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ORIGINAL REPORT

PREDICTION OF FALLING AMONG STROKE PATIENTS IN REHABILITATION

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Objective: **To identify risk factors and predict falling in stroke patients. To determine the strength of general vs mobility screening for this prediction.**
Design: **Prospective study.**
Subjects: **Patients in the first 6 months after stroke.**
Methods: **The following assessments were carried out: an interview concerning civil state and fall history, Mini-Mental State Examination, Geriatric Depression Scale, Falls Efficacy Scale (FES), Star Cancellation Task (SCT), Stroop test, Berg Balance Scale, Functional Ambulation Categories (FAC), Motricity Index, grip and quadriceps strength, Modified Ashworth Scale, Katz scale, and a 6-month fall follow-up.**
Results: **Sixty-five patients were included for analysis. Thirty -eight (58.5%) reported falling. Risk factors were: being single (odds ratio (OR) 4.7; 95% confidence interval (95% CI) 1.2–18.3), SCT–time (OR 1.2; 95% CI 1.0–1.3), grip strength on unaffected side (US) (OR 0.1; 95% CI 0.0–0.8), FAC 3 vs FAC 4–5 (OR 8.1; 95% CI 1.5–43.2), and walking aid vs none (OR 5.1; 95% CI 1.4–17.8). These parameters were included in predictive models, which finally implied a general model (I) with inclusion of SCT–time, FAC category and use of walking aid. A mobility model (II) included: FAC category and strength (US). These models showed a sensitivity of 94.1% and 76.3%, respectively.**
Conclusion: **Several assessments and both prediction models showed acceptable accuracy in identifying fall-prone patients. A purely physical model can be used; however, looking beyond mobility aspects adds value. Further validation of these results is required.**

Key words: stroke; falls; prediction; rehabilitation.

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INTRODUCTION

Fall risk among stroke survivors is significantly higher than among age-matched controls (1, 2). The specific fall incidence among stroke patients in acute care ranges from 14% to 64.5% and, in the rehabilitation setting, from 24% to 47% (2). Falls are most likely to occur during the day, indoors and during transfers. Falls can have severe consequences, such as injuries, decreased mobility, and a debilitating fear of falling (1, 3). Risk factors are disease-related balance and gait deficits (3–5), increased dependency in activities of daily living (ADL) (3, 5), and decreased transfer ability (6), as well as disease-related mental factors (depression and cognitive deficits) (3, 5, 7). Conflicting results have been reported for other potential risk factors, such as quadriceps strength, spasticity and neglect (1).

Although every stroke patient can be considered at risk for falling, knowing which patients are at greatest risk and therefore in need of additional preventative measures would be useful. Regarding fall prediction, two important factors to consider are the multi-factorial nature of falls and the bell-shaped correlation between fall risk and physical abilities (1). Yates et al. (2) found that the risk of falling is not linearly related to the number of impairments among stroke patients. Less mobile patients are often less likely to fall. Therefore the best-fitting cut-off value for a single test (often standard evaluations of balance and gait), does not always have the best predictive value. Hyndman & Ashburn (8) examined the Stops Walking When Talking test (SWWT) in community-dwelling stroke patients and found a specificity of 70% and sensitivity of 53% for falling and a specificity of 69% and sensitivity of 73% for recurrent falling. For patients at a stroke unit, the combination of SWWT with the Berg Balance Scale (BBS) (with a cut-off value of 45) revealed a specificity of 98%, but a low sensitivity (21%) for falling vs non-falling (4). Other studies investigated the prediction of recurrent falling. Ashburn et al. (9) found that a composite score of near-falls in hospital and upper limb function was the best predictor, with 70% specificity and 60% sensitivity. Mackintosh et al. (10) reported high sensitivity and specificity values (greater than 80%) for recurrent falling by combining the history of falling in the hospital or during rehabilitation and an ascertainment of poor balance (BBS < 49 or step test score < 7).

This study aimed to assess the incidence and circumstances of falls and to determine the risk factors for falling among stroke patients in rehabilitation. Subsequently, it was decided to identify fall-prone patients based on clinical assessments. Acknowledging the facts that fallers in stroke populations are more likely to become repeated fallers than elderly people in the general population (3, 4), and that even one fall can have serious consequences, a model differentiating between non-fallers and fallers (≥ 1 fall) was chosen. Also, by taking into account aspects other than mobility, in order to serve the multifactorial complexity of falls, it was opted to look for a general risk model (with inclusion of all risk factors) as well as a specific mobility

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risk model. By comparing these models one can determine which of these approaches to screening is preferable.

