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Neurological Gait Abnormalities And Risk Of Falls In Older Adults

Joe Verghese, MD[1], **Anne F Ambrose, MD**[3], **Richard B Lipton, MD**[1,2], and **Cuiling Wang, PhD**[2]

[1]Department of Neurology, Albert Einstein College of Medicine, Yeshiva University, Bronx, NY, USA

[2]Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Yeshiva University, Bronx, NY, USA

[3]Department of Physical Medicine and Rehabilitation, Mt. Sinai Medical Center, NY

Abstract

Objective—To estimate the validity of neurological gait evaluations in predicting falls in older adults.

Methods—We studied 632 adults age 70 and over (mean age 80.6 years, 62% women) enrolled in the Einstein Aging Study whose walking patterns were evaluated by study clinicians using a clinical gait rating scale. Association of neurological gaits and six subtypes (hemiparetic, frontal, Parkinsonian, unsteady, neuropathic, and spastic) with incident falls was studied using generalized estimation equation procedures adjusted for potential confounders, and reported as risk ratio with 95% confidence intervals (CI).

Results—Over a mean follow-up of 21 months, 244 (39%) subjects fell. Mean fall rate was 0.47 falls per person year. At baseline, 120 subjects were diagnosed with neurological gaits. Subjects with neurological gaits were at increased risk of falls (risk ratio 1.49, 95% CI 1.11 – 2.00). Unsteady (risk ratio 1.52, 95% CI 1.04 – 2.22), and neuropathic gait (risk ratio 1.94, 95% CI 1.07 – 3.11) were the two gait subtypes that predicted risk of falls. The results remained significant after accounting for disability and cognitive status, and also with injurious falls as the outcome.

Conclusions—Neurological gaits and subtypes are independent predictors of falls in older adults. Neurological gait assessments will help clinicians identify and institute preventive measures in older adults at high risk for falls.

Keywords

Gait; Clinical Neurology; Incidence studies; Falls; Epidemiology

INTRODUCTION

One third of community-residing older adults fall each year.[21] Falls result in major adverse outcomes in older adults including injury, institutionalization, and death.[28] Falls are a common presenting complaint in Neurology clinics. Neurological diseases such as stroke, dementia, and Parkinson's disease have high rates of falls.[24] However, there is a paucity of studies that have examined risk factors, screening tests, and interventions for falls related to neurological diseases.[24] Gait abnormalities are considered among the most consistent predictors of falls.[8,26,27,31] Also, they represent a potentially modifiable risk factor.[8,26] Gait evaluation is recommended in fall guidelines.[2,8,24] Yet, most fall studies have either

Corresponding Author: Joe Verghese, M.D. Albert Einstein College of Medicine, 1165 Morris Park Avenue, Room 301, Bronx, New York 10461, USA. Tel: 718 430 3888 Fax: 718 430 3870 jverghes@aecom.yu.edu.

not addressed the role of neurological gaits or focused on the role of specific neurological gait subtypes or particular neurologic disorders.[7,8,14,18,27]

To our knowledge, a systematic examination of fall risk associated with neurological gaits in community residing older adults is lacking. Knowledge of fall risk associated with neurological gaits, a standard element of the neurological examination, will help neurologists, geriatricians, internists, and other health professionals who evaluate older patients presenting with falls or at risk of falls a quick and practical way to help decide to institute preventive measures to reduce risk of falls. We undertook this cohort study to prospectively determine whether and to what extent neurological gaits are associated with falls, after accounting for potential confounders in community residing older adults.

METHODS

Study Population

We undertook a prospective cohort study nested within the Einstein Aging Study (EAS).[29,31] The primary aim of the EAS is to identify risk factors for dementia. Study design has been previously reported.[29,31,33] In brief, potential subjects (age 70 and over) identified from Bronx County population lists were contacted by letter explaining the purpose and nature of the study, and then by telephone. Subjects who gave verbal consent on the telephone were invited for further evaluation at our research center. Exclusion criteria included severe audiovisual loss, bed bound due to illness, and institutionalization. Written informed consents were obtained at enrollment according to protocols approved by the local institutional review board.

Falls

Falls were defined as the subject unintentionally coming down on the floor or to a lower level not due to a major intrinsic or extrinsic event.[26] At baseline and annual follow-up visits, subjects were asked about falls in the previous year. Research assistants also contacted subjects by telephone every two to three months in between clinic visits to ascertain new falls and any associated injuries (laceration, fracture, or emergency care).

