Original Article

Clinical measures as valid predictors and discriminators of the level of community ambulation of hemiparetic stroke survivors

GYUCHANG LEE, PT, PhD¹⁾, SEUNGHEON AN, PT, PhD²⁾, YUNBOK LEE, RN, PhD³⁾,
DONG-SIK PARK, MD, PhD⁴⁾*

¹⁾ Department of Physical Therapy, College of Natural Sciences, Kyungnam University, Republic of Korea

²⁾ Department of Physical Therapy, National Rehabilitation Center, Republic of Korea

³⁾ Department of Nurse, Dongseo University, Republic of Korea

⁴⁾ Department of Rehabilitation Medicine, Kangdong Sacred Heart Hospital, Hallym University College of Medicine: 445 Gil-dong, Gangdong-gu, Seoul 134-701, Republic of Korea

Abstract. [Purpose] To investigate clinical measures as valid predictors and discriminators of the level of community ambulation of hemiparetic stroke survivors. [Subjects and Methods] Seventy-five hemiparetic stroke patients were separated into a community ambulation group (>0.8 m/s) and a limited community ambulation group (0.4 – 0.8 m/s). The dorsiflexor strength of the affected side, Sit to Stand (STS) test, Timed Up & Go (TUG) test, Berg Balance Scale (BBS), Fugl-Meyer Assessment (FMA), Falls Efficacy Scale (FES), 2-min step test (2mST), and 6-min walk test (6mWT) were used for evaluation. The discriminative powers of the tests and measures were investigated using the receiver-operating characteristic (ROC) curve, and odd ratios were calculated to predict the level of community ambulation. [Results] The cutoff values for predicting the level of community ambulation (>0.8 m/s) were <14.77 s for TUG, <12.6 s for STS, a score >46.5 for BBS, a score >25.5 for FMA, a score <13.5 for FES, >7.5 kg for dorsiflexor strength, >30 times for 2mST, and >318 m for 6mWT. All clinical measures except FES had moderate accuracy according to the area under the curve of 0.76 – 0.88 (70 – 93%). [Conclusion] Clinical measures (except FES) have moderate validity in predicting the level of community ambulation of stroke survivors.

Key words: Stroke, Community ambulation, Predictive validity

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INTRODUCTION

Recovery of the gait ability of stroke survivors is an important goal of rehabilitation¹⁾ and is known to be influenced by environmental factors (e.g., walking on the ground, climbing stairs, and avoiding obstacles), physical factors (e.g., muscle strength, endurance, and balance), and psychological factors (e.g., judgment, attention, stress, and fear of falls)²⁾. Because several factors affect the gait ability of stroke survivors, assessing only a few factors is likely to limit the plan of care for gait recovery³⁾. Therefore, it is extremely important to assess the diverse range of factors influencing the gait ability of stroke survivors⁴⁾.

The methods commonly used in clinical settings to examine the gait ability of stroke survivors include the StepWatch Activity Monitor (SAM), Functional Ambulation Category (FAC), Dynamic Gait Index (DGI), gait scale in Performance-Oriented Mobility Assessment (POMA-gait), Wisconsin Gait Scale (WGS), 5- to 10-m walk test, 2-min step test, and 6-min walk test. However, it has been reported that these methods have limitations. Issues related to the validity of SAM hinder

*Corresponding author. Dong-sik Park (E-mail: don@hallym.or.kr)

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the proper assessment of gait levels⁵). Among stroke survivors who scored 4 points or more on FAC^{4, 6}), which indicates the capability of independent gait without any extrinsic assistance, 32–47% were unable to perform community ambulation without extrinsic assistance^{4, 7}). In addition, DGI and POMA-gait were originally designed to predict falls by and the gait ability of the elderly, respectively^{8, 9}). The WGS was found to have low inter-rater reliability and prone to learning effects because the method's accuracy relies on repeated measurements¹⁰). The 6-min walk test, which was devised to predict the level of community ambulation, has low discriminative power in comparison with the gait speed test and may be impractical for patients with significant declines in cardiopulmonary endurance.

