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Gait speed and balance function strongly determine the ability to walk independently without using a wheelchair in a facility setting for stroke patients

Yuta Ichinosawa,[1] Shinobu Shimizu,[2] Nami Takemura,[3] Katsuya Taira,[3] Michiru Hamakawa,[3] Yuki Nakachi,[3] Morihiko Goya,[3] Tomoya Yamazato,[3] Ryota Shimose,[1] Hajime Miura,[1] Satoshi Tsunoda,[1] Ryuichiro Yamada,[1] Takayuki Nakanishi,[3] Atsuhiko Matsunaga[1,2]

[1] Kitasato University Graduate School of Medical Sciences
[2] Kitasato University, School of Allied Health Sciences
[3] Okinawa Rehabilitation Center Hospital, Okinawa

Objective: There appears to be a gap between ambulatory ability and actual walking performance in stroke patients in facility settings. Few studies have reported on indicators that can accurately assess patient ability to walk independently in facility settings without wheelchair assistance (practical ambulation). This study aimed to examine whether or not measures of physical function can determine practical ambulation status in stroke patients admitted to a convalescent rehabilitation ward.
Methods: A total of 443 stroke patients who received inpatient rehabilitation services were enrolled in this cross-sectional study. In addition to clinical characteristics including cognitive function, lower limb motor function on affected and unaffected sides (Stroke Impairment Assessment Set and leg strength, respectively), the Berg Balance Scale (BBS), comfortable gait speed (CGS), and walking ability were examined in patients who were divided into three groups according to time after stroke onset (early, middle, and late phases). Multivariate logistic regression and receiver operating characteristic curve analyses were performed to examine whether these indicators can discriminate between non-practical and practical walkers after adjusting for clinical characteristics in each group.
Results: Affected lower limb function in the early- and middle-phase groups ($P < 0.001$), and BBS and CGS in all groups ($P < 0.001$), were significantly associated with practical ambulation. Cut-off points of BBS and CGS for discriminating between non-practical and practical walkers were approximately 45 points and 30 m/minute, respectively, in all groups.
Conclusion: BBS and CGS are useful determinants of practical ambulation in stroke patients admitted to a convalescent rehabilitation facility.

Key words: stroke, walking ability, balance, gait speed

Introduction

Acute phase rehabilitation for stroke patients has been actively performed in recent years. Early post-stroke rehabilitation programs can effectively improve physical function and the ability to perform activities of daily living (ADLs) in patients and make early hospital discharge possible.[1] In Japan, patients with mild stroke are usually discharged home within a short period of time after the event, although a substantial number of patients with moderate to severe stroke, especially those in need of intensive rehabilitation, are admitted to specialized wards for rehabilitation (i.e., convalescent rehabilitation ward), where they stay for several months even after completing an acute stroke rehabilitation program.[1] In convalescent rehabilitation wards, patients receive seamless interventions not only in a rehabilitation training room but also in their living spaces and undergo rehabilitation programs that focus on improving ADL ability.[1] Because recovery of ambulation is one of the

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Correspondence to: Atsuhiko Matsunaga, Department of Rehabilitation Sciences, Graduate School of Medical Sciences, Kitasato University
1-15-1 Kitasato, Minami-ku, Sagamihara, Kanagawa 252-0373, Japan
E-mail: atsuhikonet@gmail.com

most important goals for post-stroke patients,[2] accurate assessment of actual walking performance in facility settings is important.[3]

The Functional Independence Measure (FIM) and Functional Ambulation Category (FAC)[4-8] are mainly used to assess walking ability in patients undergoing rehabilitation. FIM scores ≥6 indicate walking independence (6: "modified independence," 7: "complete independence") in a hospital ward or facility.[4] "Modified independence" means the patient can walk a minimum of 150 ft (50 m) without supervision using assistive devices such as a brace (orthosis) and cane.[5] However, this assessment also applies to patients who are normally ambulant but use a wheelchair under certain circumstances, such as going to the toilet, albeit independently. As such, the FIM alone cannot discriminate between practical and non-practical walking abilities in facility patients. On the other hand, the FAC is used to evaluate ambulation ability on a 6-point scale based on the extent of physical support patients require when walking.[6,7] For example, patients who can only walk indoors are assessed as level 2 ("household ambulation").[8] However, temporary wheelchair use is not taken into consideration in this assessment either.

