Original

# The Targeted Value of Physical Function That is Necessary to Cross the Pedestrian Crossing in Patients with Cerebrovascular Accident

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## Abstract

The purpose of this study was to determine the level of physical function necessary for a gait speed faster than 1.0 m/s. In total, 123 cerebrovascular accident patients (71 men, 52 women) without a higher cortical function disorder were included in this study. Age, sex, muscle strength of both paretic and non-paretic limbs, Brunnstrom stage of the lower limbs, deep sensation, one leg standing time (OLST) of both the paretic and non-paretic limbs and fast gait speed were the variables studied. Patient age, muscle strength of both the paretic and non-paretic limbs, Brunnstrom stage of the lower limbs, deep sensation and the OLST of both the paretic and non-paretic limbs were significantly different between the more than 1.0 m/s and less than 1.0 m/s groups. The results of the logistic regression analysis showed that the muscle strength of the paretic limb and OLST of the paretic limb were significant predictors of the more than 1.0 m/s group ($p<0.05$). A cut-off value of 0.295 kgf/kg for the muscle strength of the paretic limb and a cut-off value of 1 s for the OLST of the paretic limb predicted a gait ability faster than 1.0 m/s. Therefore, to achieve a gait ability of faster than 1.0 m/s, the muscle strength or OLST on the paretic limb must be developed above a certain level.

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—Key words—
balance, gait speed, muscle strength

## Introduction

Despite the finding that a substantial proportion of the patients with stroke regain walking independently[1], several studies have shown that only approximately 20–66%[2)~4)] manage to walk independently in the community again. A qualitative study showed that not being able to walk independently, especially outdoors, was one of the most disabling aspects for patients after a cerebrovascular accident[5].

The gait speed is currently used as a proxy measure to evaluate community walking[6]. The gait speed is a reliable and objective measure of recovery of the walking ability[7] and walking performance[8)~10)]. In addition, the gait speed has been found to be the most sensitive parameter to evaluate changes in hemiplegic gait[11] and has often been established as the most pronounced marker to demonstrate effects to improve walking competency in intervention trials[12)~14)].

Empirical data have shown that the gait velocity of patients with cerebrovascular accident of varying severity ranges from approximately 0.18 to 1.03 m/s[15)~18)], whereas that of healthy adults of similar ages averages at 1.4 m/s[19]. Nojiri et al.[20] previously reported that 1.0 m/s is necessary for Japanese pedestrian crossing. Therefore, in Japan, acquisition of a walk speed faster than 1.0 m/s is important to perform normal outdoor activities.

Balance studies that have examined cerebrovascular accident patients have shown increased postural sway, decreased area of stability, and uneven weight-bearing upon quiet standing with a decreased percentage of body weight transferred through the hemiplegic leg[21)~26)]. Some investigators have shown a moderate correlation between the standing balance and gait performance of patients with cerebrovascular accident of varying severity[26)~31)]. Suzuki et al.[30)], however, reported no significant correlation between the standing balance and maximal walking speed for cerebrovascular accident patients with good standing balance ability. Winstein et al.[32)] found that standing balance training which led to a better improvement in standing symmetry failed to result in a greater improvement in hemiplegic gait symmetry of patients with moderate cerebrovascular accident. Thus, the association between standing balance ability and gait performance of cerebrovascular accident patients remains to be determined. The determination of the minimal level of physical function necessary for a walk speed faster than 1.0 m/s would help physiotherapists to select therapeutic exercises, and identification of the target value for a walk speed faster than 1.0 m/s could become the motivation for participating in rehabilitation.

The purpose of this study was to determine the level of physical function necessary for a gait speed faster than 1.0 m/s.

## Materials and Methods

### Participants

In total, 123 cerebrovascular accident patients (71 men, 52 women) without a higher cortical function disorder were included in this study. All cerebrovascular accident patients were admitted to the Rehabilitation Hospital. All patients were able to maintain a standing position without supporting devices. Informed consent was obtained from all patients. Seventy-eight of the patients were paretic on the right, and 45 were paretic on the left. The patients' mean time since onset of hemiplegia was 97.7 days (SD 57.3 days). Their mean age was 66.6 years (SD 11.1 years).

### Procedure

Age, sex, muscle strength of both paretic and non-paretic limbs, Brunnstrom stage of the lower limbs, deep sensation, one leg standing time (OLST) of both the paretic and non-paretic limbs and fast gait speed were the variables studied.