METHODS

Subjects

This study was conducted in 5 rehabilitation centres[1] that provide multidisciplinary care for stroke patients. Eligible participants were hemiparetic patients receiving inpatient or outpatient rehabilitation within the first 6 months after a first-time stroke. Patients were excluded for the following reasons: major musculoskeletal problems, neurological disorders in addition to stroke, and, clinically observed or suspected cognitive deterioration. The cognitive deterioration was based on a Mini-Mental State Examination (MMSE) score of < 18. All patients had to be able to understand the meaning of the study and to follow instructions. They all signed an informed consent to participate. The study was approved by the central (University Hospital Ghent) and local ethics committees.

Design

Patients underwent an extensive baseline screening, performed by the first author, and were enrolled in a fall-registration system. When patients were not able to perform one or more tests due to pathology-specific problems, e.g. aphasia or shoulder pain, this was registered, but patients were not excluded. This method ensured that patients who were potentially at risk were not excluded; however, it resulted in different number of cases for some analyses.

Prior to all tests a structured interview was carried out in order to collect personal information. Data were collected from the patients or families and from the patients' medical records.

Neuropsychological tests

Patients' cognitive status was examined using the MMSE (11). The 30-item Yesavage Geriatric Depression Scale (GDS) was used as a screening test for depressive symptoms (12). The Star Cancellation Task (SCT) assessed the presence of attention deficit and visuospatial neglect (13). Completion time, as well as the number of forgotten targets (on the left- and right-hand sides of the page), were registered. Patients who omitted 3 or more targets were classified as having inattention. When the absolute difference between left-sided and right-sided omissions equals or exceeds 3, patients were identified as having neglect (14). Executive functioning was assessed by the Stroop test (15). All 3 cards (100 Black colour names (I)/Coloured dots (II) and Coloured colour names (III)) were used. Errors were not corrected, and the time needed to complete the test, together with the number of correct responses on card II and III were registered. An interference score (number correct card II minus number correct card III) and alternative interference score (time card III minus time card II) were calculated. Fear of falling was assessed with the Swedish modification of the Falls Efficacy Scale (FES) (16).

Physical assessments

Balance was measured with the 14-item Berg Balance Scale (BBS) (17). Gait independency was scored, together with the attending physiotherapist, with the Functional Ambulation Categories (FAC) (18). Besides the general FAC score, the use of a walking aid as well as the type of aid, were registered.

Grip strength was measured on both sides with a Norgren® pneumatic (squeeze bulb, Norgren, Lot, Belgium) dynamometer that measures in bar (0–1) and pounds per square inch (psi) (0 to +14 psi). Measurements were made in bar (at 0.05). Assessment was performed according to the American Society of Hand Therapists' guidelines (19). The best of 3 trials (on each side) was recorded. Quadriceps strength was measured by a part of the Physiological Profile Assessment (20); a spring gauge is attached to the patient's leg using a webbing strap and measures in kilograms. The best of 3 trials was recorded. The Motricity Index (MI) evaluated global limb motor impairment (21).

The Modified Ashworth Scale (MAS) quantified muscle tone (22) in plantar flexors, knee flexors and extensors, hip flexors and adductors for the lower limb, as well as palmar flexors, elbow flexors and extensors and shoulder adductors for the upper limb. A score of 1 or more for any of the muscles categorized the patient as having spasticity.

The Katz scale, scored together with hospital staff, evaluated the patients' level of functionality (as scored on 24 points) (23). Ratings of dependence in urinary continence were used to categorize patients in this aspect.

Follow-up

Patients were enrolled in a fall-registration system for 6 months. A fall was defined as "an unexpected loss of balance resulting in coming to rest on the ground or an object below knee level, not due to a violent blow or intrinsic event such as fainting or an epileptic seizure" (24). Patients were provided "fall-calendars", on which they or their family could indicate falling on a daily basis. Fall calendars were sent in every month. When a calendar was not returned or a fall was reported, the patient was contacted. During the period of inpatient rehabilitation falls were also registered by the staff. Finally, at the end of the follow-up period, all patients were also contacted to check the gathered information. The last 2 procedures served as additional sources of information, to avoid under-reporting. Based on this information subjects were classified into 2 groups "non-fallers (no fall)" or "fallers (≥ 1 fall)".