The ability of patients to walk independently without wheelchair assistance around a hospital ward or facility, i.e., practical ambulation, is not taken into account when assessing ambulation status; and, to our knowledge, no study has adequately examined indicators of practical ambulation in patients living in facilities. There is likely to be a gap between ambulation ability and actual ambulatory performance in stroke patients in hospital wards or facilities.[9-11]

Walking training by therapists in a rehabilitation training room alone may not result in gains in physical fitness due to the limited time inpatients spend participating in exercise training.[12,13] Measures or indicators of practical ambulation in stroke patients in facility settings, such as in convalescent rehabilitation wards, need to be established, as they will help determine or predict practical ambulation status in patients, and help to develop concrete guidelines aimed at actively promoting walking guidance in convalescent rehabilitation wards.

Moreover, few studies have reported on the relationship between functional impairment and disability in terms of phase or time after stroke although functional recovery appears to be influenced by time after stroke.[14] Several previous reports have pointed out that the first 3 months correspond to the period of greatest neuroplasticity, and changes in functional recovery decrease and gradually reach a plateau beyond the 3-month period post-stroke.[15]

Therefore, this study aimed to examine whether or not measures of physical function can determine practical ambulation status in stroke patients admitted to a convalescent rehabilitation ward by time after stroke.

Materials and Methods

Participants were patients with stroke hemiparesis who underwent inpatient rehabilitation therapy at the Okinawa Rehabilitation Center Hospital from 2011 to 2016. Inclusion criteria were patients who were diagnosed with cerebral hemorrhage or cerebral infarction by computed tomography or magnetic resonance imaging, able to walk 10 m with or without assistive devices, and provided informed consent. Patients who were diagnosed with subarachnoid hemorrhage or brain tumor, had significant musculoskeletal or neurological disorders unrelated to stroke (e.g., multiple sclerosis or Parkinson's disease), orthopedic diseases (e.g., spinal canal stenosis, osteoarthritis, or spine or leg fractures), and visual deficits, or had difficulty understanding instructions were excluded from the study.

Participants underwent a rehabilitation program consisting of physical therapy, occupational therapy, and speech therapy on a daily basis, with the goal of achieving 9 units per day (1 unit comprised a 20-min session) in accordance with the 2014 Japanese Guidelines for the Management of Stroke.[16] Physical therapy involved performing standing up, sitting, and standing motions in daily living, transfer motions, wheelchair driving, walking, and stair climbing and descending practice in a stepwise manner. Occupational therapy included exercises involving ADLs, such as toilet activities, grooming, dressing, and bathing activities, upper extremity functional exercises including switching the dominant hand, and evaluation and training of higher brain dysfunctions. In speech therapy, rehabilitation targeted improving aphasia, dysarthria, eating disorders, and dysphagia.[17,18] All the patients agreed to participate in the follow-up study.

This study was approved by the Okinawa Rehabilitation Center Hospital Research Ethics Committee and was conducted in accordance with the Declaration of Helsinki.

Patient clinical characteristics

Clinical characteristics including age, sex, body weight, stroke type, affected side, and time from stroke onset were collected from patient medical records. In addition, cognitive function was assessed using the cognitive subscale of the Functional Independence Measure (Cog

FIM®). The Cog FIM® subscale is a part of the global FIM assessment and includes two items (communication and social cognition) that relate to cognitive functions such as comprehension, expression, social interaction, problem-solving, and memory.[19] A score of 35 points represents optimal performance. A significant positive correlation has been found with the Cog FIM® and Mini-Mental State Examination.[20]

Physical function

Affected lower limb function

Affected lower limb function was assessed with the motor items of the Stroke Impairment Assessment Set (SIAS) for neurological impairment.[21] The SIAS, developed for stroke outcome research in Japan,[22] assesses various aspects of impairment in hemiplegic patients, and has been shown to demonstrate interrater reliability, predictive validity, sensitivity, and scale quality.[23] The SIAS motor subscore of the lower limb ranges from 0 to 15 points[21] and consists of scores from three tests for the lower extremity (hip-flexion, knee-extension, and foot-pat); each score ranges from 0 to 5 points: 0 indicating complete paralysis, 3 indicating an ability to complete the task with difficulty, and 5 indicating no paresis.

