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ORIGINAL REPORT

COMMUNITY AMBULATION IN PATIENTS WITH CHRONIC STROKE: HOW IS IT RELATED TO GAIT SPEED?

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Objective: **To explore the strength of the association between gait speed and community ambulation and whether this association is significantly distorted by other variables.**
Design: **Cross-sectional study conducted 3 years after stroke.**
Subjects: **A total of 102 patients after first-ever stroke following inpatient rehabilitation who are now living in the community.**
Methods: **Community ambulation was determined by a self-administered questionnaire with 4 categories. Gait speed was assessed by the 5-m walking test. Possible confounding factors included in the analyses were: age, hemisphere, living alone, history of falls, use of assistive walking devices, executive function (Trail Making Test), depression (Center for Epidemiologic Studies-Depression scale), fatigue (Fatigue Severity Scale), motor function (Motricity Index), standing balance (Berg Balance Scale) and walking endurance (SF36).**
Results: **Twenty-six percent of the patients were non-community walkers or limited community walkers. The optimal cut-off point for community ambulation was 0.66 m/sec, with an area under the curve of 0.85. Although gait speed was significantly related to community ambulation, this association was confounded by balance, motor function, endurance and the use of an assistive walking device. These factors reduced the regression coefficient of gait speed by more than 15%.**
Conclusion: **Gait speed is an important factor related to community walking; however, ability to walk in the community is determined by several underlying factors, e.g. balance, motor function, endurance and assistive walking device.**

Key words: cerebrovascular disorders, gait, community walking, confounding factors.

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INTRODUCTION

Despite the finding that a substantial proportion of stroke patients regain independent gait (1), recent studies have shown that only approximately 20–66% (2–4) manage to walk independently in the community again. A qualitative study showed that loss of independent ambulation, especially outdoors, was one of the most disabling aspects for patients after stroke (5). In addition, Lord et al. (4) found that the ability to "get out and about" in the community was considered to be either essential or very important by 75% of the stroke patients.

Attempts are being made currently to evaluate community ambulation with well-defined outcome measures, and gait speed has often been used as a proxy measure (6). Gait speed is a reliable and objective measure of recovery of walking ability (7) and walking performance (8–10). In addition, gait speed has been found to be the most sensitive parameter to objectify change in hemiplegic gait (11) and has often been established as the most pronounced marker to show effects in intervention trials to improve walking competency (12–18).

Despite the robustness of gait speed as an outcome measure, the relationship between gait speed and walking independence and distance is not unequivocal. Although it has been suggested that gait speed is a useful and discriminative measure for different ambulation levels (2, 4, 19), in a review by Lord & Rochester (6) they concluded that there was a moderate relationship and concluded that gait speed does not consistently reflect community ambulation. Therefore, relying on gait speed as a proxy measure was suggested to be inappropriate. The above findings suggest that regaining sufficient walking speed is not the only factor that determines the ability of patients after hemiplegic stroke to walk in their own community. Theoretically, the relationship between gait speed on the one hand and community walking on the other might be confounded by other physical, cognitive and psychological factors, such as lack of confidence and fear, social support, feelings of fatigue and depression, or lack of necessary physical condition (20–23).

The first aim of the present study was to explore the strength of the association between gait speed and community ambulation. Subsequently, we investigated whether this association was significantly confounded by other variables related to both gait speed and the capacity for community walking. On the basis of existing evidence from the literature and clinical considerations, we hypothesized that potential covariates that could confound the relationship between gait speed and community ambulation in patients with chronic stroke would be age, living alone (20), history of falls, the use of assistive

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walking devices (24), executive function (21), depression, fatigue (20), motor function, control of standing balance (19, 20, 25) and walking endurance (4).

METHODS

Subjects

Subjects were recruited for the Functional Prognosis after Stroke (FuPro-Stroke) study in 4 Dutch rehabilitation centres (see acknow ledgements). Inclusion criteria for the FuPro-Stroke study were: age over 18 years, first-ever stroke, and a supratentorial lesion located on one side (cortical infarctions, subcortical infarctions, intracerebral haemorrhages or subarachnoid haemorrhages). Stroke was defined according to the World Health Organization (WHO) definition. Exclusion criteria were pre-stroke Barthel Index lower than 18 (0–20) and insufficient Dutch language skills (*viz.* non-native speakers). For the present analyses, only communicative subjects were included, since non-communicative patients were unable to complete some parts of the questionnaires.

This cross-sectional study was approved by the medical ethics committees of UMC Utrecht and the participating rehabilitation centres. All patients gave their informed consent.