Data analysis

Data were analysed using SPSS version 17.0. All variables were examined to determine whether they needed re-coding or grouping. Based on this evaluation some of the FAC-categories were combined in order to avoid categories with too few observations. Based on clinical interpretation, the "new" classifications were: FAC 0–1–2 (non-functional and ambulatory-dependent for physical assistance), FAC 3 (ambulatory-dependent for supervision) and FAC 4–5 (ambulatory independent). No inputs for missing data were made. The Kolmogorov-Smirnov test was used to check normality assumptions. Group differences were evaluated using the Pearson χ^2 or Fisher's exact test (for categorical variables) or the independent *t*-test or Mann–Whitney *U* test (for continuous variables). All tests were 2-sided with significance set to $p < 0.05$. For all variables reporting differences between fall and non-fallers, odds ratios (OR) and 95% confidence intervals (95% CI) were calculated. After checking for co-linearity, significant variables were entered in a logistic regression analysis. The entry probability for this was set at a 0.10 level of significance, in order to reduce the chance of type II error due to the sample size. The enter-method was performed to assess the importance of each potential variable as it affects the other parameter OR estimates in the model. In the final model, associations were considered significant if *p*-value < 0.05. Sensitivity (Sn), specificity (Sp), predictive values (PV) and likelihood ratios (LR) of the models were calculated. Receiver operating curve (ROC) analyses were performed to compare both models, using MedCalc, version 11.

RESULTS

Subjects

Seventy-three patients were enrolled in this study. Eight patients were excluded because of unfinished screening and/or incomplete fall follow-up. Thus, the data for 65 (39 men (60%) and 26 women (40%)) could be used for analysis. A description

[1] The participating hospitals were: Centre for Musculoskeletal and Neurological Rehabilitation (Ghent), Heilig Hart Hospital (Roeselare), Jan Palfijn Hospital (Ghent), Rehabilitation Centre De Mick (Brasschaat), and Sint-Jan Hospital (Bruges).

Table I. *Characteristics of stroke patients*

Characteristics	Total, $n=65$	Non-fallers, $n=27$ (41%)	Fallers, $n=38$ (59%)	p-value
Age, years, mean (SD)	64.6 (15.0)	62.6 (13.3)	66.1 (16.0)	0.35
Sex, male/female, *n* (%)	39 (60)/26 (40)	18 (27.7)/9 (13.8)	21 (32.3)/17 (26.2)	0.44
Stroke type, ischaemic/haemorrhagic, *n* (%),	51 (78.5)/14 (21.5)	23 (35.4)/4 (6.2)	28 (43.1)/10 (15.4)	0.36
Hemiplegic side, right/left hemiplegia, *n* (%)	34 (52.3)/31 (47.7)	15 (23.1)/12 (18.5)	19 (29.2)/19 (29.2)	0.80
Time since stroke onset, weeks, median (range)	7 (0–24)	7 (0–17)	7 (1–24)	0.69
Inpatient/outpatient, *n* (%)	54 (83.1)/11 (16.9)	22 (33.8)/5 (7.7)	32 (49.2)/6 (9.2)	1.00
Aphasia, not present/present, *n* (%)	54 (83.1)/11 (16.9)	24 (36.9)/3 (4.6)	30 (46.2)/8 (12.3)	0.34
Civil status, single/with partner, *n* (%)	17 (26.2)/48 (73.8)	3 (4.6)/24 (36.9)	14 (21.5)/24 (36.9)	0.024*
Fall history, no/yes, *n* (%)	41 (63.1)/20 (30.8)	18 (27.7)/8 (12.3)	23 (35.4)/12 (18.5)	0.45

*Significant difference between non-fallers and fallers.
SD: standard deviation.

of patients' characteristics is provided in Table I. The mean age was 64.6 years, with no significant gender difference. Strokes were predominantly ischaemic in origin.

During the 6-month follow-up 38 patients (59%) reported one (28%) or more (31%) falls. No significant differences between non-fallers and fallers were observed, except for the civil state ($p=0.024$). Fall history could not be obtained for 4 patients, due to severe aphasia ($n=3$) or lack of clarity in answers and patient files ($n=1$). No group differences based on the retrospective fall data were found.

