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Predictors of ambulatory recovery and walking proficiency in community-dwelling stroke survivors: a cross-sectional study

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Abstract

Background: Although the major goal of rehabilitation is to return a stroke survivor (SSv) to as close to their pre-stroke functioning, limitation in ambulatory recovery and walking proficiency is the major impediment. Despite the importance of walking to the outcomes in stroke, factors predicting its recovery remain unclear. This study therefore was aimed at exploring the predictors of ambulatory recovery and walking proficiency in community-dwelling SSv.

Methods: This study involved 164 (83females) SSv from four tertiary health institutions in Nigeria. Ambulatory level and status was assessed using Functional Ambulatory Classification, motor function using the Fugl-Myer Assessment scale (lower limb), and ambulatory/waking endurance using the 6-min walk test. Ambulatory capability was assessed using the Lower Extremity Functional Scale, ambulatory self-confidence using the Ambulatory Self-Confidence Questionnaire, and functional ambulatory profile using the Modified Emory Functional Ambulation Profile. Mobility was assessed using the Modified Rivermead Mobility Index, functional mobility using Time Up and Go, balance using the Berg Balance Scale, and cognitive function using the modified Mini-Mental State Examination. Spatial indexes were assessed using the Footprint method and temporal variables using a stopwatch and gait speed on a 10-m walkway. Data was analyzed using multiple regression analysis at $p \leq 0.05$.

Results: Participants (mean age = 54.3±11.36 years) have had stroke for 12.9 ± 17.39 months and spent 9.82 ± 13.19 months in hospital admissions. More (65.2%) had ischemic stroke with 54.3% of them having left hemispheric stroke. The predictors of ambulatory onset in SSv were stroke duration and length of stay in hospital admission contributing 40.3% ($\beta = 0.403$) and 17.6% ($\beta = 0.176$) respectively to the variance. Mobility ($\beta = 0.249$, $p < 0.001$), gait speed ($\beta = 0.185$, $p = 0.012$), paretic double-limb support time ($\beta = 0.155$, $p = 0.03$), balance ($\beta = 0.334$, $p <$ 0.001), and cognition ($\beta = 0.155$, $p = 0.01$) were predictors of ambulatory self-confidence contributing 59.5% to the variance. Balance ($\beta = 0.363$, $p < 0.001$) and mobility ($\beta = 0.155$, $p = 0.015$) were predictors of ambulatory capability contributing 52.9% to the variance. Balance ($\beta = -0.489$, $p < 0.001$), paretic double-limb support time ($\beta = 0.223$, $p = 0.003$), gait speed ($\beta = -0.181$, $p = 0.022$), and paretic swing phase duration ($\beta = 0.177$, $p = 0.01$) were predictors of functional ambulatory profile ($p < 0.05$) contributing 52.9% to the variance. Gait speed ($\beta = -0.648$, $p < 0.001$) and step length ($\beta = -0.157$, $p = 0.003$) were predictors of walking endurance contributing 76.5% to the variance.

Conclusion: Ambulatory recovery and walking proficiency depend on the interplay among duration of stroke and length of hospitalization on the one hand and balance performance, cognitive function, and the spatiotemporal integrity of the affected limb on the other hand.

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Keywords: Ambulatory recovery, Walking proficiency, Community-dwelling, Stroke survivors, Predictors

Introduction

The major goal of rehabilitation in stroke is to return a stroke survivor to an independent functioning as close to their pre-stroke status as possible. One of the major aspirations of a stroke survivor and their family alike is when and how to return to walking. However, a clinician is not only looking out for walking but the recovery of effective and efficient walking to reduce dependency in activity of daily living and burden of care on the informal caregivers. Hence, the focus is on community re-integration and return to productive lifestyle. Therefore, the recovery of function is not qualified but quantified for effective outcomes.

Stroke is a major cause of disability of adult onset and one of the major causes of loss of productivity in an individual who has been hitherto active before the onset of stroke. Therefore, recovery of ambulatory performance and walking proficiency is both the concern of everyone for improve quality of life [1–3]. The motor impairments in stroke survivors do not only result in deficiency ambulation, it negatively affects their ability to perform everyday activities without assistance resulting in activity limitation and participation restriction [4]. The impairment and dysfunction in walking typified by obvious gait asymmetry is a usual difficulty which occurs in the majority of stroke survivors as they recover from stroke especially in those with ischemic stroke and of older age [5–7]. This walking disability becomes the common obstacle affecting their community participation, community functioning, and productive lifestyle [1, 8]. It hinders their reaction time to challenges within their environment especially in negotiating obstacles, climbing stairs, walking on inclines, and uneven surfaces [9]. Hence, evaluation of motor function recovery typified by prior movement reemergence like in pre-stroke stage is key in stroke patients' assessment and a fundamental part of stroke rehabilitation to project for adequate societal re-integration and community participation especially from the onset of a stroke [10, 11].