Procedure

Data were collected at 3 years post-stroke (February 2003– May 2005). Subjects were visited by a trained research assistant for a face-to-face interview, either at home or at the institution where they resided.

Community ambulation was measured according to Lord et al. (4) by a self-administered questionnaire and served as the dependent variable in the association model. Four categories could be distinguished: (*i*) the patient was unable to walk outside, (*ii*) the patient could walk outside e.g. as far as the car or mailbox in front of the house without physical assistance or supervision, (*iii*) the patient could walk in the immediate environment (e.g. down the road, around the block) without physical assistance or supervision, (*iv*) the patient could walk to stores, friends or activities in the vicinity without physical assistance or supervision. Subjects allocated to the fourth category were considered community walkers, which includes the ability to confidently negotiate uneven terrain, shopping venues and other public venues. Others were regarded as non-community walkers (category (*i*)) or limited community walkers (categories (*ii*) and (*iii*)). Subjects who did not walk outside at all were also classified as non-community walkers.

Gait speed (m/sec; m/s) was measured by the 5-m walking test (5MWT) in the patients' own home environment and served as the independent variable in the association model. The 5MWT was chosen since the tests were conducted indoors and space was limited. In addition, a standing start was chosen, since a rolling start would require more space. The assessor walked alongside the patients and timed them with a hand-held digital stopwatch. Patients were instructed to walk at their usual (comfortable) walking speed, and they were timed from the moment their first foot crossed the starting line until their first foot crossed the finish line. Patients were allowed to use walking devices where needed. The mean speed over 3 attempts was calculated. If it was not possible to conduct the walking test over 5 m, gait speed was not assessed.

Variables that were considered as possible co-variates in the association model were age, hemisphere, living alone, history of falls, the use of assistive walking devices, executive function, depression, fatigue, motor function, control of standing balance and walking endurance.

History of falls was determined retrospectively by asking patients if they had experienced one or more falls during the previous 6 months (yes = 1, no = 0). In the case of memory problems, a proxy was asked to answer the question. Executive function was measured by the time needed to complete part B of the Trail Making Test (TMT) (26). This involves complex visual scanning, motor speed and (divided) attention. The participant has to connect 25 encircled numbers and letters, as quickly as possible, alternating between numbers and letters (1-a-2-b-3-c, etc.). The assessor did not correct the errors made by the patient and the total time needed was divided by the number of correct connections. This ratio (time/correct connections) was dichotomized on the basis of the median score and used as a measure of executive function. Depression was measured by the Center for Epidemiologic Studies-Depression scale (CES-D) (27) and dichotomized into "non-depressed" (CES-D < 16 points) and "depressed" (CES-D ≥16 points) (28). Fatigue was determined by the Fatigue Severity Scale (FSS) (29, 30). The FSS consists of 9 questions and total scores range between 9 and 63 points. The mean score (total score/9) was dichotomized into "non-fatigued" (FSS < 4 points) and "fatigued" (FSS ≥ 4 points) (31). The Motricity Index (MI) (32) was used to determine motor function. Scores range from 0 (no activity) to 100 (maximum muscle force) and were dichotomized into non-optimal range of motion (MI < 76) and optimal range of motion (MI ≥76). Balance was determined by the Berg Balance Scale (BBS) (33). The BBS evaluates a person's ability to perform 14 functional balance tests. The summed score of the BBS ranges from 0 to 56 points. A cut-off score of 45 was used (≤ 45 = impaired) (33). Walking endurance was reflected by question 3g of the Short Form 36 (SF36) (34) questionnaire (i.e. "are you able to walk more than 1 km"), and dichotomized into limitations (scores 1 and 2) and no limitations (score 3).

Statistical analysis

All variables were examined by descriptive statistics. We used the Fisher's exact test to examine possible significant differences between the patients who were included and those excluded. A receiver operating characteristic (ROC) curve was constructed to establish the diagnostic validity of gait speed in discriminating between community walkers and non-community walkers. An optimal cut-off point was determined and the area under the curve (AUC) was calculated. The AUC can be interpreted as the probability of correctly identifying community walkers vs non-community walkers. The area ranges from 0.5 (no accuracy in discriminating community walkers from non-community walkers) to 1.0 (perfect accuracy) (35). Positive (PPV) and negative predictive values (NPV) were calculated to determine the proportion of patients with a walking speed above the cut-off score who were community walkers (PPV) and the proportion with a walking speed below the cut-off score who were non-community walkers (NPV).

