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Multimorbidity and functional motor and balance outcomes post-stroke: A retrospective analysis across all age groups

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Abstract

Background & Objective: Multimorbidity is defined as the co-existence of two or more chronic conditions, which is common in stroke survivors and may influence their functional recovery. However, its impact on post-stroke outcomes remains poorly understood especially in a lower-to-middle income country. This study aimed to describe the distribution and severity of multimorbidity among post-stroke patients and examine its association with sociodemographic and clinical factors and its correlation with motor and balance outcomes; and to examine predictors of functional these outcomes. *Methods:* This is a retrospective cross-sectional study on medical records of patients with first-time ischemic or hemorrhagic stroke referred to the physiotherapy division, in Universiti Malaya Medical Centre between January 2022 and December 2023. Inclusion criteria included age ≥18, at least two chronic conditions, and availability of Motor Assessment Scale (MAS) and/or Berg Balance Scale (BBS) scores. Multimorbidity was measured using the Charlson Comorbidity Index (CCI). Functional motor performance and balance were assessed using the Motor Assessment Scale (MAS) and Berg Balance Scale (BBS), respectively at an average of 6.5 months post-stroke (SD = 2.61). Statistical methods included Chi-square test, Spearman's correlation, and multiple linear regression. *Results:* A total of 384 patients were included in the analysis. Most patients (83.3%) had severe multimorbidity (CCI ≥5). The most common comorbidity was diabetes (48.9%) followed by dementia (17.2%). CCI severity was significantly associated with age group ($p<0.0001$) and ethnicity ($p=0.010$). No significant correlation was found between CCI and MAS ($\rho = –0.014$, $p=0.870$) or BBS ($\rho = 0.073$, $p=0.258$). Age was the only significant predictor of MAS ($B = –0.322$, $p=0.016$). CCI did not predict MAS or BBS outcomes. *Conclusions:* Although multimorbidity is highly prevalent in post-stroke patients and associated with demographic factors, it was not significantly related to functional motor and balance performance. Age remains a key factor influencing functional motor performance. These findings emphasize the need for individualized rehabilitation strategies especially in the older stroke survivors.

Keywords: Multimorbidity, stroke, Charlson Comorbidity Index, functional outcomes, Motor Assessment Scale, Berg Balance Scale

INTRODUCTION

Stroke is a leading cause of mortality and long-term disability worldwide, resulting in significant impairments in mobility, balance, and activities of daily living among survivors. Globally, millions of individuals experience strokes each year, with many facing prolonged or incomplete recovery. In Malaysia, stroke ranks as the third leading cause of death, with 47,911 new cases recorded in 2019. Worryingly, stroke incidence is rising among younger adults, particularly males. Post-stroke recovery is often unpredictable and incomplete. Many survivors continue to experience deficits even one-year

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post-onset, particularly in motor control and movement precision, which are more critical to mobility than strength alone.[9] These challenges are frequently compounded by multimorbidity which is defined as the co-occurrence of two or more chronic conditions within an individual. In stroke populations, common comorbidities include diabetes, hypertension, renal disease, and cardiovascular disease. Such conditions can slow recovery, increase long-term disability, and complicate clinical management. Multimorbidity is no longer confined to the elderly. Its prevalence is growing among younger adults, especially in low- and middle-income countries like Malaysia. A recent global estimate suggests that 37.2% of adults live with multimorbidity, with rates exceeding 50% among those aged 60 years and older.[10] Among stroke patients, prevalence estimates are even higher, with up to 94.2% having at least one other chronic condition. Despite its clinical importance, patients with multimorbidity are often excluded from randomized controlled trials, resulting in limited evidence to guide rehabilitation strategies. In Malaysia, although 40.6% of older adults are estimated to have multimorbidity, few studies have examined how this burden affects functional recovery after stroke. Most local research has focused on disease prevalence rather than post-stroke functional outcomes. Furthermore, studies often rely on simple disease counts rather than weighted indices that better capture the complexity of multimorbidity. The Charlson Comorbidity Index (CCI), although originally designed to predict mortality based on comorbidity burden, has been widely adopted in stroke research as a proxy for multimorbidity severity. Recent studies have validated its use in stroke populations to evaluate functional outcomes and in-hospital recovery.[11] Therefore, this study aims to (1) describe the distribution and severity of multimorbidity among post-stroke patients; (2) assess its association with sociodemographic and clinical variables; (3) examine the correlation between multimorbidity severity and functional outcomes; and (4) identify demographic and clinical predictors of motor and balance outcomes, as measured by the Motor Assessment Scale (MAS) and Berg Balance Scale (BBS) Understanding these patterns is essential to refining stroke rehabilitation strategies and guiding personalized care planning in Malaysia.