From one repetitive faller the exact number of falls and circumstances was unclear. From the other 37 patients a total of 64 falls was registered. Most of these falls occurred during the daytime, and especially during walking (28.1%). A description of fall circumstances is given in Table II. After most falls patients reported no (50%) or minor injuries (44.4%), such as bruises or grazes. Three patients (2 single, and 1 recurrent faller) reported more severe injuries (5.6%). Two of them sustained a fracture (1 hip and 1 shoulder fracture, both at the paretic side) and one a brain concussion. The mean duration between the stroke and the first falls (reported in the 6-month prospective study) was 17 weeks (range 3–32 weeks). Twenty-seven percent of falls happened in the first 12 weeks, 54.1% between 13 and 24 weeks after stroke, and 18.9% later than 24 weeks after stroke.

Comparison of non-fallers and fallers

Bivariate analysis (Table III) revealed some factors that differ significantly between non-fallers and fallers needed significantly longer time to complete the SCT ($p=0.013$). Scores on the GDS and the Stroop test did not show any significant differences. For these last two tests subgroup analyses were performed. Group difference in GDS was evaluated for patients aged 65 years and older. For the Stroop test left and right hemiplegic patients were assessed separately, but both subgroup analyses showed no significant differences.

Table II. *Circumstances of falls in % of total number of falls (*n*=64)*

	%
Walking	28.1
Transfer from "sit-to-stand"	14.1
Falling off a (wheel) chair or toilet chair	12.5
Exercising in rehabilitation	9.4
Getting out of bed	4.7
Stair climbing	4.7
Stance	3.1
Other activities	6.3
Exact circumstance unknown	17.1

Concerning the physical evaluations, there was a significant difference for grip strength US ($p=0.026$). No other strength measures, including balance performance, or presence of spasticity, differed significantly. FAC categories differed significantly ($p=0.027$), with an important higher number of fallers in FAC 3. Further analysis of walking ability is shown in Table IV. To describe the use of walking aids, patients were divided into 3 groups: "no walking aid", "walking aid" and "not applicable" when they were seated in a wheelchair and could not (yet) walk without the assistance of 2 persons. Results showed that fallers more often used a walking aid ($p=0.024$). The different types of walking aids in themselves did not reveal a significant difference.

Bivariate odds ratios

Bivariate ORs, calculated for the most discriminating variables between fallers and non-fallers, are shown in Table V. Being single appeared to be a strong predictive variable (OR=4.7; $p=0.027$). Grip strength on unaffected side yielded an OR of 0.1 ($p=0.031$). Overall tardiness on the SCT, with 10 s as the unit of time, rather than 1 s, for clarity, also appeared to be a predictor, with an OR of 1.2 ($p=0.038$). Thus, an increase of 10 s in SCT time leads to a 20% increase in odds of falling. Regarding patients' walking ability, a significant OR was observed for FAC 3 vs FAC 4 and 5 (OR=8.1; $p=0.014$) and a trend was observed for FAC 3 vs FAC 0, 1 and 2 (OR=5.0; $p=0.06$). Using a walking aid (vs no aid) also appears to be predictive (OR=5.1; $p=0.01$), especially the use of a 4-point cane (vs no aid) (OR=5.9; $p=0.02$).

For grip strength on unaffected side and SCT time cut-off values (corresponding with the Youden index) were calculated. For grip strength on unaffected side cut-off value was ≤ 0.55 bar (OR 3.3; 95% CI 1.1–9.3; $p=0.027$, with grip strength > 0.55 bar as reference category). For SCT time, cut-off value was 95 s (OR 5.3; 95% CI 1.5–19.0; $p=0.01$ with SCT ≤ 95 s as reference category).

Prediction model

Logistic regression analyses were performed to obtain a predictive risk model. The first analysis (for a general risk model)

Table III. *Bivariate analysis: differences between fallers (F) and non-fallers (NF)*