The effective return of stroke survivor to the community depends on the proficiency of the independent walking and performance. Hence, walking rehabilitation and gait recovery is a major focus for stroke survivors and substantial efforts and resources are being deployed to aid the walking recovery post-stroke [12–15]. More importantly that the ability to walk independently after stroke event is a crucial functional goal that is used for gauging recovery and ability to participate in activities of daily living [16–18]. Return to walking also has the potential of preventing or reducing certain secondary musculoskeletal and cardiovascular complications post-stroke [13, 19]. Hence, it is pertinent to understand the determinants of effective walking performance by exploring the predictors of ambulatory efficiency in stroke survivors.

Despite the importance of walking to the outcomes in stroke, factors predicting its recovery remain unclear. Although previous studies have explored the predictors of motor and functional recovery after stroke [7, 20], the predictors of ambulatory recovery and walking proficiency in stroke survivors have not been well delineated. Neurological and functional recovery has been reported to improve rapidly within the initial 6 months post-stroke which continues even beyond, though not as rapidly [7, 21–23]. Nevertheless, normal walking function ability in stroke survivors is affected by several factors such as cognitive dysfunction, cognitive task, motor task, and cognitive-motor interference [24, 25]. This is because many factors affect effective walking as there are many indexes that contribute to functional ambulation.

Many stroke patients are discharged home with cares on the informal caregivers. Hence, the recovery of ambulatory function and proficiency in walking will help in reducing the burden of care at home and improve community functioning thereby reducing the possibility of other secondary complications. Although many studies have focused on improving walking functioning in stroke survivors, the factors predicting the ambulatory indices especially the specificity of such factors to specific ambulatory function remain elusive. More importantly, the contribution of spatiotemporal indexes with balance and cognitive factors to productive ambulation remain a subject for debate. Thus, it will be vital to determine the precise predictors of such indices which will aid in tailoring gait rehabilitation strategies. This study, therefore, explores the predictors of ambulatory recovery and walking efficiency in community-dwelling stroke survivors to contribute to clinical decision-making in effective stroke rehabilitation. Hence, the question is, what are the predictors of ambulatory recovery and walking proficiency in community-dwelling stroke survivors?

Methods

The study was a cross-sectional analytical which involved 164 (83 females) stroke survivors from four tertiary health institutions in Kano State, Nigeria. Ethical approval for the study was obtained from the Health Research Ethics of Committees of Kano State Ministry of Health, Aminu Kano Teaching Hospital, and College of Medicine, University of Lagos. This study involved ambulatory (with or without support) stroke survivors who had been discharged to the community and are still attending rehabilitation services in the chosen hospitals. They were included if they could walk 10 m with or without walking aid or human assistance but with a Mini-Mental State Examination (MMSE) score of at least 24. Individual with psychiatric disorders, seizure disorders, severe cardiopulmonary compromise, and severe visual and auditory defects and those with history of neurological and musculoskeletal conditions that would affect walking efficiency were excluded from the study. The sample size was calculated using a standard formula, $n= Z^2\ SD^2/d^2$ [26] where n is the required sample, Z is the standard normal variate at 5% type 1 error which is constant = 1.96, SD is the standard deviation derived from previous similar study = 0.30, and d is the absolute error or precision or acceptable margin of error at 0.05. With 15% possible attrition added to the calculation, a sample of 159 participants was obtained, but this study involved 164 participants.

Sociodemographic and clinical characteristics such as stroke onset, duration, laterality, type, and comorbidity were assessed using proforma. Their ambulatory status pre-stroke, ambulation onset post-stroke, and duration of ambulation post-stroke were also assessed. Ambulatory indices, ambulatory status, motor function, ambulatory endurance, ambulatory capabilities, ambulatory self-confidence, functional ambulatory profile, mobility level, and functional mobility, were assessed. Spatial variables, stride length, step length, and stride/step width, as well as temporal variables, speed, cadence, gait cycle duration, paretic limb stance phase duration, paretic limb swing phase duration, and paretic initial double-limb support time, were also assessed.