In contrast, the gait speed test is simple compared to the walking distance test, and it can be used regardless of spatial constraints, thus placing lower psychological burden on the subjects¹¹). Moreover, gait speed is reported to be better than walking distance at predicting the gait ability of stroke patients^{7, 11–13}). As such, gait speed could serve as a predictor of the level of community ambulation of stroke survivors and as an objective indicator of their gait ability^{7, 14}). However, few studies have investigated gait speed using tests or measures that are commonly used in clinical settings. Most of the tests or measures are used to determine intervention effects. According to previous studies, the following tests and measures are significantly associated with the level of community ambulation: the Sit to Stand test (STS) performed five times for evaluating muscle strength of the lower extremities; the Fugl-Meyer Assessment of lower extremities (FMA-LE) for evaluating motor function of the affected lower extremity; the Timed Up & Go (TUG) test for evaluating mobility; the Berg Balance Scale (BBS) for evaluating the dynamic balance; the Falls Efficacy Scale (FES) for evaluating the fear of falls; and the walking distance test^{11, 15}). These tests and measures may help predict the gait speed for community ambulation. Thus, this study investigated the validity of clinical measures, such as dorsiflexor strength of the ankle joint, STS, TUG, BBS, FMA-LE, FES, and walking endurance tests, as predictors and discriminators of the level of community ambulation of hemiparetic stroke survivors.

SUBJECTS AND METHODS

For this study, stroke patients were recruited through advertisements at M rehabilitation center. The recruited volunteers were screened using the following criteria: more than 6 months since onset of chronic stroke; walking more than 10 m without assistive devices; no lower motor neuron injuries or musculoskeletal problems; and a score of least 24 on the Mini-Mental State Examination (MMSE). Patients with uncontrolled blood pressure, cardiac problems, pacemakers, or diabetes were excluded. Ninety-eight stroke patients were recruited and eight were excluded for not meeting the criteria. Ten subjects dropped out of the study (six subjects who were absentees, three subjects who were discharged, and one subject with a worsened condition). In addition, data of five subjects were missing or faulty. In total, the data of 75 subjects were analyzed. All participants provided their signed informed consent after receiving an explanation of the purpose and procedure of the study. The study was approved by Kyungnam University Institutional Review Board.

Information regarding gender, age, disease period, etiology, walking status (with or without assistive devices), and MMSE was collected from either medical charts or in brief interviews. Subjects were separated into two groups (community ambulation group [>0.8 m/s] or limited community ambulation group [0.4 – 0.8 m/s]) based on the gait speed required for community ambulation during the 5-m walk test reported in previous studies (>0.8 m/s)^{7, 13, 16}). Then, tests and measures including dorsiflexor strength of the affected side, STS, TUG, BBS, FMA, FES, 2-min step test, and 6-min walk test were performed.

To examine the gait speed of the subjects, the 5-m walk test was performed¹⁷). This test has high test–retest reliability ($ICC=0.88$ – 0.97)¹⁸). To examine dorsiflexor strength of the affected side, a hand dynamometer was used. The hand dynamometer is reported to be highly reliable ($ICC=0.84$ – 0.99)^{19, 20}). STS was used to examine the muscle strength of the lower extremity. For this test, subjects repeatedly sat down and stood up five times²¹). The inter-rater reliability of this test is high ($ICC=0.87$)²²). TUG and BBS were used to examine functional mobility and balance. The test–retest reliability of TUG is high ($ICC=0.96$)¹⁸). Also, the test–retest reliability of BBS is excellent ($ICC=0.98$)^{23, 24}). The motor function of the lower extremity on the affected side was examined using FMA²⁵). The inter-rater and intra-rater reliabilities of FMA were reported as $r=0.94$ and $r=0.99$, respectively²⁶). Fear of falling was examined with FES. FES consists of 13 items. Each item is rated using a score of 0–10 (0=having no fear, 5=somewhat confident, 10=having much fear). Higher scores indicate greater fear of falling or lower fall-related self-efficacy²⁷). The 2-min step test and 6-min walk test were used to examine aerobic endurance. The 2-min step test measures the number of times that the lower extremities were lifted (one at a time if possible) up to the point halfway between the patella and the crista iliaca within 2 min²⁸). The subjects were told to lift the affected lower extremity as high as the unaffected side¹⁴). In the 6-min walk test, the subjects were asked to repeatedly walk up and down a 20-m straight walkway for 6 min²⁹).