To determine fast gait speed, the time to walk 10 m of a 14 m walkway in a controlled room was recorded. The patients were informed that they would be timed for part of the 14 m walkway and to walk as fast and safely as possible without running. Each patient performed the test twice, and the fastest time was recorded. A gait speed faster than 1.0 m/s is required for pedestrian crossing in Japan. Therefore, the patients who had a gait speed faster than 1.0 m/s were categorized as the more than 1.0 m/s group, and those who had a gait speed slower than 1.0 m/s were placed in the less than 1.0 m/s group.

To measure the muscle strength of the lower limb, the quadriceps muscle strength was measured using a hand-held dynamometer (ANIMA, μ-Tas MT-01). The dynamometer was attached to the front of the distal crus with the patient sitting upright on a mat platform, with both upper extremities crossing in front of the trunk, without back support, and keeping the knees flexed at 90 degrees. The patient was then asked to make a maximum isometric contraction of the quadriceps for 5 seconds, twice, with a time interval of more than 30 seconds. The stronger value (kgf) of the two was divided by the body weight, and this value (kgf/kg) was defined as the muscle strength of the lower limb.

Motor paralysis was used as a measure of the Brunnstrom approach[33)].

Joint sensation was used as a measure of deep sensation. First, the patient's hip joint, knee joint and ankle were moved passively, and then the patient was asked to imitate the movements on the non-paralyzed side. Each joint was evaluated five times; a difference of up to 10 degrees in the joints was considered to be normal, while a difference of $\geq$ 11 degrees at least once was considered to be abnormal.

For the OLST, the patients were asked to stand on one leg at a time with their eyes open and their non-paretic hands on their hips. The test was over when the patients were not able to maintain their balance and the suspended leg touched the floor. The performance time was measured using a stop watch. The OLST was taken as the maximum of three separate measurements. The maximum achievable OLST was 30 s.

The differences between the more than 1.0 m/s group and less than 1.0 m/s group were compared using

**Table 1** Comparison of valuables between more than 1.0 m/s group and less than 1.0 m/s group (n = 123)

| Variable | more than 1.0 m/s group (n = 57) | less than 1.0 m/s group (n = 66) | p value |
|---|---|---|---|
| Age (y) [a] | 64.2 (11.6) | 68.7 (10.4) | .027[c] |
| Muscle strength of the paretic limb (kgf/kg)[a] | 0.41 (0.16) | 0.20 (0.12) | $p<0.001$[c] |
| Muscle strength of the non-paretic limb (kgf/kg)[a] | 0.54 (0.18) | 0.45 (0.16) | .004[c] |
| Brunnstrom stage of lower limbs (n)[b] | Ⅲ: 2, Ⅳ: 3, Ⅴ: 13, Ⅵ: 39 | Ⅱ: 2, Ⅲ: 20, Ⅳ: 19, Ⅴ: 16, Ⅵ: 9 | $p<0.001$[d] |
| Deep sensation (normal/abnormal) (n) | 43/14 | 27/39 | $p<0.001$[e] |
| OLST of the paretic limb (s)[a] | 21.6 (26.9) | 0.74 (2.6) | $p<0.001$[c] |
| OLST of the non-paretic limb (s)[a] | 28.5 (26.8) | 8.9 (15.8) | $p<0.001$[c] |

a) mean (SD), b) proportion, c) student *t*-test, d) Mann-Whitney U test, e) $\chi^2$-test

**Table 2** Predictors of gait speed ability (n = 123)

| Variable | Odds Ratio (95%CI) | p value |
|---|---|---|
| Age (y) | 0.973 (0.913–1.036) | .394 |
| Muscle strength of the paretic limb (kgf/kg) | 1.084 (1.002–1.173) | .046 |
| Muscle strength of the non-paretic limb (kgf/kg) | 1.002 (0.946–1.062) | .941 |
| Brunnstrom stage of lower limbs (n) | 1.887 (0.849–4.197) | .119 |
| Deep sensation (n) | 0.782 (0.199–3.072) | .725 |
| OLST of the paretic limb (s) | 1.312 (1.083–1.588) | .005 |
| OLST of the non-paretic limb (s) | 1.004 (0.967–1.042) | .831 |

CI: confidence interval.