The assessment of ambulatory characteristics entails assessing the ambulatory status, motor function, ambulatory/walking endurance, ambulatory capabilities, ambulatory self-confidence, functional ambulatory profile, mobility level, and functional mobility. Ambulatory status was assessed using Functional Ambulatory Classification (FAC): to classify ambulatory status/level. A reliable, valid, and responsive FAC scale which is a 6-point scale was used to assess the amount of support the patient requires when walking [27]. Motor function was assessed using the Fugl-Myer Assessment scale (lower-limb part) developed by Fugl-Myer [28] in 1975. The motor scale is recommended as an outcome measure for better motor recovery assessment in stroke patients [29]. Ambulatory/waking endurance was assessed using a 6-min walk test [30]. Ambulatory capability was assessed using the Lower Extremity Functional Scale. The scale is valid and reliable and is sensitive to changes in lower limb dysfunction among stroke survivors [31]. Their ambulatory self-confidence was assessed using the Ambulatory Self-Confidence Questionnaire (ASCQ) [32], while their functional ambulatory profile was assessed using he Modified Emory Functional Ambulation Profile which was reported to be a responsive, reliable, and valid scale [33]. The mobility level was assessed using Modified Rivermead Mobility Index which has its psychometric properties tested [34].

Their functional mobility was assessed using the Time Up and Go test which was shown to be valid and reliable [35]. Balance performance (dynamic and static balance) was assessed using Berg Balance Scale [36]. Their cognitive functional performance was assessed using the modified Mini-Mental State Examination [37].

In assessing their spatial indexes, their stride length, step length, and stride/step width were assessed using the Footprint method [38, 39]. Foot and marks were used to measure the respective distances between one point and another. Stride length was measured as distance between the heel strike of one foot to the next successive heel strike of the same foot using midpoint of the heel bisection as the reference point. Step length is the distance between the heel strike of one foot to the next successive heel strike of the other foot using midpoint of the heel bisection as the reference point. Their stride/step width or base of support was measured as the distance between midpoints of two opposite heels. To minimize/avoid measurement error and to ensure accuracy in the values/readings obtained, each parameter was measured at least twice, and the average value was taken and recorded. All measurements were done for both paretic and non-paretic extremities.

In assessing their temporal variables, a standard digital stopwatch was used [40]. The procedure involved measurement of time taken to carry out different activities in the gait cycle. In order to minimize/avoid measurement error and ensure accuracy in the values/readings obtained while measuring gait cycle and its components, each parameter was measured midway along the 10M track at least twice and the average value was taken and recorded. Except for speed and cadence, all measurements were done for both paretic and non-paretic extremities. The parameters assessed include gait speed, cadence, stride time/gait cycle duration, stance phase duration, swing phase duration, and initial double-limb support time.

Gait speed in meters per second was assessed using 10-m walk test which is recommended for assessing gait speed [41]. Their cadence was measured as number of steps per minute. Stride time which is the gait cycle duration was measured as time in seconds between the first heel contact of one foot (right or left) to the subsequent successive heel contact of the same foot. Stance phase duration was measured as the time in seconds when the reference lower limb is in contact with the ground. Swing phase duration was measured as time in seconds when the reference lower limb is not in contact with the ground. Initial double-limb support time was measured as the initial time in seconds when both feet are in contact with the ground.

Data analysis

Descriptive statistics of mean, standard deviation, frequency, and percentage were used to present the sociodemographic and clinical characteristics of the participants. Hierarchical and standard multiple regression analysis was used to determine the predictors of ambulatory recovery and walking proficiency. Statistical Package for Social Sciences (SPSS) version 25 was used for the analysis. The level of significance was set at $p \leq 0.05$.

Results

The mean age of the participants was 54.3 ± 11.36 years. More of the participants were male (50.6%), had ischemic stroke (65.2%), and had left-sided affectation (54.3%) (Table 1). They have had stroke for 12.9±17.39 months and were hospitalized for 9.82±13.19 months. Their mean ambulatory onset after stroke was 1.86±2.89 months with post-stroke ambulatory duration of 11.14±16.30 months.