Evaluation item	Number NF/F	Non-fallers	Fallers	*p*-value
MMSE, median (range)	23/29	27 (18–30)	28 (20–30)	0.82
GDS, median (range)	24/30	7 (1–22)	9.5 (1–27)	0.26
FES, mean (SD)	25/31	72.72 (36.46)	82.32 (35.44)	0.32
SCT score (0–54), median (range)	25/35	53 (15–54)	53 (41–54)	0.48
Time to complete (s)	23/34	60 (36–180)	98 (37–309)	**0.013***
Inattention (not/present)	25/35	18 (30)/7 (11.7)	23 (38.3)/12 (20)	0.78
Neglect (not/present)	25/35	21 (35)/4 (6.7)	28 (46.7)/7 (11.7)	0.75
Stroop number correct card II, median (range)	22/25	100 (93–100)	100 (97–100)	0.24
Time card II (s)	22/25	86.5 (59–146)	73 (55–142)	0.25
Number correct card III	22/25	99 (49–100)	97 (15–100)	0.17
Time card III (s)	22/25	145 (93–360)	150 (86–440)	0.94
Score correct II–III	22/25	0 (–2–44)	3 (0–85)	0.09
Score time III–II	22/25	61 (18–223)	69 (24–298)	0.61
Katz scale, mean (SD)	27/38	10.31 (3.61)	11.74 (3.88)	0.15
Continence (no/yes), *n* (%)	27/38	5 (7.7)/22 (33.8)	15 (23.1)/23 (35.4)	0.10
MI upper limb, median (range)	26/37	49.5 (0–100)	60 (0–100)	0.78
Lower limb	26/37	64.42 (16.96)	63.68 (18.49)	0.87
Total	26/37	59 (23.5–100)	58.5 (9–91)	0.88
Grip strength (bar) AS, median (range)	27/38	0 (0–0.95)	0 (0–0,75)	0.85
US	27/38	0.69 (0.20)	0.57 (0.21)	**0.026***
Difference AS/US	27/38	0.48 (0.29)	0.45 (0,26)	0.63
Qceps-strength (kg) A<S, median (range)	24/34	16.88 (10.70)	14.85 (9.16)	0.44
US	25/35	25.40 (8.38)	24.11 (8.36)	0.56
Difference AS/US	24/34	10 (0–20)	5.5 (0–42)	0.75
FAC[3] (0–1–2/3/4–5)	27/38	10 (15.4)/2 (3.1)/15 (23.1)	13 (20)/13 (20)/12 (18.5)	**0.027***
MAS_UL (no spasticity/spasticity), *n* (%)	25/31	8 (14.0)/18 (31.6)	14 (24.6)/17 (29.8)	0.29
MAS_LL (no spasticity/spasticity), *n* (%)	26/31	7 (12.5)/18 (32.1)	14 (25.0)/17 (30.4)	0.27
BBS, mean (SD)	26/37	34.08 (17.56)	32.27 (15.9)	0.67

*Bold: Significant difference between NF and F.

MMSE: Mini Mental State Examination; GDS: Geriatric Depression Scale; FES: Falls Efficacy Scale; SCT: Star Cancellation Task; MI: Motricity Index; AS: affected side; US: unaffected side; Qceps-strength: Quadriceps-strength; FAC[3]: functional ambulation categories: modified Ashworth scale for the lower limb; BBS: Berg Balance Scale; SD: standard deviation.

included all risk factors; civil state, FAC categories, grip strength on unaffected side (cut-off), SCT time (cut-off), use and type of walking aid. The second (for a mobility risk model) included only those variables that were strictly related to mobility; grip strength on unaffected side (cut-off), FAC categories, use and type of walking aid. These mobility variables were always registered for all patients, in contrast to the general predictors, where the SCT could not always be performed.

Integration of the continuous variables was performed using the cut-off value to obtain a model that was easy to interpret. To build the general prediction model, "type of walking aid" was excluded because of the creation of a redundant number of variables reducing the degrees of freedom as well as the high standard error (> 2). Table VI shows the final prediction models. For a general prediction model a combination of SCT time

Table IV. *Differences in use and type of walking aid between non-fallers and fallers (*n*=65)*

Evaluation		Non-fallers *n* (%)	Fallers *n* (%)
Use/type of walking aid	None	11 (16.9)	6 (9.2)*
	Walking aid	9 (13.8)	25 (38.5)*
	Crutch/stick	*2 (3.1)*	*5 (7.7)*
	Four-point cane	*4 (6.2)*	*13 (20)*
	Walking frame/walker	*3(4.6)*	*7 (10.8)*
	Aid not applicable[a]	7 (10.8)	7 (10.8)*

[a]Patients were seated in wheelchair and could not (yet) walk without the assistance of 2 persons.

*Significant difference in use of walking aids between Non-fallers and Fallers ($p = 0.024$).