METHOD

Study Design

This study employed a hospital-based, retrospective cross-sectional design. Medical records from 2022 to 2023 were reviewed at Universiti Malaya Medical Centre (UMMC) to assess functional outcomes in stroke patients with multimorbidity. Data were collected at a single time point for each patient, without any follow-up. A purposive sampling method was applied: records were screened sequentially and included if they met the study criteria. Sampling stopped once the required sample size of 384 was reached. No active participant recruitment was involved. All data were anonymized and handled according to institutional ethical guidelines.

Ethical approval

The study protocol followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines and received approval from the Medical Research Ethics Committee of Universiti Malaya Medical Centre (MREC UMMC ID: 2023722-12694), in accordance with the Helsinki Declaration of 1975. Permission to extract data was obtained from the hospital's Medical Record Department.

Study population and setting

The study included Malaysian adults aged 18 years and above who were referred for physiotherapy services (inpatient or outpatient) at UMMC between January 2022 and December 2023. Patients were included if they had documented MAS and/or BBS scores; availability of both measures was not mandatory. Eligible patients had a first-time diagnosis of ischemic or hemorrhagic stroke, documented scores on either the MAS or BBS within one year of stroke onset, and at least two chronic conditions. Patients with missing or incomplete MAS or BBS data were excluded. Prevalence of multimorbidity in this population was 100% due to inclusion criteria.

Study procedures

Referrals received by the Physiotherapy Division at UMMC from various departments were screened. Screening was sequential based on predefined criteria. Two independent researchers

extracted sociodemographic and clinical data (e.g., age, sex, BMI, smoking status, stroke type, lesion side, and time since stroke). Discrepancies were resolved through discussion. The Charlson Comorbidity Index (CCI) was used to assess multimorbidity. All data were anonymized and entered a standardized Excel sheet. The most recent documented MAS and/or BBS assessment within one-year post-stroke was extracted.

Measurement tools

Three validated tools were used: the Charlson Comorbidity Index (CCI), the Motor Assessment Scale (MAS), and the Berg Balance Scale (BBS). The CCI assigns weights to 16 conditions to estimate mortality risk. It was categorized into mild (1–2), moderate (3–4), and severe (≥5) groups following., MAS assesses eight motor functions (score 0–6 per item, max total 48); it has excellent inter-rater reliability (ICC > 0.95). BBS assesses balance using 14 tasks (score 0–4 per item, max total 56); it has excellent test–retest reliability (ICC = 0.98).,

Sample size calculation

The required minimum sample size was calculated using Lemeshow's formula for a single proportion, based on a 95% confidence level (Z = 1.96), a 25% expected prevalence (p = 0.25), and 5% precision (d = 0.05). The formula yielded 288 cases. To account for missing data, 30% was added, resulting in a target of 384 records. Listwise deletion was applied during analysis. For regression analysis with up to 10 predictors, a sample of 384 was deemed adequate to ensure statistical power.

Statistical analysis

All statistical analyses were conducted using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY). Sociodemographic (e.g., age, sex, ethnicity) and clinical variables were summarized using means and standard deviations for continuous variables, and frequencies and percentages for categorical variables. To examine the distribution and severity of multimorbidity, descriptive statistics were used to report the frequency of each comorbidity. Charlson Comorbidity Index (CCI) scores were categorized into mild (1–2), moderate (3–4), and severe (≥5) levels. To assess the association between multimorbidity and sociodemographic/clinical characteristics, Chi-square tests were used to analyze the distribution of the top eight comorbidities across key variables (e.g., age group, gender, ethnicity, stroke subtype). Both CCI and age were converted into categorical variables to meet test assumptions. Spearman's rank correlation was used to evaluate the relationship between continuous CCI scores and functional outcomes, namely Motor Assessment Scale (MAS) and Berg Balance Scale (BBS) scores. This non-parametric method was chosen due to non-normal distribution of the outcome variables, confirmed by the Shapiro-Wilk test. Multiple linear regression analyses were used to determine the predictors of functional outcomes. Two separate models were constructed: one for MAS (n = 143) and one for BBS (n = 241). Each model included CCI score as the primary independent variable and adjusted for age, gender, ethnicity, BMI, stroke subtype, lesion side, smoking status, and time since stroke. Listwise deletion was applied for handling missing data. Model assumptions were checked using variance inflation factor (VIF) for multicollinearity, residual plots for normality, and scatterplots for homoscedasticity. All tests were two-sided, and statistical significance was set at $p < 0.05$. 95% confidence intervals (CIs) were reported for effect estimates. There was no funding source for this study. The funder had no role in study design, data collection, data analysis, interpretation, or manuscript preparation.

