354
Bowel control	1.7 (2.4)	0.4 (1.8)	< 0.05*
Bladder control	2.4 (3.4)	1.1 (2.4)	0.071
Ability to walk	8.5 (4.3)	6.2 (5.2)	0.057
Climbing stairs	4.1 (3.7)	3.3 (2.9)	0.290
Transfer from a wheelchair to bed	5.8 (4.3)	4.0 (2.8)	< 0.05*

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

SD: standard deviation.

BI, mRS, and IADL, this study offers a more comprehensive perspective, suggesting that PAC improves basic self-care abilities, reduces overall disability, and enhances the potential for community reintegration.

Multiple regression analysis identified younger age (< 65 years) and hemorrhagic stroke types as independent predictors of favorable physical functional recovery. Younger patients demonstrated significantly greater improvements in BI and mRS scores, potentially attributable to higher baseline physical reserves and superior neuroplasticity.²⁴ Notably, the regression model revealed that age remained a significant predictor even after adjusting for baseline severity (mRS score at admission).

Regarding stroke subtype, our study observed that patients with hemorrhagic stroke exhibited remarkably higher functional gains (change in BI scores) than those with ischemic stroke, aligning with previous literature.^{25,26} Furthermore, an itemized analysis of the 10 BI components revealed that patients with hemorrhagic stroke outperformed those with ischemic stroke in bowel control and transfers (from wheelchair to bed). These findings suggest that upon achieving clinical stability, patients with hemorrhagic stroke can possess a greater capacity for recovering transitional mobility during the PAC phase.

Furthermore, the observed improvement

in IADL scores (from 1.8 to 3.6) indicates improved performance in complex ADLs among patients engaging in the PAC program. Although our regression model did not identify specific predictors for IADL improvement, potentially owing to inpatient environment-related constraints, stroke severity and baseline mRS scores were observed to be independently associated with IADL outcomes.²⁷ This multidimensional progress is crucial, as prior research underscores that IADL is essential for independent living and active community participation.²⁸

The BI score improvement observed in this study (from 39.1 to 70.7) represents an 80.8% increase, which is substantial compared with other models. Garcia-Rudolph *et al.* reported that individual domains of the BI are rarely independently analyzed; even when they are, only a few activities are frequently discussed.²⁹ Our results explicitly indicate that younger patients exhibit an advantage in high-mobility tasks, including bathing and climbing stairs, offering a clear roadmap for developing individualized rehabilitation plans.

This study had several limitations. First, owing to the lack of lesion location-related neuroimaging data, we could not evaluate its specific influence on functional domains. Second, although mRS scores were adjusted for baseline severity, we did not account for cognitive status or socioeconomic factors that might

impact prognosis.³⁰ Third, although our findings support the multidimensional benefits of PAC, further research is required to determine the long-term sustainability of these improvements following discharge. Last, the item-level analysis of the BI encompassed several comparisons, potentially elevating the risk of Type I error. Consequently, these sub-item findings should be interpreted as exploratory, providing clinical insights into specific functional gains rather than definitive conclusions.

Conclusions

PAC interventions significantly improved daily living and physical function among patients with stroke. Comprehensive subgroup and item-level analyses revealed that younger patients derived greater benefit in physically demanding tasks, whereas patients with hemorrhagic stroke improved more in specific self-care and transfer activities. These findings highlight the significance of early, individualized, and multidisciplinary PAC programs, offering guidance for tailoring rehabilitation to address the specific needs of targeted patient groups, thereby maximizing functional recovery and reducing long-term care dependency.

Author Contributions

Study Design, M.H. Kuo and Y.F. Wang; Data Collection, S.F. Cheng; Statistical Analysis, L.Y. Yu; Data Interpretation, M.H. Kuo, L.Y. Yu, S.F. Cheng, and Y.F. Wang; Manuscript Preparation, L.Y. Yu; Literature Search, L.Y. Yu and S.F. Cheng; Manuscript Revision and Supervision, Y.F. Wang. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of E-Da Hospital (approval no. EMRP-112-162).

Informed Consent Statement

Patient consent was waived due to the retrospective nature of this study and the use of de-identified medical records.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgements

The authors gratefully acknowledge Professor Chiung-Yu Huang for her guidance and valuable suggestions.

Conflicts of Interest

The authors declare no conflict of interest.

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