For the statistical analysis, SPSS version 16.0 was used. For the comparison of the two groups based on the level of community ambulation, the chi-square test or the independent t-test was used. To determine cutoff values of the tests and measures for predicting the level of community ambulation, the receiver-operating characteristic curve (ROC curve) was determined. To determine the accuracy of the tests and measures, the positive predictive value (PPV) and negative predictive value (NPV) were calculated. The area under the ROC curve (AUC) was divided into the following ranges: $0.5 < AUC \leq 0.7$ (less accurate); $0.7 < AUC \leq 0.9$ (moderately accurate); $0.9 < AUC < 1$ (very accurate); and $AUC = 1$ (perfect)³⁰). To determine the predictive validity of clinical measures for the level of community ambulation, a logistic regression analysis (forward Wald) was performed and odds ratios (OR) were calculated, with a cutoff value for each test or measure. The significance level was $\alpha=0.05$.

Table 1. Characteristics of the subjects

	Total (n=75)	Community ambulation group (n=33)	Limited community ambulation group (n=42)
Gender (M/F)	40/35	21/12	19/23
Age (years)	58.19 ± 9.03	56.27 ± 7.02	59.69 ± 10.17
Disease duration (month)	8.94 ± 3.79	9.78 ± 5.19	8.27 ± 1.98
Etiology (infar./hemor.)	47/28	18/15	29/13
Walking status (without-/with-)	55/20	26/7	29/13
MMSE (score)	26.45 ± 2.00	26.85 ± 1.96	26.14 ± 2.00
5-m walk speed (m/s)	0.85 ± .21	1.06 ± .14	0.69 ± .06*
Dorsiflexor strength (kg)	6.93 ± 2.64	8.33 ± 2.10	5.83 ± 2.52*
STS (sec)	12.60 ± 4.24	10.13 ± 2.70	14.54 ± 4.26*
TUG (sec)	15.89 ± 8.10	10.97 ± 3.87	19.75 ± 8.49*
BBS (score)	44.84 ± 5.32	47.82 ± 4.22	42.50 ± 4.94*
FMA (score)	24.28 ± 5.89	28.61 ± 4.50	20.88 ± 4.48*
FES (score)	18.27 ± 12.17	12.91 ± 5.74	22.48 ± 14.15*
	Total (n=68)	Community ambulation group (n=33)	Limited community ambulation group (n=35)
2-min step test (frequency)	29.09 ± 15.21	3 ± 14.52	20.69 ± 10.37*
	Total (n=66)	Community ambulation group (n=33)	Limited community ambulation group (n=33)
6-min walk test (meter)	300.03 ± 135.846	377.45 ± 113.78	222.61 ± 110.340*

*p<0.001.

MMSE: Mini Mental State Examination; STS: Sit to Stand test; TUG: Timed Up & Go test; BBS: Berg Balance Scale; FMA: Fugl-Meyer Assessment; FES: Falls Efficacy Scale

RESULTS

There were no significant differences between the two groups in gender, age, disease duration, etiology, walking status, or MMSE; however, there were significant differences between the two groups regarding 5-m gait speed, dorsiflexor strength of the affected side, STS, TUG, BBS, FMA, FES, 2-min step test (7 out of 75 subjects failed the test), and 6-min walk test (9 out of 75 subjects failed the test) (Table 1).