Student's *t*-test, the $\chi^2$ test and the Mann-Whitney U test. A logistic regression analysis was used to identify the optimal predictor variable in the more than 1.0 m/s group. The cut-off value necessary for the more than 1.0 m/s group was determined using a receiver operating characteristic (ROC) curve. Predictability was evaluated using the sensitivity, false-positive rate (1-specificity), predictive accuracy, and the positive predictive value. The results were considered to be statistically significant when the possibility of error (p) was less than 5%.

## Results

Of the 123 patients, 57 were categorized in the more than 1.0 m/s group and 66 were categorized in the less than 1.0 m/s group. The results of the univariate analysis are shown in Table 1. Patient age, muscle strength of both the paretic and non-paretic limbs, Brunnstrom stage of the lower limbs, deep sensation and the OLST of both the paretic and non-paretic limbs were significantly different between the more than 1.0 m/s and less than 1.0 m/s groups ($p<0.05$).

The results of the logistic regression analysis showed that the muscle strength of the paretic limb and OLST of the paretic limb were significant predictors of the more than 1.0 m/s group ($p<0.05$) (Table 2).

Fig. 1 shows the ROC curves of the muscle strength of the paretic limb and OLST of the paretic limb for the more than 1.0 m/s group. The area under the curve (AUC) of the muscle strength of the paretic limb was 0.861 (SE 0.032, 95% CI 0.798–0.925). A cut-off value of 0.295 kgf/kg for the muscle strength of the paretic limb resulted in a sensitivity of 75.4%, a false-positive rate of 18.2%, a predictive accuracy of 79.7%, and a positive predictive value of 78.2%. The AUC of the OLST of the paretic limb was 0.943 (SE 0.023, 95% confidence interval (CI) 0.898–0.987). A cut-off value of 1 s for the OLST of the paretic limb resulted in a sensitivity of 89.5%, a false-positive rate of 9.1%, a predictive accuracy of 85.4%, and a positive predictive value of 78.3%.

## Discussion

In this study, age, sex, muscle strength of both the paretic and non-paretic limbs, Brunnstrom stage of the lower limbs, deep sensation, the OLST of both the paretic and non-paretic limbs and fast gait speed in cerebrovascular accident patients were studied. The results of this study demonstrated that cerebrovascular acci-

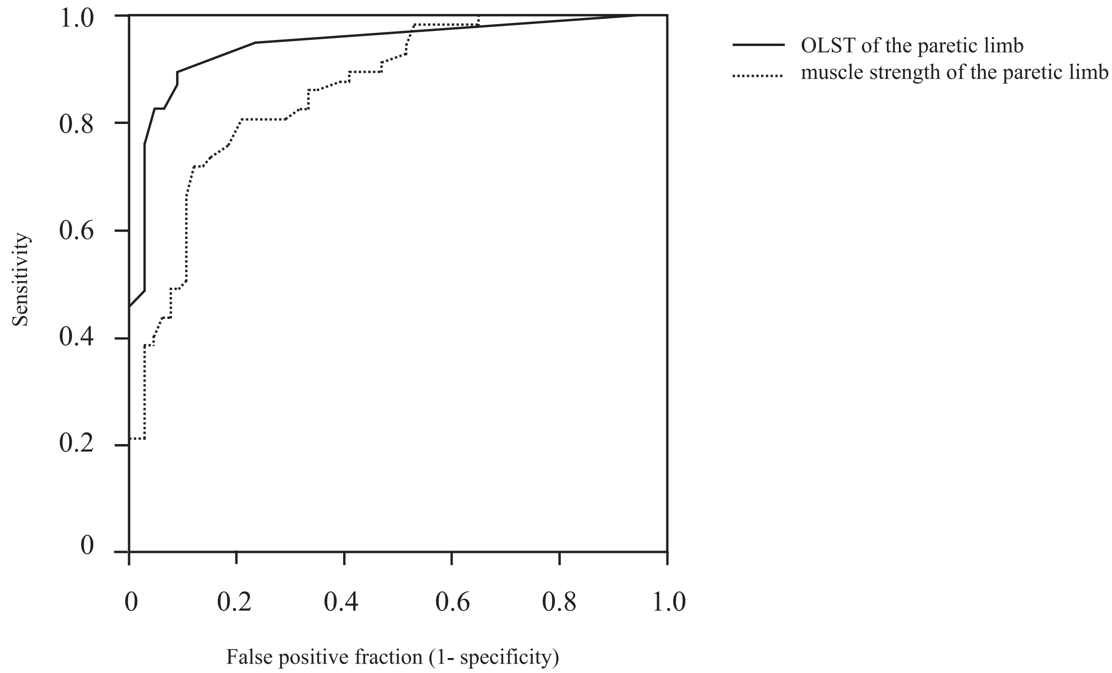


**Fig. 1** ROC curve for prediction of gait speed ability (n = 123)

dent patients more than 1.0 m/s group were influenced by the muscle strength of the paretic limb and OLST of the paretic limbs.