Univariate logistic regression analysis was used to determine the relation between community ambulation and gait speed. Subsequently, other candidate covariates associated with both gait speed and community walking were added to the model. If the regression coefficient of gait speed with community walking changed by more than 15% after the variable had been added to the model, the variable was considered to be a covariate that confounded the relationship between gait speed and community walking.

We used a 2-tailed significance level of 0.05 for all statistical tests applied (SPSS version 13.0).

RESULTS

Data regarding community walking were available for 102 patients after stroke. Gait speed data of 12 subjects could not be collected because there was not enough space in their place of residence to conduct the 5MWT. After non-communicative patients had been excluded (n = 18), 72 complete datasets were available for analyses. Sixty-four percent of the subjects were male. The patients' mean age was 59 years (standard deviation (SD) = 10) and the majority had suffered an infarction (67%) (Table I).

Based on the self-administered questionnaire, 8 subjects were not able to walk outside without supervision or assistance,

Table I. *Patient characteristics at 3 years post-stroke for patients included and not included in the data analyses*

	Included (*n* = 72)	Not included (*n* = 30)
Gender (% male)	64	53
Age (% > 65 years)	26	30
Hemisphere (% right)	56	43
Type of stroke (% infarction)	67	77
Living alone (%)	24	23
Walking device (%)	14	33*
TMT (% impaired executive function)	50	60 (*n* = 5)
CES-D (% depressive symptoms)	10	44* (*n* = 9)
FSS (% fatigued)	46	63 (*n* = 8)
MI (% no optimal range of motion)	61	80
BBS (% balance problems)	17	48*
Walking endurance (% impaired)	63	86*

*$p < 0.05$ Fisher's exact test for cross-tabs.
TMT: Trail Making Test; CES-D: Center for Epidemiologic Studies-Depression; FSS: Fatigue Severity Scale; MI: Motricity Index; BBS: Berg Balance Scale.

Table II. *Logistic regression analysis with community walking as outcome measure (n = 72). Percentages above the 15% change in beta coefficient in bold*

Variables in the model	Confounder β (SE)	Gait speed β (SE)	Proportional change in the coefficient of gait speed (%)
Gait speed		2.903 (0.710)	
Candidate confounders			
Balance (impaired)	–2.140 (0.780)*	2.140 (0.776)*	**26.3**
Motor function (impaired)	–1.841 (1.146)	2.287 (0.754)*	**21.2**
Walking endurance (impaired)	–2.003 (1.127)	2.412 (0.738)*	**16.9**
Walking device (yes)	–2.001 (0.947)*	2.467 (0.742)*	**15.0**
Age (> 65 years)	1.601 (0.824)	3.220 (0.759)*	10.9
Fatigue (present)	–0.994 (0.699)	3.134 (0.761)*	8.0
Living alone (yes)	2.209 (1.152)	2.970 (0.736)*	2.3
Hemisphere	–1.219 (0.703)	2.970 (0.735)*	2.3
Depression (present)	–0.669 (1.118)	2.956 (0.724)*	1.8
History of falls	–0.414 (0.829)	2.918 (0.713)*	<1
Trail Making Test	0.012 (0.723)	2.908 (0.770)*	<1

*$p < 0.05$.
SE: standard error.

3 subjects walked as far as the car or post-box in front of the house, 8 subjects walked the immediate outside vicinity (e.g. around the block), and 53 walked outside to stores, friends or activities in their neighbourhood without physical assistance or supervision. These results indicate that 26% of the subjects were non-community walkers or limited community walkers and 74% were unlimited community walkers.

Mean gait speed was 0.74 m/sec (SD 0.30). ROC analysis revealed a high diagnostic validity in terms of distinguishing between community walkers and non-community walkers, with an AUC of 0.85. A cut-off score of 0.66 m/sec correctly allocated 93% (PPV) of the subjects to the group of unlimited community walkers and 57% (NPV) were correctly classified as non-community walkers.

Univariate logistic regression analysis, with the dichotomized gait speed score as the independent variable, showed that gait speed was significantly related to community ambulation, with an odds ratio of 18.2 (95% confidence interval (CI): 4.5–73.2).

Subsequently, we investigated the association between gait speed and community walking while controlling for the other variables. Balance control, motor function, walking endurance and the use of assistive devices distorted the correlation between walking speed and community ambulation, as it changed the regression coefficient of gait speed by more than 15% (Table II). However, gait speed remained a significant determinant of community ambulation after the confounders had been added to the model. No significant distortion was found for age, hemisphere, living alone, history of falls, executive function, fatigue or depression.