For predicting the level of community ambulation (defined as gait speed >0.8 m/s), the cutoff values of the test or measure were as follows: >7.5 kg for the dorsiflexor strength of the affected side; <12.6 s for STS; <14.77 s for TUG; a score >46.5 for BBS; a score >25.5 for FMA; a score <13.5 for FES; >30 times for the 2-min step test; and >332 m for the 6-min walk test. The AUCs of all tests and measures were moderately accurate (0.76–0.88), except for FES, which was less accurate (0.68). PPVs were found for FMA (80%), TUG (76%), and 6-min walk test (76%), whereas NPVs were found for TUG (89%), BBS (82%), FMA (82%), STS (79%), and 6-min walk test (78%). The predictive values of FES (50–60%) were relatively low compared to the other tests and measures (Table 2).

According to the logistic regression analysis that used the cutoff values of the tests and measures to predict the level of community ambulation, the following proved to have significant discriminative power: TUG (<14.77 s; OR=0.038); FMA (>25.5; OR=0.053); 6-min walk test (>332 m; OR=0.086); BBS (>46.5; OR=0.084); STS (<12.6 s; OR=0.114); 2-min step test (>30 times; OR=0.150); and dorsiflexor strength of the affected side (>7.5 kg; OR=0.179). However, no significant discriminative power was found for FES (Table 3).

DISCUSSION

The present study showed that dorsiflexor strength of the affected side, STS, TUG, BBS, FMA, 2-min step length test, and 6-min walk test may have sufficient discriminative power to predict the level of community ambulation, but that FES does not. In addition, all the tests and measures except FES were moderately accurate, with the AUC ranging from 0.72 to 0.88.

TUG involves performing daily living activities, such as rising from a chair, turning 180°, walking, and sitting in a chair. Thus, these might be reflected in the level of community ambulation. In this study, the cutoff value for TUG was <14.77 s, which is close to that reported by a previous study in which it took 16.7 s for community-dwelling stroke survivors to perform TUG³¹⁾. The cutoff value of STS for predicting the level of community ambulation was 12.6 s in this study. Mong et al. used a cutoff value of 12 s for STS to distinguish community-dwelling healthy elderly individuals from chronic stroke survivors,

Table 2. Cutoff value, AUC, sensitivity, specificity, positive predictive value, and negative predictive value for predicting of level community ambulation

	n	Cutoff value	AUC	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Dorsiflexor strength	75	>7.5 (kg)	0.76** (0.67–0.88)	21/33 (64%)	32/42 (76%)	21/31 (68%)	32/44 (73%)
STS	75	<12.6 (sec)	0.80** (0.71–0.90)	25/33 (76%)	31/42 (70%)	25/36 (69%)	31/39 (79%)
TUG	75	<14.77 (sec)	0.88** (0.80–0.96)	29/33 (88%)	33/42 (79%)	29/38 (76%)	33/37 (89%)
BBS	75	>46.5 (score)	0.79** (0.69–0.89)	26/33 (79%)	32/42 (76%)	26/36 (72%)	32/39 (82%)
FMA	75	>25.5 (score)	0.87** (0.79–0.96)	25/33 (76%)	36/42 (86%)	25/31 (80%)	36/44 (82%)
FES	75	<13.5 (score)	0.68** (0.56–0.80)	16/33 (50%)	25/42 (56%)	16/33 (55%)	25/42 (60%)
2-min step test	68	>30 (frequency)	0.81** (0.70–0.92)	24/33 (73%)	25/35 (71%)	24/34 (71%)	25/34 (74%)
6-min walk test	66	>332 (meter)	0.82** (0.72–0.93)	26/33 (78%)	25/33 (75%)	26/34 (76%)	25/32 (78%)

AUC: area under the ROC curve; STS: Sit to Stand test; TUG: Timed Up & Go test; BBS: Berg Balance Scale; FMA: Fugl-Meyer Assessment; FES: Falls Efficacy Scale