Hierarchical multiple regression analysis for prediction of ambulatory onset post-stroke showed that only stroke duration and length of hospital stay predict ambulatory onset with each contributing 40.3% ($\beta = 0.403$) and 17.6% ($\beta = 0.176$) respectively to the regression model (Table 2). The values obtained in hierarchical multiple regression and presented in Table 2 were as a result of interaction between the independent (predictor) variables and the dependent (outcome) variables in the regression model using SPSS software. Standard multiple regression revealed mobility level ($\beta = 0.249$, $p < 0.00$), gait speed ($\beta = 0.185$, $p = 0.012$), paretic initial double-limb support time ($\beta = 0.155$, $p = 0.025$), balance ($\beta = 0.334$, $p < 0.00$), and cognition ($\beta = 0.155$, $p = 0.011$) to be the significant predictors of ambulatory self-confidence (Table 3). A total of 59.5% ($R^2 = 0.595$) of the variance in the ambulatory self-confidence was predicted/explained by the final regression model ($R^2 = 0.595$, $F_{, \mathrm{df}=10,}$ =22.305, $p \leq 0.001$). Apart from the said variables, all other variables were not significant ($p > 0.005$) predictors of ambulatory onset in stroke survivors (Table 3). Balance ($\beta = 0.363$, $p < 0.001$) and mobility level ($\beta = 0.155$, $p = 0.015$) are the significant predictors of ambulatory capability ($p < 0.05$); a total of 52.9% ($R^2 = 0.529$) of the variance in ambulatory capability was explained by the final regression model ($R^2 = 0.529$, $F_{, \mathrm{df}=10,} = 17.039$, $p \leq 0.001$) (Table 4). Except for balance and mobility level, all other variables were non-significant ($p > 0.005$) predictors of ambulatory capability (Table 4). The values obtained in standard multiple regression and presented in Tables 3 and 4 were as a result of interaction between the independent (predictor) variables and the dependent (outcome) variables in the regression model using SPSS software. In all the regression analysis tables, the R^2 represents the variance in the dependent variable while β is the standardized coefficient representing the individual contribution of the independent (predictor) variables to the variance of the dependent (outcome) variable.

Table 1 Sociodemographic and clinical characteristics of the participants

Variables	*n* (%)
Sex	
Male	83 (50.6)
Female	81 (49.4)
Type of stroke	
Ischemic	107 (65.2)
Hemorrhagic	57 (34.8)
Side of stroke affectation	
Right	75 (45.7)
Left	89 (54.3)
Functional Ambulatory Category	
2	5 (3)
3–4	51 (31.1)
5–6	108 (65.9)
Comorbidities	
Diabetes mellitus	22 (13.4)
Gynecological/others	12 (7.3)
None	130 (79.3)

n frequency, % percentage

Furthermore, balance ($\beta = -0.489$, $p < 0.001$), paretic initial double-limb support time ($\beta = 0.223$, $p = 0.003$), gait speed ($\beta = -0.181$, $p = 0.022$), and paretic swing phase duration ($\beta = -0.177$, $p = 0.011$) are the significant predictors of functional ambulatory profile ($p < 0.05$); a total of 52.9% ($R^2 = 0.529$) of the variance in functional ambulatory profile was explained by the final regression model ($R^2 = 0.529$, $F_{4, \mathrm{df}=10,} = 17.098$, $p \leq 0.001$) (Table 5). All other variables except the one mentioned above were not significant ($p > 0.005$) predictors of functional ambulatory profile in stroke survivors (Table 5). In addition, gait speed ($\beta = -0.648$, $p < 0.001$) and step length ($\beta = -0.157$, $p = 0.003$) are the significant predictors of walking endurance ($p < 0.05$); a total of 76.5% ($R^2 = 0.765$) of the variance in walking

Table 2 Hierarchical multiple regression analysis for the prediction of ambulatory onset and contributions of the respective predictors to the prediction model

Model summary								
Model	*R*	R^2	Adjusted R^2	R^2 change	*F* change	Sig. *F* change	Durbin-Watson	SE
1	0.111	0.012	0.000	0.012	0.996	0.372	-	2.89
2	0.507	0.257	0.233	0.245	17.331	0.000	1.976	2.55
Predictive factor input								
Model	Predictors	(*B*)	(*β*)	Part C.	95% CI	*p*-value	*t*-value	
1	Constant	2.475			−0.12–5.07	0.061	1.88	
	Age	−0.022	−0.86	−0.088	−0.06–0.02	0.274	−1.10	
	Gender	0.386	0.067	0.067	−0.51–1.28	0.394	0.86	
2	Constant	1.048			−1.68–3.78	0.450	0.76	
	Age	0.006	0.023	0.023	−0.03–0.40	0.742	0.33	
	Gender	0.237	0.041	0.041	−0.55–1.02	0.550	0.60	
	Stroke DR	0.067	0.403	0.390	−0.04–0.09	<0.00*	5.70	
	Hosp. DR	0.038	0.176	0.166	0.01–0.07	0.017*	2.42	
	LEMF	−0.047	−0.119	−0.114	−0.10–0.01	0.098	−1.67	

a. Predictors: (constant), gender of the participants, age of the participants

b. Predictors: (constant), gender, age (years), stroke duration (months), lower extremity motor function, duration of in-patient hospital stays (days) of the participants

c. Dependent variable: ambulatory onset post-stroke

General regression predictive equation: $Y = a + bx$

Y = value of dependent variable; a = constant; b = regression coefficient of each predictor variable; x = value of each predictor variable