RESULTS

A total of 384 post-stroke patients were included in the study. Table 1 summarizes the baseline sociodemographic and clinical characteristics. The mean age of participants was 61.9 years (SD = 11.23), and the mean BMI was 27.1 kg/m² (SD = 4.74). Males constituted 62.2% (n = 239), while females made up 37.8% (n = 145). The majority of participants were Malay (44.8%), followed by Chinese (35.9%) and Indian (19.3%). Most participants were married (83.6%). Ischemic stroke was more common (71.9%), and the left hemisphere was more frequently affected (68.8%). The mean duration since stroke onset was 6.5 months (SD = 2.61). MAS and BBS scores were extracted from the most recent documented assessment within one-year post-stroke, with a mean assessment time point of 6.5 months post-stroke. In terms of functional measures, the average baseline Modified Barthel Index (MBI) was 72.0 (SD

Table 1: Sociodemographic and clinical characteristics of participants

Variable	Category / Value	n / Mean (SD)	% / Range
Baseline Modified Barthel Index (MBI)	–	72.0 (11.52)	52–90
Age (years)	–	61.9 (11.23)	40–89
Gender	Male	239	62.2%
	Female	145	37.8%
Race	Malay	172	44.8%
	Chinese	138	35.9%
	Indian	74	19.3%
Marital Status	Married	321	83.6%
	Not Married (Single/Divorced/ Separated)	63	16.4%
BMI (kg/m²)	–	27.1 (4.74)	19.6–39.8
Smoking Status	Yes	128	33.3%
	No	256	66.7%
Stroke Type	Ischemic	276	71.9%
	Hemorrhagic	108	28.1%
Side of Stroke	Left	264	68.8%
	Right	120	31.3%
Duration of Stroke (months)	–	6.5 (2.61)	1–12
Comorbidity Severity (CCI)	Mild (1–2)	35	9.1%
	Moderate (3–4)	29	7.6%
	Severe (≥5)	320	83.3%
Functional Mobility	Wheelchair	86	22.4%
	Walk with assistance	117	30.5%
	Independent walking	38	9.9%
Motor Assessment Scale (MAS) (0–48)	–	22.9 (14.22)	7–43 (n = 143)
Berg Balance Scale (BBS) (0–56)	–	25.9 (9.14)	10–49 (n = 241)

= 11.52), with scores ranging from 52 to 90. Among participants with available data, the mean Motor Assessment Scale (MAS) score was 22.9 (SD = 14.22; n = 143), and the mean Berg Balance Scale (BBS) score was 25.9 (SD = 9.14; n = 241). CCI scores ranged from 2 to 16, with a mean of 9.1 (SD = 3.74). Severe multimorbidity (CCI ≥ 5) was observed in 83.3% of participants. A small proportion of patients demonstrated normal motor function, reflecting the clinical heterogeneity of post-stroke patients referred for rehabilitation services. Table 2 outlines the frequency of individual comorbidities. Dementia and peptic ulcer disease were the most common non-stroke-related conditions (each 17.2%), followed by chronic pulmonary disease (13.0%) and moderate to severe renal disease (9.9%). All participants had cerebrovascular disease and hemiplegia, as per inclusion criteria. Chi-square analyses were used to examine the associations between eight major comorbidities and clinical/sociodemographic variables (Table 3). Most comorbidities were not significantly associated with gender, BMI, smoking status, stroke subtype, side of lesion, or stroke duration ($p > .05$). However, age showed significant associations with dementia ($p = .001$) and congestive heart failure ($p = .006$). Additionally, stroke duration was significantly associated with dementia ($p = .001$), and marital status was significantly associated with peptic ulcer disease ($p = .024$).