Table V. *Bivariate odds ratio*

Variables	OR	SE	95% CI	*p*-value
Incontinence (vs continence)	2.9	0.60	0.9–9.2	0.077
Stroop test score correct II–III	1.0	0.03	1.0–1.1	0.253
No partner (vs partner)	4.7	0.70	1.2–18.3	0.027*
SCT time (10 s)	1.2	0.07	1.0–1.3	0.038*
Grip strength US (bar)	0.1	1.30	0.0–0.8	0.031*
FAC 3 (vs 0–1–2)	5.0	0.87	0.9–27.4	0.064
FAC 3 (vs 4–5)	8.1	0.85	1.5–43.2	0.014*
FAC 0–1–2 (vs 4–5)	1.6	0.57	0.5–5.0	0.396
Use/type of walking aid				
Walking aid (vs aid not applicable)	5.1	0.64	1.4–17.8	0.011*
Crutch/stick (vs no aid)	4.6	0.98	0.7–31.2	0.120
Four-point cane (vs no aid)	5.9	0.76	1.3–26.7	0.020 *
Walking frame/walker (vs no aid)	4.3	0.86	0.8–22.9	0.090
Aid not applicable[a] (vs no aid)	1.8	0.74	0.4–7.8	0.411
Walking aid (vs not applicable[a])	2.8	0.66	0.8–10.1	0.122

*Significant at 0.05 level.

OR: odds ratio; SE: standard error; 95% CI: 95% confidence interval for the odds ratio; SCT: Star Cancellation Task; US: unaffected side; FAC: Functional Ambulation Categories.

[a]Patients were seated in wheelchair and could not (yet) walk without the assistance of 2 persons.

(reference category SCT ≤ 95 s), FAC categories (reference category FAC 4–5) and use of walking aid (reference category no use of an aid) was found to predict falling. For the mobility risk model a simple combination between FAC categories (reference category FAC 4–5) and strength on unaffected side (reference category > 0.55 bar) was found.

The equations for the general and mobility prediction model are:

$y_{general}$=3.21 (if FAC 3) – 1.52 (if FAC 0–1–2) + 3.12 (if SCT > 95 s) + 2.50 (if walking aid) + 1.28 (if aid not applicable) – 2.22

$y_{mobility}$=2.03 (if FAC 3) + 0.04 (if FAC 0–1–2) + 1.30 (if strength on unaffected side ≤ 0.55 bar) – 0.61

Since y equals Log($odds_{falling}$), the predicted probability can be calculated as $e^y/(1+e^y)$.

Using a cut-off value of 0.5 for this probability can categorize a patient as a fallers or non-fallers (Table VII). Hereby, the overall accuracy increases to 78.9% (Sn = 94.1%; Sp = 56.5%) for the general model and to 72.3% (Sn = 76.3%; Sp = 66.7%) for the mobility prediction model. Predictive values and likelihood ratios for both models differ little. The area under the curve for the general and mobility prediction model was 0.87 (95% CI 0.75–0.94) and 0.743 (95% CI 0.63–0.86), respectively. Comparison of ROC curves revealed a difference between these 2 models; however, it did not reach significance (p = 0.057). Thus, both models can be used to predict falling.

DISCUSSION

The fall incidence (59%) and circumstances registered in the present study are comparable with previous investigations. With 31% experiencing recurrent falling, the statement that fallers in a stroke population are more likely to become repeated fallers than elderly people in the general population (21–57% for stroke patients and 15% for elderly people) was confirmed (4, 25).

Although a prospective follow-up is preferable to retrospective analysis, a longer follow-up period may have given different results. However, it can be questioned whether a longer follow-up period is the most appropriate method, due to the decrease in validity of baseline data with respect to changes in time after stroke. Most falls also occur during the first months in or after rehabilitation (5, 25). Due to the follow-up duration as well as the possible consequences of any fall, a categorization of patients as non-fallers (no fall) or fallers (1 or more falls), rather than non-fallers (no or 1 fall) or repeated fallers (more than 1 fall) was preferred.

Fall history was obtained by a dichotomous question as to whether the patients had fallen since their stroke. There were no significant group differences based on these retrospective data. Previous studies found fall history to be a risk (10, 26). This discrepancy may be due to the fact that those studies contained patients who all completed their (inpatient) rehabilitation. In our study there were differences in time after stroke, and although the question was clearly explained and patients' nursing reports were screened for notes about falling, this may have been insufficient to obtain reliable responses.

Being single appeared to differ significantly between fallers and non-fallers and could even predict falling. This finding emphasizes the important role of a partner in safety when hemiplegic patients return to their own homes.

The MMSE served as a brief global cognitive measure. Based on normative data of Crum et al. (27), a score of 18 or less (taking into account the patient's educational background and age) was used as an exclusion criterion. Patients with severe aphasia were unable to perform this test and were clinically observed and judged. To our knowledge there is no standardized brief cognitive test for aphasic patients.