Ambulatory onset post-stroke is therefore = $2.475 + bx$

Values of b and x will be added to the equation continuously depending on the number of predictor variables

Model 1 is the first showing demographics (age and gender), model 2 is the second following model 1 and shows demographics (age and gender) and other independent (predictor) variables

Key: *Adjusted* R^2 Adjusted goodness-of-fit measure for the regression model, *Part C.* part correlation, *SE* Standard error, *Hosp.* Hospital, *df* degree of freedom, *DR* Duration, *B* unstandardized coefficient, *β* standardized coefficient, *LEMF* Lower extremity motor function

*Significant at $p \leq 0.05$; ANOVA summary: $F = 10.918$, df = 5, $p < 0.001$

Table 3 Standard multiple regression analysis for the prediction of ambulatory self-confidence

Dependent variable	**Predictors**	**SE**	**β**	***t*-val.**	***p*-value**	**95% CI**
Ambulatory self-confidence	(Constant)	20.61		−3.54	0.001	−113.7 to −32.3
	LEMF	0.33	0.009	0.14	0.888	−0.60–0.69
	MBL	0.37	0.249	4.24	<0.00*	0.84–2.30
	PSTPL	0.22	0.116	1.67	0.098	−0.07–0.80
	Gait speed	10.75	0.185	2.56	0.012*	6.25–48.72
	Cadence	0.11	0.052	0.80	0.426	−0.13–0.31
	PSWT	4.56	−0.009	−0.14	0.886	−9.67–8.36
	PSTT	4.16	−0.119	−1.55	0.124	−14.66–1.78
	PIDLST	4.97	0.155	2.27	0.025*	1.46–21.11
	Balance	0.25	0.334	4.56	<0.00*	0.66–1.66
	Cognition	0.18	0.155	2.57	0.011*	0.11–0.82

Final regression model for predicting ambulatory self-confidence ($R^2 = 0.595$, $F_{, df=10,} = 22.305$, $p \leq 0.001$). Regression equation: $Y = a + bx$; thus, ambulatory self-confidence = $-72.98 + bx$ where Y = value of dependent variable, a = constant, b = regression coefficient of each predictor variable, and x = value of each predictor. Values of b and x will be added to the equation continuously depending on the number of predictor variables

Key: *LEMF* Lower extremity motor function, *MBL* Mobility level, *PSTPL* Paretic step length, *PSWT* Paretic swing time, *PSTT* Paretic stance time, *PIDLST* Paretic initial double-limb support time, *B* unstandardized coefficient, *SE* Standard error, *β* standardized coefficient, *t-val.* t-statistics, *p-value* significance level, *95% CI* 95% confidence interval, *df* degree of freedom, R^2 coefficient of determination, *F* ANOVA value

*Significant at $p \leq 0.05$

Table 4 Standard multiple regression analysis for the prediction of ambulatory capability

Dependent variable	Predictors	SE	*β*	*t*-val.	*p*-value	95% CI
Ambulatory capability	(Constant)	9.88		−2.75	0.007	−46.75 to −7.69
	LEMF	0.16	0.046	0.71	0.482	−0.20–0.42
	MBL	0.18	0.155	−2.45	0.015*	0.09–0.79
	PSTPL	0.11	0.116	1.54	0.125	−0.05–0.37
	Gait Speed	5.15	0.132	1.69	0.093	−1.47–18.89
	Cadence	0.05	0.061	0.87	0.386	−0.06–0.15
	PSWT	2.19	−0.032	−0.46	0.643	−5.34–3.31
	PSTT	2.00	−0.054	−0.65	0.518	−5.24–2.65
	PIDLST	2.38	−0.025	−0.33	0.739	−5.51–3.91
	Balance	0.12	0.363	4.61	<0.001*	0.32–0.80
	Cognition	0.09	0.102	1.57	0.118	−0.04–0.31

Final regression model for predicting ambulatory capability ($R^2 = 0.529$, $F_{, df=10,} = 17.039$, $p \leq 0.001$). Regression equation: $Y = a + bx$; thus, ambulatory capability = $-27.22 + bx$ where Y = value of dependent variable, a = constant, b = regression coefficient of each predictor variable, and x = value of each predictor. Values of b and x will be added to the equation continuously depending on the number of predictor variables