DISCUSSION

Our results show that in a relatively young, moderately disabled stroke population, 26% of the subjects were non-community walkers or limited community walkers. Gait speed was significantly related to community ambulation, and a cut-off point of 0.66 m/sec was optimal to distinguish between community walkers and non-community walkers. This cut-off point might be too pessimistic, since NPV was 57%. Despite being classified as non-community walkers because of a gait speed lower than 0.66 m/sec, 43% of the patients were community walkers by Lord's classification. This shows that patients with a low walking speed are particularly difficult to classify by gait speed alone (4, 9, 36).

Gait speed was the most powerful discriminative measure of community ambulation. Previously reported threshold gait speeds for community ambulation have varied between 0.8 m/sec and 1.2 m/sec (2, 22, 23). However, the reason why the optimal cut-off point in the present study was lower than those previously reported, remains unknown, Taylor and colleagues (37) have already suggested that the threshold of 0.8 m/sec for community ambulation might be too high. In their chronic stroke population, patients did walk in the community despite lower gait speeds. It might be hypothesized that our chronic patients use more compensatory strategies, which they have learned over the years. Also, fear may have been overcome and walking aids may be used to greater effect than in the early phase after stroke. Another explanation could be the fact that we used the 5MWT to determine gait speed. Since we used a standing start it might be suggested that our patients achieved lower gait velocities compared with measures in which longer distances and rolling starts were used.

Although gait speed is an important determinant of community walking, the present study also shows that it was not the sole determinant of community ambulation. The correlation between gait speed and community ambulation was confounded by control of standing balance, motor function, walking endurance and the use of walking devices. This latter finding is in agreement with a recent study that investigated the longitudinal relationship of improvement of walking ability and change in time-dependent covariates, such as standing balance control and lower limb strength, after stroke (25). This study also showed that improvement in balance control was the most important driver for improvement in hemiplegic gait. Obviously, balance control is an important independent compensatory factor enabling patients to walk in the community despite lower gait speeds, suggesting that patients with a slow walking speed seem to be able to compensate by an appropriate use of walking aids and sufficient control of balance. The results we found are in agreement with those of other studies (4, 20, 22) and suggest that the ability to walk in the community requires more than gait speed alone. Therefore, rehabilitation should focus not only on improving gait speed, but also on those factors that are conditional for becoming an independent community walker. Finally, our findings further suggest that clinicians should be careful in classifying community walkers on the basis of gait speed alone.

In the same vein, motor function also changed the association between gait speed and community walking; thus, when adjusting for motor function, gait speed will explain a smaller proportion of variability. In contrast to Shumway-Cook et al. (38), who suggested that endurance was less important for successful community ambulation in older adults, our results are in agreement with the findings by Lord et al. (4), who found that walking endurance was an important factor, highly associated with outdoor mobility. It has previously been suggested that the minimum walking endurance required for community walking was 300–500 m (22, 23). The use of assistive devices also confounded the correlation in our study, presumably because the use of a walking aid increases the ability to walk in the community despite lower gait speed. Although patients are often stimulated not to use assistive walking devices, community ambulation can be improved by providing them with appropriate walking aids for outdoor use. Recently, a controlled trial by Logan et al. (24) found that providing walking aids helps patients to increase outdoor mobility.

The present study was subject to some limitations. First, there might be other variables that distort the relation between gait speed and community ambulation, for example lack of confidence, and fear. Although we did include falling characteristics in the model, we were unable to analyse the role of fear of falling. Secondly, we chose to assess community ambulation according to Lord's self-administered questionnaire (4), which has not been validated. Also, endurance was determined by one question of the SF36. Although this question is a relevant one for community ambulation, other valid measures could have been chosen. Thirdly, the 15% change in the beta coefficient of gait speed that we used to decide whether a factor was a covariate is an arbitrary value. Fourthly, the present relatively small study shows limited generalizability by excluding mainly patients suffering from aphasia. At least significant differences were found in terms of balance control, use of walking aids, walking endurance and depression between the patients who were included in the analyses and those who were not.

Finally, the present study is cross-sectional, whereas a previous longitudinal conducted study has shown that mobility outcome is not stable but time-dependent. For example, it was found that approximately 20% of 205 relatively young chronic stroke victims significantly deteriorated from 1 to 3 years post-stroke (39). Therefore, we also expect that community ambulation will gradually change as a function of time after stroke.

In conclusion, gait speed is strongly related to community ambulation; however, community ambulation is a complex outcome. Simply improving the gait speed of stroke survivors during rehabilitation is not sufficient for them to regain community walking. Balance, motor function, endurance, and the use of assistive walking devices are important factors that may change the relationship between gait speed and community ambulation.

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