**p<0.001

Table 3. Odds ratios of tests or measures for predicting the level of community ambulation

	n	Regression coefficient	Standard error	Odds ratio	95% confidence interval
TUG <14.77 (sec)	75	−3.280*	0.653	0.038	0.010–0.135
FMA >25.5 (score)	75	−2.931*	0.600	0.053	0.016–0.173
6-min walk test >332 (meter)	66	−2.452*	0.588	0.086	0.027–0.273
BBS >46.5 (score)	75	−2.475*	0.559	0.084	0.028–0.252
STS <12.6 (sec)	75	−2.176*	0.537	0.114	0.040–0.325
2-min step test >30 (frequency)	68	−1.897*	0.541	0.150	0.052–0.433
Dorsiflexor strength >7.5 (kg)	75	−1.723*	0.512	0.179	0.065–0.487
FES <13.5 (score)	75	-	-	-	-

*p<0.001.

Independent variables: cutoff values of tests or measurements

Dependent variables: 0=Community ambulation group (>0.8 m/s); 1=Limited community ambulation group (0.4–0.8 m/s)

STS: Sit to Stand test; TUG: Timed Up & Go test; BBS: Berg Balance Scale; FMA: Fugl-Meyer Assessment; FES: Falls Efficacy Scale

and they used 9.4 s as the cutoff value for distinguishing healthy elderly individuals from young adults²³). In addition, the cutoff values for BBS and FMA for predicting the level of community ambulation were scores of 46.5 and 25.5, respectively, which are comparable to a previous study that reported a BBS cutoff score of 49.3 and a FMA cutoff score of 28.7 for stroke survivors capable of community ambulation⁵). Hsu et al. found that gait speed (0.95 m/s) and FMA (28) were significantly correlated ($r=0.48$)³²). In this study, the gait speed and FMA score of stroke survivors capable of community ambulation were 1.06 m/s and 28.61, respectively. These results are consistent with those reported by Ng et al. (1.0 m/s and 26, respectively)¹⁷). A previous study reported that the dorsiflexor strength of the affected side of stroke survivors is influenced by STS, gait speed ($r=0.67$, explanatory power: 30%, $r=0.73$), and walking distance ($r=0.79$, 48.8%)¹⁷). Although no cutoff value was reported for the dorsiflexor strength of the affected side in that study, the cutoff value in this study was >7.5 kg, which is comparable to the cutoff value of 6.1 kg reported by Mong et al²³). However, Mong et al. reported 17.1 s for STS, which differs from the results of this study by approximately 4.5 s²³). In the 2-min step test, given that the standard values for healthy subjects (age 65–74 years) are 65–116 times, the standard value for stroke survivors with neurological problems should be 80%¹⁴) or at least 52 times. Nevertheless, the cutoff value of the 2-min step test for predicting the level of community ambulation ability was 30 times (46%) in this study. These findings were significantly lower than those reported by a previous study, a gait speed of 0.75 m/s for predicting the level of community ambulation, and 39.7 times in the 2-min step test, or 61% of performance levels of healthy adults¹⁴). Moreover, the cutoff distances of the 6-min walk test for predicting the level of community ambulation have been reported as 348.6 m⁵) and 367.5 m¹¹), slightly longer than the cutoff value of 332 m in this study. The disparity appears to be attributable to the lower gait speed (0.85 m/s) of the subjects in this study compared with those of the

subjects in previous studies (1.0–1.01 m/s).

Taken together, except for FES, the tests and measures, such as dorsiflexor strength of the affected side, STS for muscle strength of the lower extremity, TUG for functional mobility, BBS for dynamic balance, FMA for motor function of the lower extremity, the 2-min step test for aerobic endurance, and the 6-min walk test for walking distance, were shown to have discriminative power for predicting the level of community ambulation. However, these tests or measures were performed at certain points in time, which could limit their applicability to all other patients, particularly to those who cannot perform long-distance walking despite having high gait speed, or vice versa. Therefore, more extensive studies are needed.

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