Unaffected lower limb function

Unaffected lower limb function was assessed by measuring maximum leg strength with a hand-held dynamometer (μTas F1; ANIMA, Tokyo, Japan). The accuracy and reliability of this instrument have been reported previously.[24,25] Patients were seated on a bed in an upright posture with their feet over the side of the bed and their hip and knee flexed at an angle of 90 degrees. The dynamometer pad was placed perpendicularly to the leg just above the malleoli of the ankle. Patients were told to push against the dynamometer pad by attempting to straighten their knees for a period of 5 seconds. Isometric knee extensor strength was measured twice, and the highest value was used as the maximum leg strength. To adjust for differences in physical constitution among patients, maximum isometric leg strength was divided by body weight and expressed as a percentage of body weight.[26]

Balance function

Balance function was assessed using the Berg Balance Scale (BBS), a physical performance measure comprises of 14 items. Each item rates the ability of participants to maintain stability in a specified functional task on a 5-point (0−4) scale.[27] Possible total scores range from 0 to 56, with greater scores indicating better balance. BBS has been demonstrated to show excellent test-retest reliability and inter-rater reliability for participants with stroke.[28-30]

Gait speed

Self-selected comfortable gait speed (CGS) along a 10-meter walkway was measured to assess patient walking ability. Participants were instructed to "walk at a comfortable self-selected pace." Participants walked a total of 14 meters, and the time was measured for 10 meters excluding the first and last 2 meters. Using a digital stopwatch that records time within 0.01 sec, time measurement was manually started when the 0-meter mark was crossed, and stopped when the 10-meter mark was crossed. Self-selected CGS was measured twice and the average value (m/minute) was used to represent walking ability. Participants were allowed to use the walking aid and/or orthotic device they normally used throughout the measurements. Self-selected CGS measured in seconds or minutes is a valid and reliable measure of walking ability in people who have suffered stroke.[31,32]

Practical ambulation

Practical ambulation was defined as the ability to walk independently to all places in a hospital ward without a wheelchair or supervision, and corresponded to "walking independence" according to the FIM. Patients with an FIM score ≥6 (6: "modified independence", 7: "complete independence") were observed for 1 week to determine whether they actually used a wheelchair in the hospital ward, and those who did not use a wheelchair in the hospital ward were defined as practical walkers, i.e., those who were ambulant without wheelchair assistance at least within the hospital ward. Conversely, those with an FIM score ≥6 who used a wheelchair in the hospital ward or had an FIM score ≤5 (i.e., requiring a wheelchair in the hospital ward) were defined as non-practical walkers. A physiotherapist or nurse in the hospital ward made the observations.

Statistical analysis

Data are expressed as mean ± standard deviation (SD) or number (%). Enrolled patients were divided into the following 3 groups according to time after stroke onset: the early-phase group (1−2 months after onset), the middle-phase group (3−4 months after onset), and the late-phase group (5−6 months after onset). In addition, patients in each group were classified as non-practical or practical walkers, as described above. Differences in mean age, time since stroke, Cog FIM®, SIAS of the lower limb, leg strength, BBS, and CGS between non-practical and practical walkers were assessed in each group by ANOVA (analysis of variance). The χ^2 test for trend was used to assess dose-response relations for variables (i.e., sex, stroke type, and affected side) between non-practical and practical walkers. Correlations between SIAS of the lower limb, leg strength, BBS, and CGS in both non-practical and practical walkers were analyzed by calculating Spearman's rank correlation coefficients. To minimize the effect of collinearity and avoid redundancy, a correlation matrix was developed with a cut-off value of 0.7,[33] and when performing multivariate analysis, variables having a correlation coefficient with a cut-off value of ≥0.7 were analyzed separately. Univariate and multivariate logistic regression analyses were performed to examine associations between physical function measures and practical ambulation after adjusting for clinical characteristics. The area under the receiver operating characteristic (ROC) curve (AUC) was estimated for each significant variable identified. If the AUC was significant, the point that yielded the highest combined sensitivity and specificity was used as a cut-off point to estimate accuracy and positive and negative predictive values.

Statistical significance was defined as $P < 0.05$. All statistical analyses were performed using a computerized Statistical Package for Social Sciences (IBM SPSS statics 21.0 for Mac; IBM Corp., Armonk, NY, USA).

Results

Patient characteristics and physical function

A total of 443 stroke patients met the inclusion criteria. The clinical characteristics and physical function of the early-, middle-, and late-phase groups are summarized in Table 1. The early-phase group was comprised of 165 participants including 91 non-practical walkers and 74 practical walkers, the middle-phase group was comprised of 167 participants including 78 non-practical walkers and 89 practical walkers, and the late-phase group was comprised of 111 participants including 45 non-practical walkers and 66 practical walkers.