We started systematically ascertaining falls in our cohort from September 2004 onwards. The first telephone interview was administered in November 2004. Follow-up for this study ended February 2008. Of the 789 EAS subjects seen during this 40-month period, 82 did not have neurological gait assessments and 75 had no fall assessments. Thus, 632 subjects (80.1%) with gait and telephone fall assessments were eligible. Subjects who did and did not receive gait and fall assessments (mostly due to tester unavailability[31]) were similar in terms of age, sex, and cognitive status. The 632 eligible subjects (100%) all completed one or more follow-up telephone interviews, and 448 subjects (71%) completed one year or more follow-up in the study.

Gait assessment

Subjects were observed while they walked up and down a well lit hallway by board certified or eligible study neurologists who rated gaits as normal or abnormal following visual inspection of walking patterns as previously described.[31] Gait was evaluated as part of the standard neurological examination, which also tested cranial nerves, strength, sensation, and deep tendon reflexes. Abnormal gaits were classified as either neurological (one of eight subtypes described below) or non-neurological (due to causes such as arthritis or cardiac disease).[31,32] Neurological gaits were subtyped as unsteady if two or more of the following features were present: marked swaying or losing balance while walking in a straight line, in tandem, or making turns. Ataxic (cerebellar) gait is wide-based and unsteady with other cerebellar signs such as intention tremor or inability to perform rapid alternating movements. Since ataxic and unsteady gaits share many clinical characteristics, we combined these two subtypes for this study. Patients with neuropathic gaits have unilateral or bilateral foot drop with associated signs such as sensory loss and depressed or absent deep tendon reflexes. Frontal gait is characterized by short steps, wide base, and difficulty in lifting the feet off the floor. Older adults with Parkinsonian gaits have small shuffling steps, flexed posture, absent arm swing, en bloc turns, and festination. Patients with hemiparetic gait swing their leg outward and in a semicircle from the hip (circumduction). In spastic gait both legs circumduct, and when severe cross in front of one another (scissoring). Clinicians were also allowed to classify other rare subtypes of neurological gait such as waddling gaits (due to proximal myopathy) not included in the main classification. Severity of gait abnormalities were graded as mild (walks without assistance), moderate (uses walking aid such as cane), or severe (wheelchair or stands only with assistance). Clinicians were allowed to assign more than one subtype to subjects and ranked them in order of contribution to the gait. The highest ranked subtype was used for this study. More detailed descriptions and video weblinks of abnormal gaits are available.[31,32]

Clinicians who evaluated gait in any given year were blinded to results of any previous gait or clinical examinations. The methods used herein have established test-retest reliability and predictive validity.[30,32] In 189 subjects assessed one year apart agreement on the presence or absence of neurologic gait was 89% (kappa 0.6) [32]. Because gait may change over the course of a year, this likely represent underestimates. As expected, in a contemporaneous assessment, two study neurologists independently diagnosed neurologic gait with excellent inter-rater reliability (kappa 0.8).[30] For subjects diagnosed with unsteady gait, the most common subtype, there was a 75% agreement between annual assessments. Clinical gait abnormalities diagnosed by this method were associated with increased risk of dementia and death in this cohort, demonstrating predictive validity. [31,32]

Quantitative gait assessments were also conducted using a computerized walkway (180 × 35.5 × 0.25 inches) with embedded pressure sensors (GAITRite, CIR systems, USA). Subjects were asked to walk on the mat at their usual pace for two trials in a quiet well-lit hallway wearing comfortable footwear and without any attached monitors. Start and stop points were marked by white lines on the floor, and included three feet from the walkway edge for initial acceleration and terminal deceleration. Based on footfalls recorded on the walkway, the software computes gait variables such as velocity (cm/sec) as the mean of two trials for both conditions. We recently reported the association of quantitative gait parameters and fall risk in the same cohort.[29]