Further chi-square analyses revealed a significant association between CCI severity and age group ($\chi^2 = 45.44$, $p < 0.001$), and between CCI severity and race ($\chi^2 = 13.35$, $p = 0.010$) (Table 3). Older adults and Chinese participants were more likely to present with severe comorbidity. No significant associations were found between CCI severity and gender, marital status, or smoking status ($p > 0.05$). Shapiro-Wilk tests confirmed non-normal distribution for CCI, MAS, and BBS (all $p < 0.001$). Therefore, Spearman's rank correlation was employed (Table 4). No significant correlation was found

Table 2: Frequency and percentage of CCI comorbidities (n = 384)

Comorbidity	Yes (n, %)	No (n, %)
Cerebrovascular disease / TIA	384 (100.0%)	0 (0.0%)
Hemiplegia or paraplegia	384 (100.0%)	0 (0.0%)
Diabetes (total)	188 (48.9%)	196 (51.1%)
— Uncomplicated diabetes	148 (38.5%)	—
— With end-organ damage	40 (10.4%)	—
Dementia / Chronic cognitive deficit	66 (17.2%)	318 (82.8%)
Peptic ulcer disease	66 (17.2%)	318 (82.8%)
Chronic pulmonary disease	50 (13.0%)	334 (87.0%)
Moderate to severe renal disease	38 (9.9%)	346 (90.1%)
Myocardial infarction	29 (7.6%)	355 (92.4%)
Congestive heart failure	23 (6.0%)	361 (94.0%)
Peripheral vascular disease	16 (4.2%)	368 (95.8%)
Liver disease (mild)	4 (1.0%)	380 (99.0%)
AIDS	1 (0.3%)	383 (99.7%)
Localized solid tumor	1 (0.3%)	383 (99.7%)
Metastatic solid tumor	1 (0.3%)	383 (99.7%)
Lymphoma	0 (0.0%)	384 (100.0%)
Leukemia	0 (0.0%)	384 (100.0%)
Connective tissue disease	0 (0.0%)	384 (100.0%)

Table 3: Association between diabetes severity and patient characteristics using chi-square analysis

Variable	Subcategory	None or Diet-Controlled n (%)	Uncomplicated n (%)	End-Organ Damage n (%)	p-value
Gender	Male	**124 (63.3%)**	**93 (62.8%)**	**22 (55.0%)**	0.606
	Female	72 (36.7%)	55 (37.2%)	18 (45.0%)	
Age Group	< 60 years	85 (43.4%)	67 (45.3%)	13 (32.5%)	0.206
	≥ 60 years	**111 (56.6%)**	**81 (54.7%)**	**27 (67.5%)**	
Race	Malay	**89 (45.4%)**	**66 (44.6%)**	**17 (42.5%)**	0.977
	Chinese	68 (34.7%)	54 (36.5%)	16 (40.0%)	
	Indian	39 (19.9%)	28 (18.9%)	7 (17.5%)	
Marital Status	Married	**167 (85.2%)**	**127 (85.8%)**	**32 (80.0%)**	0.651
	Not Married	29 (14.8%)	21 (14.2%)	8 (20.0%)	
BMI Category	Normal	74 (37.8%)	48 (32.4%)	17 (42.5%)	0.406
	Overweight/Obese	**122 (62.2%)**	**100 (67.6%)**	**23 (57.5%)**	
Smoking Status	Smoker	64 (32.7%)	53 (35.8%)	11 (27.5%)	0.588
	Non-smoker	**132 (67.3%)**	**95 (64.2%)**	**29 (72.5%)**	
Stroke Subtype	Ischemic	**146 (74.5%)**	**101 (68.2%)**	**29 (72.5%)**	0.441
	Hemorrhagic	50 (25.5%)	47 (31.8%)	11 (27.5%)	
Side of Lesion	Right	**141 (71.9%)**	**98 (66.2%)**	**25 (62.5%)**	0.350
	Left	55 (28.1%)	50 (33.8%)	15 (37.5%)	
Duration of Stroke	< 6 months	**129 (65.8%)**	**110 (74.3%)**	**26 (65.0%)**	0.203
	≥ 6 months	67 (34.2%)	38 (25.7%)	14 (35.0%)	

between CCI and MAS ($\rho = -0.014$, $p = 0.870$) or CCI and BBS ($\rho = 0.073$, $p = 0.258$), suggesting that comorbidity severity was not associated with motor or balance function. Multiple linear regression analysis was conducted to identify predictors of MAS and BBS scores (Table 5 and Table 6). For MAS, only age was significantly associated with poorer motor outcomes (B = -0.322, 95% CI [-0.58, -0.06], $p = 0.016$). CCI, gender, BMI, ethnicity, stroke subtype, side of stroke, duration since stroke, smoking status, and marital status were not significant predictors (all $p > 0.05$). Regression diagnostics indicated no violation of assumptions. For BBS scores, none of the predictors, including age, CCI, and other sociodemographic or clinical variables, showed significant associations (all $p > 0.05$). Regression assumptions were satisfied. These findings collectively suggest that while comorbidity severity was prevalent in the study population, it was not significantly associated with post-stroke motor or balance function. Age emerged as the only consistent factor influencing functional outcomes.