Cognitive function according to Cog FIM® was higher in practical walkers than in non-practical walkers in all 3 groups ($P < 0.01$). SIAS of the lower limb, leg strength, BBS, and CGS were also significantly higher in practical walkers than in non-practical walkers in all 3 groups ($P < 0.05$).

Correlation matrix

Spearman's rank correlation coefficients for SIAS of the lower limb, leg strength, BBS, and CGS are shown in Table 2. SIAS of the lower limb was significantly correlated with leg strength ($P < 0.05$) only in the early-phase group, and with BBS and CGS in all 3 groups ($P < 0.01$). Leg strength was significantly correlated with BBS and CGS in all 3 groups ($P < 0.01$). A significant correlation was also observed between CGS and BBS in all 3 groups ($P < 0.01$).

Univariate and multivariate logistic regression analyses

The results of univariate and multivariate logistic regression analyses for determinants of practical ambulation are shown in Table 3. The correlation coefficient between BBS and CGS, calculated to minimize the effect of multicollinearity, showed a cut-off value of ≥0.7. Therefore, when performing multivariate analysis, BBS and CGS were analyzed separately.

In the early-phase group, multivariate logistic regression analysis revealed that SIAS of the lower limb ($P = 0.005$) and BBS ($P < 0.001$) were significantly associated with practical ambulation in the BBS model, whereas SIAS of the lower limb ($P = 0.031$) and CGS ($P < 0.001$) were significantly associated with practical ambulation in the CGS model.

In the middle-phase group, multivariate logistic regression analysis revealed that SIAS of the lower limb ($P = 0.004$) and BBS ($P < 0.001$) were significantly associated with practical ambulation in the BBS model, whereas Cog FIM® ($P = 0.032$), SIAS of the lower limb ($P = 0.027$), and CGS ($P < 0.001$) were significantly associated with practical ambulation in the CGS model.

In the late-phase group, multivariate logistic regression analysis revealed that BBS ($P = 0.004$) was significantly associated with practical ambulation in the BBS model, whereas time since stroke ($P = 0.024$), Cog FIM® ($P = 0.024$) and CGS ($P < 0.001$) were significantly associated with practical ambulation in the CGS model.

ROC analysis

ROC curves were generated for each variable as shown in Figure 1. In the early-phase group, the AUC for BBS was 0.930 ($P < 0.001$), with a cut-off point of 44.5. The AUC for CGS was 0.955 ($P < 0.001$), with a cut-off point of 37.1 m/minute. In the middle-phase group, the AUC for BBS was 0.915 ($P < 0.001$), with a cut-off point of 49.5. The AUC for CGS was 0.921 ($P < 0.001$), with a cut-off point of 33.5 m/minute. In the late-phase group,

Table 1. Characteristics and physical function of non-practical and practical walkers

		Early-phase group		Middle-phase group		Late-phase group	
		Non-practical walkers (n = 91)	Practical walkers (n = 74)	Non-practical walkers (n = 78)	Practical walkers (n = 89)	Non-practical walkers (n = 45)	Practical walkers (n = 66)
Age	(yrs)	66.0 ± 14.1	63.1 ± 14.6	64.5 ± 14.2	63.3 ± 13.8*	64.8 ± 15.0	61.1 ± 13.8*
Sex	(Male/Female)	60/31	50/24	51/27	61/28	32/13	45/21
Stroke type	(Hemorrhage/Infarction)	39/52	29/45	45/33	39/50	31/14	29/37*
Affected side	(Right/Left)	48/43	41/33	41/37	45/44	24/21	42/24
Time since stroke	(months)	1.9 ± 0.3	1.9 ± 0.3	3.7 ± 0.5	3.7 ± 0.5	5.7 ± 0.5	5.5 ± 0.5
Cog FIM®		27.6 ± 7.1	31.1 ± 5.2**	27.1 ± 7.1	30.7 ± 5.5**	25.6 ± 7.4	30.5 ± 5.9**
SIAS of lower limb		9.6 ± 3.7	13.6 ± 1.5**	8.4 ± 4.0	12.8 ± 2.5**	7.7 ± 4.1	11.4 ± 3.9**
Leg strength	(%BW)	33.8 ± 14.5	45.5 ± 17.9**	33.7 ± 13.8	42.9 ± 15.6**	36.1 ± 15.5	45.1 ± 16.1*
BBS		32.9 ± 13.3	51.6 ± 5.2**	34.7 ± 11.2	51.1 ± 7.1**	34.4 ± 12.2	49.6 ± 6.7**
CGS	(m/minute)	21.2 ± 11.4	57.8 ± 18.3**	18.2 ± 10.2	50.4 ± 21.4**	17.9 ± 10.2	44.1 ± 19.2**