Key: *LEMF* Lower extremity motor function, *MBL* Mobility level, *PSTPL* Paretic step length, *PSWT* Paretic swing time, *PSTT* Paretic stance time, *PIDLST* Paretic initial double-limb support time, *B* unstandardized coefficient, *SE* Standard error, *β* standardized coefficient, *t-val.* t-statistics, *p-value* significance level, *95% CI* 95% confidence interval, *Part C.* part correlation, *Tolr*. tolerance, *df* degree of freedom, R^2 coefficient of determination, *F* ANOVA value

*Significant at $p \leq 0.05$

Table 5 Standard multiple regression analysis model for the prediction of functional ambulatory profile

Dependent variable	Predictors	SE	*β*	*t*-val.	*p*-value	95% CI
Functional ambulatory profile	(Constant)	156.19		4.09	<0.001	330.32–947.48
	LEMF	2.46	0.075	1.14	0.255	−2.05–7.68
	MBL	2.81	0.105	1.66	0.099	−0.89–10.21
	PSTPL	1.66	0.042	0.56	0.575	−2.35–4.21
	Gait speed	81.45	−0.181	−2.32	0.022*	−349.55–−27.72
	Cadence	0.86	−0.085	−1.22	0.224	−2.74–0.65
	PSWT	34.57	−0.177	−2.58	0.011*	−157.52 to −20.91
	PSTT	31.54	0.142	1.72	0.087	−8.01–116.59
	PIDLST	37.67	0.223	3.03	0.003*	39.73–188.59
	Balance	1.93	−0.489	−6.21	<0.001*	−15.77 to −8.16
	Cognition	1.36	−0.071	−1.09	0.278	−4.16–1.21

Regression equation: $Y = a + bx$; thus, functional ambulatory profile = 638.90 $+bx$ where Y = value of dependent variable, a = constant, b = regression coefficient of each predictor variable, and x = value of each predictor. Values of b and x will be added to the equation continuously depending on the number of predictor variables

Key: *LEMF* Lower extremity motor function, *MBL* Mobility level, *PSTPL* Paretic step length, *PSWT* Paretic swing time, *PSTT* Paretic stance time, *PIDLST* Paretic initial double-limb support time, *B* unstandardized coefficient, *SE* Standard error, *β* standardized coefficient, *t-val.* t-statistics, *p-value* significance level, *95% CI* 95% confidence interval, *Part C.* part correlation, *Tolr*. tolerance, *df* degree of freedom, R^2 coefficient of determination, *F* ANOVA value

Final regression model for predicting functional ambulatory profile (R^2 =0.529, $F_{4, df=10,}$ =17.098, $p \leq 0.001$)

*Significant at $p \leq 0.05$

endurance was explained by the final regression model ($R^2 = 0.765$, $F_{4,\ df=10,} = 49.395.82$, $p \leq 0.001$) (Table 6). Apart from gait speed and step length, all other variables were not significant ($p > 0.005$) predictors of walking endurance. The values obtained in standard multiple regression and presented in Tables 5 and 6 were as a result of interaction between the independent (predictor) variables and the dependent (outcome) variables in the regression model using SPSS software. In all the regression analysis tables, the R^2 represents the variance in the dependent variable while β is the standardized coefficient representing the individual contribution of the independent (predictor) variables to the variance of the dependent (outcome) variable.

Table 6 Standard multiple regression analysis model for the prediction of ambulatory endurance

Dependent variable	Predictors	SE	β	t-value	p-value	95% CI
Ambulatory endurance	(Constant)	31.02		1.99	0.842	−55.10–67.47
	LEMF	0.49	−0.064	−1.40	0.165	−1.65–0.28
	MBL	0.56	−0.023	−0.52	0.605	−1.39–0.81
	PSTPL	0.33	0.157	2.97	0.003*	0.33–1.63
	Gait speed	16.18	0.648	11.75	<0.001*	158.10–222.02
	Cadence	0.17	0.078	1.59	0.114	−0.07–0.61
	PSWT	6.87	−0.055	−1.14	0.258	−21.36–5.77
	PSTT	6.26	−0.029	−0.50	0.620	−15.48–9.27
	PIDLST	7.48	−0.042	−0.82	0.416	−20.98–8.68
	Balance	0.38	0.108	1.95	0.054	−0.01–1.50
	Cognition	2.70	0.025	0.55	0.583	−0.39–0.68

Final regression model for predicting ambulatory/walking endurance ($R^2 = 0.765$, $F_{4,\ df=10,} = 49.395.82$, $p \leq 0.001$). Regression equation: $Y = a + bx$; thus, walking endurance = 6.19+*bx* where *Y* = value of dependent variable, *a* = constant, *b* = regression coefficient of each predictor variable, and *x* = value of each predictor. Values of *b* and *x* will be added to the equation continuously depending on the number of predictor variables