Table 4: Association between multimorbidity severity (CCI) and sociodemographic characteristics (n = 384)

Variable	Category	Mild n (%)	Moderate n (%)	Severe n (%)	χ^2 (df)	p-value
Age Group	< 50	22 (24.4%)	6 (6.7%)	62 (68.9%)	45.44 (8)	**< 0.001***
	50–59	6 (7.5%)	4 (5.0%)	70 (87.5%)		
	60–69	5 (4.8%)	12 (11.4%)	88 (83.8%)		
	70–79	2 (2.5%)	2 (2.5%)	77 (95.1%)		
	≥ 80	0 (0.0%)	5 (17.9%)	23 (82.1%)		
Gender	Male	22 (9.2%)	16 (6.7%)	201 (84.1%)	0.67 (2)	0.717
	Female	13 (9.0%)	13 (9.0%)	119 (82.1%)		
Race	Malay	23 (13.4%)	12 (7.0%)	137 (79.7%)	13.35 (4)	**0.010***
	Chinese	3 (2.2%)	13 (9.4%)	122 (88.4%)		
	Indian	9 (12.2%)	4 (5.4%)	61 (82.4%)		
Marital Status	Married	29 (8.9%)	25 (7.7%)	272 (83.4%)	0.155 (2)	0.925
	Not Married (S/D/W/Sep)	6 (10.3%)	4 (6.9%)	48 (82.8%)		
Smoking	Yes	14 (10.9%)	14 (10.9%)	100 (78.1%)	4.24 (2)	0.120
	No	21 (8.2%)	15 (5.9%)	220 (85.9%)		

Table 5: Multiple linear regression coefficients predicting MAS among post-stroke patients

Predictor Variable	B (Unstandardised)	β (Standardised)	95% CI for B	p-value	VIF
Constant	21.504	–	–	–	–
Charlson Comorbidity Index	0.001	< 0.001	[-0.63, 0.63]	0.997	1.056
Age	-0.322	-0.250	[-0.58, -0.06]	**0.016***	1.420
Gender (ref: Male)	5.210	0.176	[-0.59, 11.01]	0.078	1.527
BMI	0.049	0.016	[-0.46, 0.56]	0.848	1.051
Ethnicity (ref: Malay)	3.323	0.170	[-0.29, 6.93]	0.071	1.256
Stroke Subtype (ref: Ischemic)	3.252	0.097	[-3.07, 9.57]	0.311	1.304
Duration Since Stroke	0.429	0.081	[-0.45, 1.31]	0.337	1.026
Side of Stroke (ref: Left)	5.384	0.176	[-0.32, 11.09]	0.064	1.290
Smoking (ref: Non-smoker)	-3.861	-0.123	[-9.85, 2.13]	0.205	1.350
Marital Status (ref: Not Married)	0.735	0.019	[-5.58, 7.05]	0.818	1.000

Table 6: Multiple linear regression coefficients predicting BBS among post-stroke patients

Predictor Variable	B (Unstandardised)	β (Standardised)	95% CI for B	p-value	VIF
Constant	26.165	–	–	–	–
Charlson Comorbidity Index	0.106	0.043	[-0.21, 0.42]	0.514	1.022
Age	0.037	0.045	[-0.07, 0.14]	0.505	1.076
Gender (ref: Male)	0.460	0.025	[-2.26, 3.18]	0.740	1.284
BMI	0.036	0.019	[-0.21, 0.28]	0.780	1.036
Ethnicity (ref: Malay)	-0.880	-0.074	[-2.48, 0.72]	0.279	1.104
Stroke Subtype (ref: Ischemic)	0.262	0.013	[-2.41, 2.94]	0.847	1.115
Duration Since Stroke	-0.176	-0.049	[-0.63, 0.28]	0.454	1.017
Side of Stroke (ref: Left)	0.091	0.005	[-2.58, 2.76]	0.946	1.109
Smoking (ref: Non-smoker)	-1.726	-0.091	[-4.53, 1.08]	0.227	1.318
Marital Status (ref: Not Married)	-0.104	-0.004	[-3.26, 3.05]	0.948	1.000

DISCUSSION

This study identified a high prevalence of severe multimorbidity among post-stroke patients, with over 83% scoring ≥5 on the Charlson Comorbidity Index (CCI). These findings directly address the study's objectives and underscore the complex clinical burden that affects stroke populations in Malaysia. Despite the high comorbidity burden, CCI severity did not significantly correlate with motor or balance outcomes, suggesting that functional recovery post-stroke is influenced by multifactorial elements beyond comorbidity count alone.