Cog FIM®, Cognitive Functional Independence Measure; SIAS, Stroke Impairment Assessment Set; BW, body weight; BBS, Berg Balance Scale; CGS, comfortable gait speed
Early-phase: 1 to 2 months after stroke onset, middle-phase: 3 to 4 months after stroke onset, late-phase: 5 to 6 months after stroke onset
*P < 0.05 (vs. non-practical walkers), **P < 0.01 (vs. non-practical walkers)

Table 2. Spearman's rank correlation coefficients between physical function measures

	Early-phase group				Middle-phase group				Late-phase group			
	SIAS of lower extremity	Leg strength	BBS	CGS	SIAS of lower extremity	Leg strength	BBS	CGS	SIAS of lower extremity	Leg strength	BBS	CGS
SIAS of lower limb	1.00	0.17*	0.57**	0.62**	1.00	0.07	0.48**	0.59**	1.00	0.02	0.51**	0.64**
Leg strength		1.00	0.43**	0.47**		1.00*	0.40**	0.38**		1.00*	0.42**	0.29**
BBS			1.00**	0.73**			1.00**	0.72**			1.00**	0.73**
CGS				1.00**				1.00**				1.00**

SIAS, Stroke Impairment Assessment Set; BBS, Berg Balance Scale; CGS, comfortable gait speed
Early-phase: 1 to 2 months after stroke onset, middle-phase: 3 to 4 months after stroke onset, late-phase: 5 to 6 months after stroke onset
*Significant correlation at P<0.05, **Significant correlation at P<0.01

the AUC for BBS was 0.868 (P < 0.001), with a cut-off point of 45.5. The AUC for CGS was 0.890 (P < 0.001), with a cut-off point of 26.3 m/minute.

Discussion

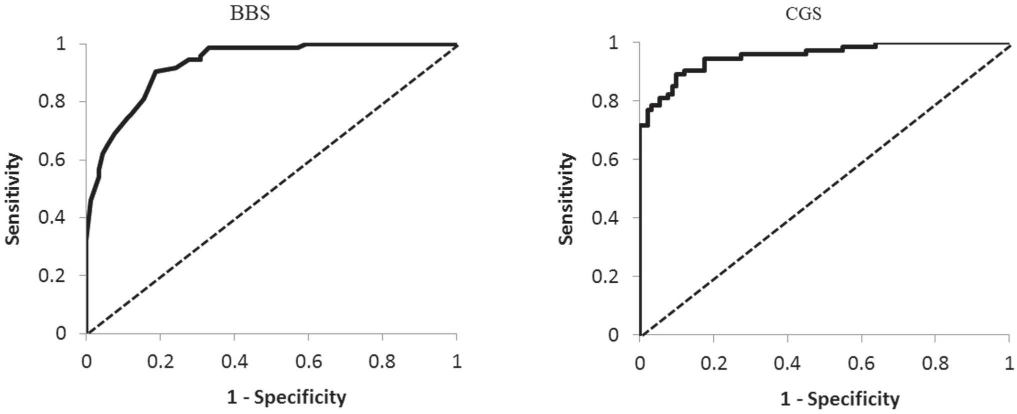
To our knowledge, this is the first study to report indicators that can accurately assess the ability of patients to walk independently in facility settings without wheelchair assistance in terms of phase after stroke. Recovery phase rehabilitation focuses on improving the ability of patients to perform ADLs, including walking ability.[1] However, ADL ability in a controlled environment, such as in a rehabilitation training room, may not be fully utilized in actual life situations in facility settings. In clinical situations, even though patients are judged to have independent walking ability in a rehabilitation setting, there may be occasions where they use wheelchairs in certain situations such as going to the toilet or the dining room. It is easy to envision a substantial difference in walking time and/or distance when comparing patients who use wheelchairs and those who do not when moving around the ward. Therefore, it is highly likely that physical activity after stroke affects improvements in walking ability. An early, supported discharge training program, in which family members or rehabilitation staff actively support patients to carry out physical activities of daily living, is reportedly more closely associated with improved physical function than conventional training in a rehabilitation room alone.[12,13] In other words, patients should have increased opportunities for walking not only in a rehabilitation training room but also in their actual