The gait speed has been established as an important predictor of gait capability along the spectrum from limited household walking to unlimited community walking[34]. Additionally, the gait speed is a simple, but highly reliable and responsive parameter for the gait [35][36]. The velocity for healthy adults has been reported to be approximately 1.49 m/s[37]. Nojiri et al.[20] previously report that 1.0 m/s is necessary for Japanese pedestrian crossing. Therefore, being able to walk faster than 1.0 m/s is necessary for community walking for cerebrovascular accident patients.

Numerous studies regarding the standing balance in cerebrovascular accident patients have consistently demonstrated that a greater proportion of body weight is distributed to the non-paretic limb than to the paretic limb[25][38]. Richard and Bohannon showed that the gait performance in hemiparetic persons was significantly correlated with maximum weight-bearing through the paretic limb and knee extension strength[39][40]. Maximum weight-bearing, however, explained a greater percentage of the variance in the gait speed compared with the knee extension strength[40]. The present study showed that age, muscle strength of the non-paretic limbs, Brunnstrom stage of the lower limbs, deep sensation and the OLST on both the paretic and non-paretic limbs were significantly different between the more than 1.0 m/s group and the less than 1.0 m/s group. The logistic regression analysis showed that the muscle strength of the paretic limb and the OLST of the paretic limbs were critical factors that influenced the gait ability for patients in the more than 1.0 m/s group. A greater strength of the paretic limb may provide better stabilization of the paretic limb in the mid-stance phase of the gait cycle. Therefore, although multiple factors influence the gait speed in cerebrovascular accident patients, the muscle strength of the paretic limb and the OLST of the paretic limbs were the most useful factors for predicting a gait ability faster than 1.0 m/s.

In the present study, a cut-off value of 0.295 kgf/kg for the muscle strength of the paretic limb and a cut-off value of 1 s for the OLST of the paretic limb predicted a gait ability faster than 1.0 m/s. Thus, to achieve a gait ability of faster than 1.0 m/s, the muscle strength or OLST on the paretic limb must be developed above a certain level.

There are some limitations associated with this study. The patients enrolled in this study were restricted to cerebrovascular accident patients not accompanied by visual deficits or high cortical function disorders.

Therefore, the cut-off values established in this study may not be applicable to patients with visual deficits, high cortical function disorders or diplegia. Additionally, we could not determine the optimal therapeutic exercise to improve the muscle strength or OLST on the paretic limb due to the cross-sectional nature of this study. Therefore, further investigations are necessary.

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# 脳卒中患者における道路横断に必要な身体機能の目標値

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―キーワード―
バランス，歩行速度，筋力

本研究では，1.0m/s 以上の歩行速度に必要な身体機能を明らかにすることを目的に検討した．対象は，高次脳機能障害を伴っていない脳卒中患者 123 名（男性 71 名，女性 52 名）とした．調査項目は，年齢，性別，麻痺側・非麻痺側下肢筋力，下肢 Brunnstrom stage，深部感覚障害，麻痺側・非麻痺側片脚立位時間，歩行速度とした．年齢，麻痺側・非麻痺側下肢筋力，下肢 Brunnstrom stage，深部感覚障害，麻痺側・非麻痺側片脚立位時間は，1.0m/s 以上群と 1.0m/s 未満群間で有意差を認めた．ロジスティック回帰分析の結果，麻痺側下肢筋力と麻痺側片脚立位時間が 1.0m/s 以上群に影響を及ぼすことが示された．歩行速度 1.0m/s 以上は，麻痺側下肢筋力 0.295 kgf/kg，麻痺側片脚立位時間 1 秒が cut-off 値となることが明らかとなった．これらのことから，歩行速度 1.0m/s 以上を有するには，麻痺側下肢筋力と麻痺側片脚立位時間が一定以上必要であることが示唆された．

利益相反：利益相反基準に該当無し

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