The observed prevalence of diabetes mellitus (48.9%), dementia or chronic cognitive deficits (17.2%), peptic ulcer disease (17.2%), and chronic pulmonary disease (13.0%) reflects trends seen in both local and international stroke populations. These results are consistent with national health statistics and previous registry-based studies from Malaysia. Notably, the frequent occurrence of dementia aligns with existing evidence describing a bidirectional relationship between cognitive decline and cerebrovascular disease, while peptic ulcer disease may be linked to chronic NSAID use or stress-related gastrointestinal dysfunction. This study adds novel insights by identifying a disproportionately high burden of severe multimorbidity among Chinese patients, as well as among adults aged 70–79 years. Although age is a known predictor of comorbidity burden, the high prevalence of severe CCI scores even in midlife raises concern. Younger patients with high comorbidity may face worse long-term outcomes, as supported by recent findings. Ethnic variation in CCI scores also warrants attention. While Chinese ethnicity showed the highest proportion of severe multimorbidity, Malays were significantly associated with higher CCI severity overall. These observations echo national patterns of cardiovascular and metabolic disease distribution across ethnic groups in Malaysia., Despite these findings, this study did not identify any significant association between CCI severity and functional outcomes as measured by the Motor Assessment Scale (MAS) and the Berg Balance Scale (BBS). The absence of correlation may reflect the limitations of CCI in predicting physical performance, as

it was originally developed to assess mortality risk and does not include functionally impactful conditions like depression, arthritis, or post-stroke pain. Moreover, baseline functional independence, as indicated by a mean Modified Barthel Index (MBI) score of 72.0, may have contributed to the narrow range of post-stroke functional variation. Previous studies have shown mixed results regarding the utility of CCI in stroke outcome prediction., While some advocate for indices such as the Elixhauser or Functional Comorbidity Index, these tools are less practical in retrospective clinical settings due to their complexity., In this context, the CCI remains a feasible, internationally recognized index and is widely used in stroke research. The MAS and BBS were used in this study due to their relevance in tracking rehabilitation progress in Malaysian hospitals. However, both instruments have limitations. The BBS has a ceiling effect in higher-functioning patients, while the MAS lacks detailed assessment of tone and fine motor coordination., These issues may have masked subtle variations in function across CCI categories. Despite these methodological constraints, this study provides important context for clinical rehabilitation. The retrospective nature allowed the inclusion of a large dataset reflective of real-world practice. However, key variables such as lesion site, stroke severity (e.g., NIHSS), rehabilitation frequency, mood, and social support were unavailable, which may have influenced the findings. Furthermore, selection bias may have occurred, as the study excluded patients discharged early or treated elsewhere, possibly underestimating the impact of multimorbidity on stroke recovery.

This study's strengths include its relatively large sample size, use of validated tools, and reflection of real-world clinical practice at a tertiary center. Nonetheless, future research should adopt a prospective, longitudinal design with broader data collection—including stroke-specific indices, mental health assessments, and social determinants of health—to better understand the relationship between multimorbidity and functional recovery.

Several limitations should be acknowledged. First, the retrospective design limited the availability of key stroke severity indicators such as NIHSS scores, lesion characteristics, ICU admission, and length of hospitalization. Second, rehabilitation-related variables including therapy intensity, timing of initiation, adjunctive therapies, and continuation of rehabilitation at home were not consistently documented and could not be analyzed. We acknowledge that rehabilitation dose, timing, adjunctive therapies, and continuation of therapy at home are important determinants of recovery. However, these variables were not uniformly documented across patient records and could not be reliably extracted. The current practice in majority of the patients are once weekly therapy sessions for the first 3 months and thereafter, once fortnightly. However, we did not have other details on adjunctive home-based rehabilitation which were not consistently documented, preventing further analysis. Third, functional outcomes were assessed at varying time points within the first-year post-stroke, and ongoing neurological recovery may have influenced results. The study was designed to specifically examine multimorbidity severity within a multimorbid stroke population. Therefore, the absence of a non-multimorbid comparison group is acknowledged as a limitation. Additionally, the study focused exclusively on patients with multimorbidity, precluding comparison with non-multimorbid stroke survivors. These factors may have contributed to the absence of significant associations between comorbidity severity and functional outcomes.