Table 3. Univariate and multivariate logistic regression analyses for determinants of practical ambulation

Early-phase group		Univariable analysis			Multivariable analysis BBS model			Multivariable analysis CGS model		
		OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	P value
Age	1 year	0.99	0.97－1.01	0.196	1.01	0.96－1.06	0.707	1.01	0.95－1.08	0.729
Female (vs. male)	－	1.08	0.56－2.07	0.825	1.46	0.44－4.90	0.539	2.16	0.49－9.43	0.307
Infarction (vs. hemorrhage)	－	0.86	0.46－1.61	0.634	0.49	0.16－1.52	0.216	0.77	0.19－3.19	0.720
Left affected side (vs. right)	－	1.11	0.60－2.06	0.733	0.62	0.21－1.84	0.391	0.26	0.06－1.12	0.071
Time since stroke	1 month	0.97	0.40－2.40	0.951	1.52	0.30－7.68	0.613	1.56	0.27－8.93	0.616
Cog FIM®	1	1.10	1.04 －1.16	0.001	0.99	0.90－1.08	0.791	1.03	0.94－1.12	0.537
SIAS of lower limb	1	1.85	1.52－2.27	<0.001	1.53	1.14－2.04	0.005	1.53	1.04－2.25	0.031
Leg strength	1 % BW	1.05	1.02－1.07	<0.001	1.01	0.97－1.05	0.685	0.99	0.94－1.04	0.609
BBS	1	1.30	1.20－1.41	<0.001	1.24	1.13－1.37	<0.001			
CGS	1 m/minute	1.17	1.12－1.23	<0.001				1.18	1.11－1.27	<0.001
R^2						0.723			0.809	
Middle-phase group										
Age	1 year	0.99	0.97－1.02	0.560	1.02	0.97－1.07	0.495	1.01	0.96－1.06	0.697
Female (vs. male)	－	1.15	0.60－2.20	0.665	2.45	0.71－8.56	0.155	1.51	0.43－5.26	0.516
Infarction (vs. hemorrhage)	－	0.57	0.31－1.06	0.075	0.57	0.20－1.58	0.277	0.78	0.26－2.32	0.657
Left affected side (vs. right)	－	0.92	0.50－1.70	0.796	1.02	0.36－2.86	0.972	1.33	0.48－3.71	0.590
Time since stroke	1 month	0.94	0.48－1.86	0.866	2.87	0.85－9.70	0.089	2.35	0.67－8.20	0.181
Cog FIM®	1	1.10	1.04－1.16	0.001	1.07	0.97－1.17	0.168	1.11	1.01－1.21	0.032
SIAS of lower limb	1	1.47	1.30－1.67	<0.001	1.31	1.09－1.58	0.004	1.23	1.02－1.49	0.027
Leg strength	1% BW	1.04	1.02－1.07	<0.001	1.02	0.98－1.07	0.371	1.02	0.98－1.07	0.380
BBS	1	1.23	1.16－1.31	<0.001	1.17	1.08－1.27	<0.001			
CGS	1 m/minute	1.14	1.10－1.19	<0.001				1.11	1.06－1.16	<0.001
R^2						0.674			0.698	
Late-phase group										
Age	1 year	0.98	0.96－1.01	0.181	1.00	0.95－1.05	0.987	1.02	0.97－1.08	0.473
Female (vs. male)	－	0.87	0.38－1.99	0.742	2.80	0.54－14.44	0.219	2.37	0.38－14.78	0.357
Infarction (vs. hemorrhage)	－	0.35	0.16－0.79	0.011	0.38	0.12－1.25	0.112	0.41	0.11－1.52	0.180
Left affected side (vs. right)	－	1.53	0.71－3.31	0.279	1.37	0.39－4.81	0.621	1.57	0.40－6.15	0.518
Time since stroke	1 month	0.46	0.21－1.03	0.058	0.33	0.09－1.18	0.087	0.18	0.04－0.80	0.024
Cog FIM®	1	1.12	1.05－1.19	0.001	1.09	0.98－1.22	0.097	1.14	1.02－1.28	0.024
SIAS of lower limb	1	1.24	1.12－1.37	<0.001	1.09	0.92－1.30	0.315	0.98	0.80－1.19	0.832
Leg strength	1% BW	1.04	1.01－1.07	0.006	1.01	0.97－1.06	0.572	1.03	0.98－1.08	0.287
BBS	1	1.19	1.11－1.27	<0.001	1.14	1.04－1.24	0.004			
CGS	1 m/minute	1.13	1.08－1.18	<0.001				1.14	1.06－1.22	<0.001
R^2						0.575			0.646	