Since MMSE is weighted significantly towards aspects of memory and attention, and there is little assessment of visuospatial ability and no testing of executive performance (28), the SCT and Stroop test were added. Nevertheless, the use of a single test to assess visuospatial neglect can cause dissociations, and a combination of tests may have been better (29). SCT has been shown to be one of the most sensitive neglect tests. Not only conventional scoring (overall target detec-

Table VI. *Risk model for the prediction of fallers vs non-fallers*

Predictors	OR	SE	95% CI	B	p-value
Model I (general)					
FAC 3 (vs 4–5)	24.8	1.37	1.7–363.9	3.21	0.019
FAC 0–1–2 (vs 4–5)	0.2	1.22	0.0–2.4	–1.52	0.212
SCT–time > 95 s (vs 0–95 s)	22.7	1.01	3.1–164.9	3.12	0.002
Walking aid (vs no aid)	12.1	1.08	1.4–102.0	2.50	0.021
Aid not applicable (vs no aid)	3.6	1.57	0.2–77.7	1.28	0.412
Constant	0.11	0.97		–2.22	0.022
Goodness-of-fit test[a]		0.89 (χ^2= 2.94–7 df)			
Nagelkerke R^2		0.54			
Model II (mobility)					
FAC 3 (vs 4–5)	7.6	0.87	1.4–42.1	2.03	0.020
FAC 0–1–2 (vs 4–5)	1.0	0.63	0.3–3.6	0.04	0.949
Grip strength US 0–0.55 bar (vs > 0.55 bar)	3.7	0.60	1.1–11.9	1.30	0.031
Constant	0.54	0.44		–0.61	0.165
Goodness-of-fit test[a]		0.84 (χ^2= 1.41–4 df)			
Nagelkerke R^2		0.24			

[a] Hosmer and Lemeshow Test.

OR: odds ratio; SE: standard error; 95% CI: 95% confidence interval for the odds ratio; B: regression coefficient expressed in logits; FAC: Functional Ambulation Categories; SCT: Star Cancellation Task; US: unaffected side; df: degrees of freedom.

Table VII. *Observed and predicted frequencies for falling by logistic regression with a cut-off value of 0.5*

		Predicted					
		Model I (general)			Model II (mobility)		
		NF	F	% correct	NF	F	% correct
Observed	NF	13	10	56.5	18	9	66.7
	F	2	32	94.1	9	29	76.3
Overall % correct				78.9			72.3
PPV/NPV	0.76/0.86				0.76/0.66		
LR+/LR–	2.16/0.10				2.29/0.35		

PPV: positive predictive value; NPV: negative predictive value; LR+: positive likelihood ratio; LR–: negative likelihood ratio; F: Fallers; NF: Non-fallers.

tion and lateralized bias score) was used, but time was also registered. Nowadays, the importance of examining the time course to increase the sensitivity and utility of the measure is emphasized. The time taken to perform the test can reveal patients whose alertness drops during task performance, or who use a less coherent search strategy. The conventional scoring can classify those patients as normal if they find all or most targets after searching for a long time. Thus, the non-spatial aspects of cancellation performance may form a better long-term predictor of outcome than does spatial bias (30). In our study SCT time showed significant differences between fallers and non-fallers, whereas the score did not, nor did the presence of inattention or neglect. Some previous studies found significant group differences concerning the presence of neglect during rehabilitation (31, 32). Nyberg & Gustafson (31) used the line bisection test to detect neglect, and empirically estimated patients who were not able to complete the test. In our study these patients did not receive a score.

Executive dysfunction, involving errors of planning, judgement, problem-solving and impulse control, could lead to falling. Consequently, it would be of interest to include this aspect in a fall risk evaluation. Liu-Ambrose et al. (33) have pointed out the importance of cognitive and executive function in fall evaluation and prevention for stroke patients. In our study lower scores on card III (less correct answers and longer time to complete), which are assumed to indicate difficulties in response inhibition, were found; however, these differences were not significant. Thus, impulsivity, which is thought to reflect failure of response inhibition, could not be assigned to fallers. Rapport et al. (7) performed an extensive neuropsychological assessment among right-hemisphere stroke patients, and found that general inattention, measured by digit span, was associated with falls. However, it did not add to a fall prediction model. From the neuropsychological assessment variables in our study, SCT–time added significantly to the general model. Patients needing more than 95 seconds to perform the test showed an increased risk of falling.