In conclusion, while severe multimorbidity was prevalent, it did not significantly predict functional outcome in this study. These results suggest that functional recovery is likely driven by more nuanced, multidimensional factors beyond comorbidity burden alone. Clinically, these findings support the need for age- and ethnicity-tailored rehabilitation strategies and reinforce the importance of integrating broader health and contextual factors into stroke care planning in Malaysia.

DISCLOSURE

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REFERENCES

1. Feigin VL, Stark BA, Johnson CO, *et al*. Global, regional, and national burden of stroke and its risk factors, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol 2021; 20(10): 795-820. https://doi.org/10.1016/S1474-4422(21)00252-0
2. Tan KS, Venketasubramanian N. Stroke burden in Malaysia. Cerebrovasc Dis Extra 2022; 12(2):58-62. https://doi.org/10.1159/000524271

3. Hwong WY, Ang SH, Bots ML, *et al*. Trends of stroke incidence and 28-day all-cause mortality after a stroke in Malaysia: A linkage of national data sources. Global Heart 2021; 16(1): Article 39. https://doi.org/10.5334/gh.791
4. Landi F, Onder G, Cesari M, *et al*. Functional decline in frail older people: The role of comorbidity. Eur J Neurol 2006; 13(1): 17-23. https://doi.org/10.1111/j.1468-1331.2006.01116.x
5. Lodha N, Patel P, Casamento-Moran A, Hays E, Poisson SN, Christou EA. Strength or motor control: What matters in high-functioning stroke? Front Neurol 2018; 9: 1160. https://doi.org/10.3389/fneur.2018.01160
6. van den Akker M., Buntinx F, Knottnerus JA. Comorbidity or multimorbidity: What's in a name? A review of literature. Eur J Gen Pract 1996; 2(2): 65-70. https://doi.org/10.3109/13814789609162146
7. Afshar S, Roderick PJ, Kowal P, Dimitrov BD, Hill AG. Multimorbidity and the inequalities of global ageing: A cross-sectional study of 28 countries using the World Health Surveys. BMC Public Health 2015; 15: 776. https://doi.org/10.1186/s12889-015-2008-7
8. Xi J, Li PW, Yu DS. Multimorbidity: The need for a consensus on its operational definition. J Adv Nurs 2024; 80(12): 4755-7. https://doi.org/10.1111/jan.16292
9. eBioMedicine. Multimorbidity: A complex challenge to support and optimise individual health. eBioMedicine 2024; 99: 104973. https://doi.org/10.1016/j.ebiom.2024.104973
10. Gallacher KI, Batty GD, McLean G, *et al*. Stroke, multimorbidity and polypharmacy in a nationally representative sample of 1,424,378 patients in Scotland: Implications for treatment burden. BMC Med 2014; 12(1), 151. https://doi.org/10.1186/s12916-014-0151-0
11. Downer MB, Li L, Carter S, Beebe S, Rothwell PM. Associations of multimorbidity with stroke severity, subtype, premorbid disability, and early mortality: Oxford Vascular Study. Neurology 2023; 101(6): e645–e652. https://doi.org/10.1212/WNL.0000000000207479
12. Ghazali SS, Seman Z, Zainuddin NH, *et al*. Prevalence and factors associated with multimorbidity among older adults in Malaysia: A population-based cross-sectional study. BMJ Open 2021; 11(10): e052126. https://doi.org/10.1136/bmjopen-2021-052126
13. Downer MB, Li L, Carter S, Beebe S, Rothwell PM. Associations of multimorbidity with stroke severity, subtype, premorbid disability, and early mortality: Oxford Vascular Study. Neurology 2023; 101(6): e645–e652. https://doi.org/10.1212/WNL.0000000000207479
14. Shaikh N, Mohammed A, Seddiq M, Kidwai S, Shahzad D, Mahmoud MM. The effect of the Charlson Comorbidity Index on in-hospital complications, hospital length of stay, mortality, and readmissions among patients hospitalized for acute stroke. Cureus 2024; 16(5): e60112. https://doi.org/10.7759/cureus.60112
15. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. J Chronic Dis 1987; 40(5), 373-83. https://doi.org/10.1016/0021-9681(87)90171-8
16. Huang YQ, Gou R, Diao YS, *et al*. Charlson comorbidity index helps predict the risk of mortality for patients with type 2 diabetic nephropathy. J Zhejiang Univ Sci B 2014; 15(1): 58–66. https://doi.org/10.1631/jzus.B1300109
17. Carr JH, Shepherd RB, Nordholm L, Lynne D. Investigation of a new motor assessment scale for stroke patients. Phys Ther 1985; 65(2): 175-80. https://doi.org/10.1093/ptj/65.2.175
18. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: Validation of an instrument. Can J Public Health 1992; 83(Suppl 2): S7–S11
19. Blum L, Korner-Bitensky N. Usefulness of the Berg Balance Scale in stroke rehabilitation: A systematic review. Phys Ther 2008; 88(5): 559-66. https://doi.org/10.2522/ptj.20070205
20. Institute for Public Health Malaysia. National health and morbidity survey 2019: Non-communicable diseases, healthcare demand and health literacy—Key findings. Ministry of Health Malaysia. 2020.
21. Pendlebury ST, Rothwell PM. Risk of recurrent stroke, other vascular events and dementia after transient ischaemic attack and stroke. Lancet Neurol 2009; 8(9): 876-89. https://doi.org/10.1016/S1474-4422(09)70176-0
22. Lanas A, García-Rodríguez LA, Polo-Tomás M, *et al*. The changing face of hospitalisation due to gastrointestinal bleeding and perforation. Am J Gastroenterol 2011; 106(10): 1681-9. https://doi.org/10.1038/ajg.2011.230
23. Barnett K, Mercer SW, Norbury M, Watt G, Wyke S, Guthrie B. Epidemiology of multimorbidity and implications for health care, research, and medical education: A cross-sectional study. Lancet 2012; 380(9836): 37-43. https://doi.org/10.1016/S0140-6736(12)60240-2
24. Downer MB, Luengo-Fernandez R, Binney LE, *et al*. Association of multimorbidity with mortality after stroke stratified by age, severity, etiology, and prior disability. Int J Stroke 2024;19(3):348-58. doi: 10.1177/17474930231210397
25. Soo MJ, Chow ZY, Ching SM, *et al*. Prevalence, awareness and control of hypertension in Malaysia from 1980 to 2018: A systematic review and meta-analysis. World J Meta-Analysis 2020; 8(4), 320-44. https://doi.org/10.13105/wjma.v8.i4.320
26. Institute for Public Health. National Health and Morbidity Survey 2019: Non-communicable diseases, risk factors and other health problems (Volume I). Ministry of Health Malaysia. 2019
27. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. J Chronic Dis 1987; 40(5): 373-83. https://doi.org/10.1016/0021-9681(87)90171-8
28. Quan H, Sundararajan V, Halfon P, *et al*. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. Med Care 2005; 43(11); 1130-9. https://doi.org/10.1097/01.