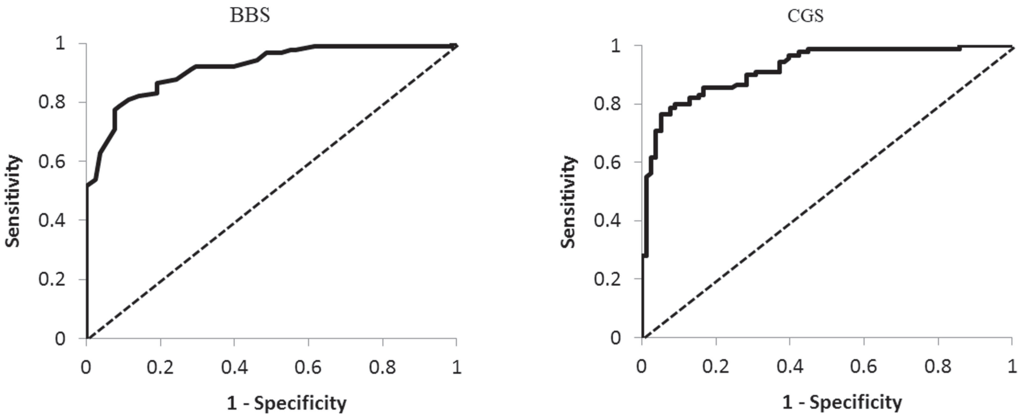
OR, odds ratio; CI, confidence interval; Cog FIM®, Cognitive Functional Independence Measure; SIAS, Stroke Impairment Assessment Set; BBS, Berg Balance Scale; CGS, comfortable gait speed

A. Early-phase group



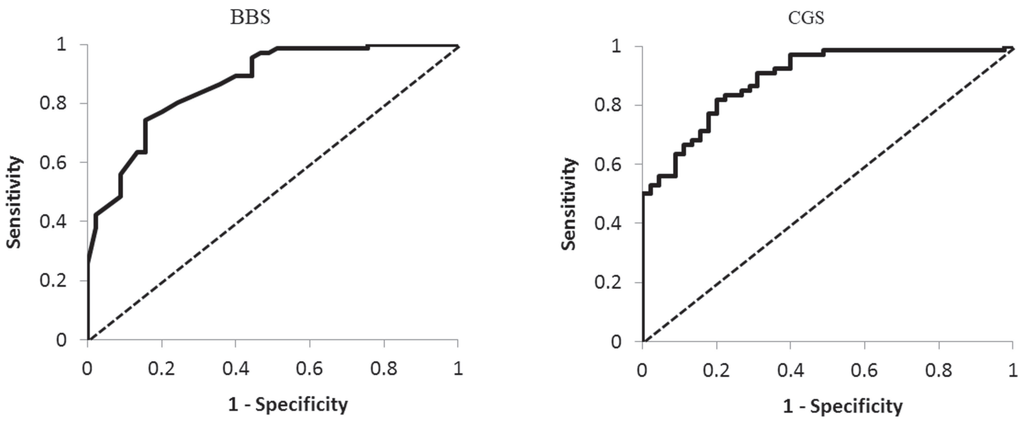
	Cut-off	AUC (95% CI)	Sensitivity	Specificity	Accuracy	PPV	NPV
BBS	44.5	0.930 (0.894−0.966)	0.905	0.813	0.855	0.798	0.914
CGS	37.1 m/minute	0.955 (0.925−0.985)	0.892	0.901	0.897	0.880	0.911

B. Middle-phase group



	Cut-off	AUC (95% CI)	Sensitivity	Specificity	Accuracy	PPV	NPV
BBS	49.5	0.915 (0.874−0.957)	0.775	0.923	0.844	0.920	0.783
CGS	33.5 m/minute	0.921 (0.881−0.961)	0.764	0.949	0.850	0.944	0.779

C. Late-phase group



	Cut-off	AUC (95% CI)	Sensitivity	Specificity	Accuracy	PPV	NPV
BBS	45.5	0.868 (0.802−0.934)	0.742	0.844	0.784	0.875	0.691
CGS	26.3 m/minute	0.890 (0.830−0.949)	0.818	0.800	0.811	0.857	0.750

AUC, area under the curve; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; BBS, Berg Balance Scale; CGS, comfortable gait speed

Figure 1. Receiver operating characteristic curve analyses to assess dichotomized practical ambulation

living spaces.