Grip strength on unaffected side also appeared to be a strong predictor of falls. To measure grip strength in our screening a pneumatic (Norgren®) dynamometer was used. Another evaluation tool could have been a mechanical instrument, which measures forces in units of kilograms or pounds of force. After some trials to optimize the study design, it was decided to evaluate grip strength with a pneumatic instrument. The trials showed that many patients had difficulty holding a dynamometer due to limited strength and stability of the paretic wrist or to hand deformities. Since the pneumatic instrument is easier for most patients to handle (18), it could be used on the non-paretic as well as the paretic side. In our study, measurement in bar was used. However, conversion to another measurement is easy; e.g. from bar to psi (multiply by 14.5) or from bar to kPa (multiply by 100). Knowing these conversions can attain decimal values, and acknowledging the accuracy of measurements, cut-off values of 0.55 bar or 8 psi or 55 kPa are proposed.

Despite evidence that poor gait and balance performance are important risk factors for falls among stroke patients, this study did not find a difference between fallers and non-fallers based on BBS score. However, previous studies have also stated that the predictive value of BBS appears to be low (4, 34). With respect to these earlier results, the present study confirms the inaccurate prediction of falls in acute stroke based on the BBS. An important difference from previous literature is that the scores on BBS in our study are lower. This can be attributed to our patient selection criteria, in which it was not required that physical abilities were included.

Poor gait performance yield as an important risk factor for falls. Most patients fell during walking, and FAC proved to be an important factor in both models. More specific "FAC 3 vs FAC 4–5" and "use of a walking aid vs no walking aid" showed significant OR. Examining the clinical meaning of FAC 3, which stated that, in FAC 3, patients are capable of walking alone, but still need supervision for their own safety (17), these findings appear to be a logical consequence. The predictive value for the use of a walking aid, and especially a 4-point cane, compared with no walking aid might be less expected. Soyuer & Öztürk (35) also found significant differences between fallers and non-fallers with respect to use and type of walking aid in chronic stroke patients. However, with respect to falls, they were not considered to be an indicator. A study on the effects of 1-point vs 4-point canes on balance and weight distribution in acute stroke patients with moderate functional impairment reported that 4-point canes did increase stability during stance more than a 1-point cane (36). The effect of these walking aids with respect to gait was not examined. Allet et al. (37) investigated the effect of 3 different walking aids (4-point cane, simple cane with ergonomic handgrip and Nordic stick) on walking capacity of hemiparetic patients at an early stage of rehabilitation. The simple cane was not only preferred by patients, but was also the most efficient. Thus, although a 4-point cane increases stability during stance, evidence suggests a better effect on gait with the use of a 1-point cane. These results emphasize the importance of gait evaluation and consideration of the use and type of walking aid.

Several clinical observations (especially of gait quality) and tests with "easy-to-administer" cut-off values have a good fall predictive value. The mobility model (II) obtained resembled the model of Ashburn et al. (9), which consisted of near falls in the hospital and upper-limb function. However, in our study, upper limb function of the non-paretic hand instead of the paretic hand appeared to be of importance. A plausible explanation could be that improvement in grip strength on unaffected side reflects a better counterbalance against postural instability. Secondly, it is debatable whether the occurrence of near falls in the hospital can be obtained unambiguously from a retrospective point of view for all patients, e.g. aphasic patients.

In addition, in our study, 2 prediction models showed acceptable overall accuracy, with higher sensitivity than specificity. Since sensitivity indicates the probability that a faller will be correctly identified as one, this appears to be the most important factor. Also, the likelihood ratios, which are independent of disease prevalence, showed acceptable results, with no large difference between the 2 models. Possible objections, that a sheer mobility model cannot be as accurate as a general prediction model due to the multifactorial cause of falls, can therefore be refuted. However, looking beyond mobility aspects alone can add value. Finally, an important aspect is the ease of use of these models. Little information is needed to make a good fall prediction; thus additional preventative measures can be taken if necessary.

Notwithstanding the limitation of the small sample size and the necessity of consequent validation, the reported results are of clinical value for everyone working with stroke patients in rehabilitation.

In conclusion, with more than half of stroke patients falling, it is important to monitor for this complication. In particular, walking and transferring, which are important goals of rehabilitation for most patients, seem to be activities that put the patient "at risk" of falling. Different clinical observations and easy-to-administer tests have a good fall predictive value and should be administered regularly during rehabilitation. Although future validation in a new large sample is required, these results suggest that the general, as well as the sheer mobility prediction model appear to be useful to identify fall-prone patients in the first 6 months after stroke. Further investigations are needed into the importance of gait parameters in falling and the implications for fall-prevention.

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