mlr.0000182534.19832.83
29. Putman K, De Wit L, Schupp W, *et al*. Inpatient stroke rehabilitation: A comparative study of admission criteria to stroke rehabilitation units in four European centres. J Rehabil Med 2007; 39(1): 21-6. https://doi.org/10.2340/16501977-0006
30. Ottenbacher KJ, Hsu Y, Granger CV, Fiedler RC. The reliability of the Functional Independence Measure: A quantitative review. Arch Phys Med Rehabil 1996; 77(12), 1226-32. https://doi.org/10.1016/s0003-9993(96)90184-7
31. de Groot V, Beckerman H, Lankhorst GJ, Bouter LM. How to measure comorbidity: A critical review of available methods. J Clin Epidemiol 2003; 56(3): 221-9. https://doi.org/10.1016/S0895-4356(02)00585-1
32. Southern DA, Quan H, Ghali WA. Comparison of the Elixhauser and Charlson/Deyo methods of comorbidity measurement in administrative data. Med Care 2004; 42(4): 355-60. https://doi.org/10.1097/01.mlr.0000119227.62432.83
33. Muir SW, Berg K, Chesworth B, Klar N, Speechley M. Quantifying the magnitude of risk for balance impairment on falls in community-dwelling older adults: A systematic review and meta-analysis. J Clin Epidemiol 2010; 63(4): 389-406. https://doi.org/10.1016/j.jclinepi.2009.06.010
34. Poole JL, Whitney SL. Motor Assessment Scale for stroke patients: Concurrent validity and interrater reliability. Arch Phys Med Rehabil 1988; 69(3 Pt 1), 195-7.