In the present study, the severity of paralysis in the affected lower limb was a determinant of practical ambulation in a convalescent rehabilitation ward in the early post-stroke phase. On the other hand, gait speed and balance function were consistently correlated with practical ambulation in all the phases. Ambulation in real-life settings demands concurrent motor and sensory skills to deal with situations, such as the need to walk faster, circumvent obstacles, and pay attention to what's going on around oneself.[34] Moving around the ward requires not only the ability to walk, but also physical function to walk without rest and quickly reach the destination. In this context, the time required for locomotion to a destination point is more important. In fact, our results showed that gait speed greatly affected practical ambulation in the hospital ward. Recent studies have reported numerous factors related to community ambulation, including outdoor movement and social participation; and gait speed was the most convenient indicator due to its relative simplicity, feasibility in measurement, and reduced psychological burden.[35-38] On the other hand, balance has been reported to be a key component that determines eventual ambulatory ability after stroke,[39] and is also known to be closely related to walking ability, as well as gait speed.[3,40,41]

We examined cut-off values of gait speed and balance as common determinants of practical ambulation in a convalescent ward in post-stroke patients. Both gait speed and balance showed a high accuracy of approximately 0.8. Cut-off values of CGS for determining practical ambulation at 1－2, 3－4, and 5－6 months after stroke were 37.1, 33.5, and 26.3 m/minute, respectively. These results suggest that the shorter the time after stroke, the higher the cut-off value of CGS for determining practical ambulation. The high CGS cut-off value in the early post-stroke phase could possibly be explained by lower confidence levels among stroke patients to move to places without wheelchair assistance due to their lack of experience in walking post-stroke. In other words, even if patients had sufficient walking ability (gait speed) for practical ambulation, they may not be able to stop using a wheelchair due to low confidence. There is also a possibility that physiotherapists or nurses in the convalescent ward might have underestimated patients' walking abilities due to insufficient walking activities during the early post-stroke phase.

These results suggest that stroke patients could achieve practical ambulation in a facility at a gait speed slower than 37.1 m/minute, which became the cut-off value of CGS for determining practical ambulation at 1－2 months after stroke, if they have more experience in walking during the early post-stroke phase. On the other hand, cut-off values of BBS for determining practical ambulation were roughly 45 points in all 3 phases. These results are consistent with previous studies reporting similar cut-off values for BBS in post-stroke[42] and healthy elderly people[43,44] to walk safely without a falling support.

Friedman[45] reported a link between the presence of cognitive disorders and recovery of walking ability in stroke patients. In the present study, Cog FIM® was found to determine practical ambulation in the CGS model, but not in the BBS model. This could be due to differences in the measuring methods between CGS and BBS. Higher cognitive function may be required in the measurement of BBS than for CGS, since the former involves many tasks under different conditions that cannot be implemented if the patient cannot sufficiently understand the tasks. Oppewal[46] pointed out that patients were not able to complete all 14 items of the BBS, largely due to limited cognitive ability, even if patients had sufficient. Therefore, Cog FIM® might not have been identified as a determinant in the BBS model due to its close relationship with BBS.

The present study has several limitations. First, due to the cross-sectional design, causal relationships could not be established between determinants of practical ambulation. Second, this study was carried out at a single center with a relatively small number of patients. Third, although the possibility that physical activity after stroke may affect improvements in walking ability, data was not collected on patients' levels of physical activity in the hospital ward. Further investigation focusing on the relationship between changes in gait speed, balance, and walking ability, in addition to physical activity levels in a convalescent rehabilitation ward, should be examined longitudinally in post-stroke patients.

The severity of paralysis in the affected lower limb(s) was found to be a determinant of practical ambulation in a facility setting during the early and the middle post-stroke phase. On the other hand, gait speed and balance function consistently discriminated between practical and non-practical walkers in all the phases. Moreover, values of CGS ≥26 m/minute and BBS ≥45 points could provide useful measures for determining practical ambulation status in post-stroke patients in facility settings. Our findings will help develop concrete guidelines aimed at actively promoting walking guidance in convalescent rehabilitation wards for stroke patients.

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