Key: *LEMF* Lower extremity motor function, *MBL* Mobility level, *PSTPL* Paretic step length, *PSWT* Paretic swing time, *PSTT* Paretic stance time, *PIDLST* Paretic initial double-limb support time, *B* unstandardized coefficient, *SE* Standard error, *β* standardized coefficient, *t-value* t-statistics, *p-value* significance level, *95% CI* 95% confidence interval, *Part C.* part correlation, *Tolr.* tolerance, *df* degree of freedom, R^2 coefficient of determination, *F* ANOVA value

*Significant at $p \leq 0.05$

Discussion

This study explored the predictors of ambulatory recovery and walking proficiency among community-dwelling stroke survivors. The preponderance of ischemic stroke and the age of the participants in this study followed the global norms of stroke types of distribution and the average age of occurrence of stroke. It substantiates the fact that stroke is still common among productive age group leaving more previously productive able adult individuals unproductive or becoming totally dependent in the performance of activities of daily living. Hence, effort at reducing the incidence of stroke should be a concern of all with healthcare professionals being at the forefront of the vanguard.

The fact that ambulatory recovery and walking proficiency in stroke survivors are predicted by those factors that usually do not attract the attention of clinicians during plan for hospital discharge calls for paradigm in the clinical reasoning and clinical decision-making among experts in stroke care. There should be patient-centered team discussion and planning involving all experts in the stroke team and the informal caregivers for proper informed decision towards the discharge of the patient for effective community re-integration. This will enhance total re-integration of stroke survivors for return to productive lifestyle after hospital discharge. It will reduce the number of stroke patients that are discharged to the community and remain non-functional and disabled. This is important because the crucial constituent of daily physical activity depends on effective ambulatory functioning [42]. The outcomes of this study are crucial as they point to salient attributes especially spatiotemporal characteristics, balance, mobility, and cognition which if not well tailored towards the ambulatory retraining of a stroke survivor will be an impediment to the full and proficient walking performance. When these attributes are well marshalled, it will improve the functional mobility, ambulatory capabilities, ambulatory endurance, ambulatory activity, and ambulatory self-confidence of a community-dwelling stroke survivors, thereby improving their societal functioning. These results will shape and sharpen clinical practice for stroke rehabilitation. It will help the stroke care teams to make optimal plan and appropriate management decision for walking recovery in stroke survivors [20].

The fact that stroke duration and duration of in-patient hospital stay predict ambulatory onset post-stroke with stroke duration having the higher contribution calls for early ambulation and walking and gait training in stroke patients. Stroke patients who are stable clinically should be discharged early for comprehensive rehabilitation. This will go a long way in reducing disability sequel to stroke. Conversely, it will also reduce the burden of care on the informal caregivers. This corroborates that of a previous study that initiation of early rehabilitation strategies within first 2 weeks after a stroke enhances better outcome for independent functional recovery in stroke survivors [43]. This also corroborates that of earlier authors who had earlier concluded that using bedside measures at 1-week post-stroke time to walking independently post-stroke algorithm can accurately predict whether and when an individual patient can walk independently [44].

The outcomes of this study showed that one of the major approaches to better ambulatory self-confidence is to improve mobility level, gait speed, paretic initial double-limb support time, balance, and cognition. Hence, effective ambulatory retraining in stroke survivors should incorporate these factors together with improved balance performance and cognitive retraining. Hence, improving balance should be a major target of rehabilitation while improving the muscle strength. The significant prediction of endurance in the participants in this study corroborates that obtained in a previous study that improvement in motor function recovery is a predictor of improvement in ambulatory endurance [45]. This can be further explained by the report in a previous study that gait endurance is a predictor of ambulatory outcome in the first 6 months of hospital discharge post-stroke [46].

One of the major clinical applications of the outcomes of this study is the fact that it may equip clinicians in the effective walking performance retraining in stroke survivors. This is because the indexes such as walking endurance and stride length are major indicators for progress of gait performance [27]. This finding agrees with that of previous authors who reported that walking endurance impacts vitally in home and community walking activity after stroke [47]. The findings about the walking recovery are vital for the stroke survivors' rehabilitation because detailed knowledge of recovery is crucial for rehabilitation and discharge planning [48]. In addition, detailed knowledge of walking performance increases chances of the ability to recover walking in stroke survivors [49].

The fact that gait speed predicts most of the ambulatory recovery characteristics can be explained by the fact that an improved self-confidence in ambulation with adequate balance will improve gait speed in an individual. A similar finding has been previously reported with the conclusion that practical ambulation ability is associated with gait speed and is valuably predicted by the gait speed [50]. In addition, fast walking speed is a useful early predictor to attain independent post-stroke community walking [51]. The outcome of this study suggests that attainment of good gait speed is an important determinant of successful ambulation. This is like those of previous reports that gait speed is a strong determinant of community mobility and that better walking speed is associated with community mobility in stroke [52, 53]. Previous studies have also concluded that gait speed is a suitable predictor of community walking post-stroke and that gait speed has exceptional ability to indicate community ambulation ability in stroke survivors [54–56].

The results of this study show the importance of balance in effective walking, as it significantly determines self-confidence, capability, and functional ambulatory profile during walking. This is important as more efficient walking pattern is obtainable in stroke survivors with higher balance performance [57]. This is clinically important as balance has been shown to have a vital role on home and community walking following stroke with its recovery ensuring safety and stability in ambulatory performance [47, 58]. Self-perceived balance is a helpful early predictor to achieve independent community walking post-stroke [51]. Hence, to attain improvement in stroke survivors' ability to walk, functional balance should be a vital target during rehabilitation [58]. This is important as deficits in balance result in reduced ambulatory activity in chronic stroke survivors [59].

The fact that specific gait cycle components especially paretic initial double-limb support time and swing time were determinants of the performance of effective ambulation shows that return to walking in stroke survivors depends on the effective recovery of the affected limb especially in improving their ambulatory self-confidence and profile. Plummer-D'Amato et al. [60] had earlier reported that double-limb support involving paretic weight acceptance may impact on cognitive-motor interference in gait which could affect community ambulation in stroke. Paretic swing time was found to be a significant predictor of ambulatory profile. This supports the opinion that long-distance walking is importantly determined in post-stroke individuals by propulsion generation ability while walking [61]. It has been reported that quantifiable markers of post-stroke impaired walking performance include increased step length and stride time variability and decreased width variability as well as inter between limb difference in swing and pre-swing time variability [62]. The contribution of cognitive functioning to the self-confidence and effective mobility performance in the participants shows the importance of adequate mental orientation, awareness, and alertness to effective walking functioning. This is a pointer to the fact that cognition and walking confidence are related. Hence, in mild to moderate stroke survivors, global cognitive performance outcomes and gait performance change are strongly associated [63].

In summary, recovery of efficient ambulation in stroke survivors is determined by factors such as duration of stroke and in-patient hospital stay, gait speed, balance, mobility level, paretic initial double-limb support time, paretic limb swing time, paretic limb step length, and cognition. It is therefore expedient to focus on such factors in gait rehabilitation of stroke survivors especially while aiming at improving ambulatory recovery and walking proficiency in the stroke survivors. Also, identifying such factors will assist clinicians especially physiotherapists to know what to focus on to ensure sustainable recovery of walking proficiency for effective community and societal functioning and return to productive lifestyle after a stroke. The outcome of this study will enhance individualized rehabilitation for stroke patients for community functioning. It will enhance individualized therapy, and it has also provided more evidence for rehabilitation of stroke survivors for effective community re-integration and return to work. Because this study is a cross-sectional study, the generalization of the results should be cautiously applied. Hence, a clinical trial is needed to provide further evidence to this finding.

Conclusions

It can be concluded that, although ambulatory recovery and walking proficiency in stroke survivors are influenced by interplay among many factors, ambulatory recovery and walking proficiency in stroke survivors depend on the interplay among duration of stroke and length of hospitalization on the one hand and balance performance, cognitive function, and the spatiotemporal integrity of the affected limb on the other hand.

Abbreviations

ADL: Activities of daily living; MMSE: Mini-Mental State Examination; FAC: Functional Ambulatory Classification; ASCQ: Ambulatory Self-Confidence Questionnaire; SPSS: Statistical Package for Social Science.

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Authors' contributions

JSU, CAOG, and OAO conceptualize the study, design the study, and wrote the paper. JSU performed the data collection. JSU and CAO analyzed the data. JSU, CAO, and OAO interpreted the data. All the authors were substantially involved in drafting and revising of the manuscript. All authors have read and approved the final version of the manuscript.

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Availability of data and materials

Data will be made available by the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Health Research Ethics Committees of College of Medicine University of Lagos, Aminu Kano Teaching Hospital, and Kano State Ministry of Health. All participants consented to participate in the study before being enrolled in the study.

Competing interests

The authors declare that they have no competing interests.

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