Clinical assessment

Clinical assistants used structured questionnaires to elicit history of medical illnesses, medication use (prescription and non-prescription), and depressive symptoms at study visits.[32,33,35] Presence of depression, diabetes, heart failure, hypertension, angina, myocardial infarction, strokes, Parkinson's disease, chronic obstructive lung disease, and arthritis was used to calculate a summary illness index as previously described.[15,33] We consulted medical records and contacted subjects' family members or physicians to verify or obtain further details. The following seven activities of daily living were assessed based on a disability scale developed for use in community-based cohorts [10]: bathing, dressing, grooming, feeding, toileting, walking around home, and getting up from a chair. Subjects were asked if they were able to perform an activity unassisted (0 points), unassisted but with difficulty (1 point), or whether they required assistance or were unable to do the activity (2 points). A summary disability score was then computed (range 0 to 14). General cognitive status was assessed by the Blessed-Information-Memory concentration test.[3] Unipedal stance time, a sensitive balance test, was recorded as the time subjects balanced on one foot without support (maximum

30 seconds).[16] Time taken to get up from a chair five times unassisted was recorded. This is a test of balance and lower extremity strength.[23]

Data analysis

Baseline characteristics were compared with descriptive statistics, applying non-parametric tests as appropriate. For analysis of the longitudinal fall data, we used generalized estimating equations (GEE) with a binomial distribution to model the probability of fall at each follow-up assessment using the log link function.[36] We examined the risk of falls associated with neurological gaits overall diagnosed at study entry. We also examined risk of falls with specific subtypes of neurological gaits as a secondary outcome. All gait predictors are examined simultaneously in the model. The reference group is those without neurological gaits. The interaction between neurological gait and time was not significant and thus not included in the models. GEE is an extension of generalized linear models for analyzing longitudinal data.[19] It can accommodate different follow-up lengths and missing data. It has the advantage that the parameter estimate from GEE analysis is consistent as long as the model for the marginal mean is correctly specified. This method has been used in recent fall studies.[4] By use of GEE models, arbitrary definitions (such as two or more falls within one year to classify recurrent fallers or falls in the first year of follow-up) are avoided and, instead, the probability of falling within the study assessment intervals is modeled.[4] Furthermore, GEE takes into account interval censoring arising from fall ascertainment at discrete time points unlike other methods such as the Cox proportional hazard models.[34] Risk ratios and 95% confidence intervals (CI) were estimated from the models.

All analyses reported include age, gender, and years of education as well as the following baseline covariates: illness index, number of medications, falls in the year prior to entry, Blessed test scores, and disability score.[3,8,13,16,27] Univariate associations of these covariates with fall risk were examined using GEE. We also repeated the full models including traditional clinical tests of balance and strength (unipedal stance and repeated chair rise tests). The following variables did not influence results in preliminary analyses, and were not included in reported models: individual illnesses, specific medication categories (psychotropics or sedatives), clinical rating of strength [5], or presence of abnormal sensation on clinical examination.

We conducted a number of sensitivity analyses to support our results. Since walking patterns may be influenced by non-neurological diseases such as arthritis that may occur with or without neurological gaits, we repeated the analysis excluding all subjects with non-neurological gaits as the primary diagnosis. Cognitive impairment may increase risk of falls.[8] Hence, we included Blessed scores[3] as a covariate in our final models. In additional analyses, we examined the interaction of Blessed scores with neurological gaits on fall risk. To account for recall bias for falls among cognitively impaired subjects [9], we examined injurious falls as a secondary outcome.

RESULTS

The 632 eligible subjects completed 4296 telephone and in-house follow-up assessments. The mean number of telephone and in-house follow-up interviews completed during the study was 6.8 (range 1 to 17), corresponding to a mean follow-up of 20 ± 10 months. Falls were reported in 442 interviews (10%). The median time from baseline to first fall was eight months (inter-quartile range 4 to 17 months). Falls occurred in 244 subjects (39%), of whom 119 (49%) had more than one fall.

The average age of participants was 80.6 years. Subjects who fell during follow-up were older at baseline than non-fallers (mean age 81.2 versus 80.2 years, p = 0.03). There were 241 men (38%) and 391 women (62%).

Subjects with neurological gaits were older, more men, had higher frequency of previous falls, and had higher illness index compared to remaining subjects (Table 1). Subjects with neurological gaits walked slower than those without gait abnormalities (77.2 vs. 96.5 cm/sec, p<0.0001). The mean gait velocity for individual gait subtypes were also slower compared to those without gait abnormalities: hemiparetic (86.6 cm/sec), frontal (71.3 cm/sec), Parkinsonian (77.0 cm/sec), unsteady (81.2 cm/sec), spastic (73.9 cm/sec), and neuropathic (72.8 cm/sec). Older age (risk ratio 1.03, p = 0.02) and disability scores (risk ratio 1.04, p = 0.003) among the individual variables examined, including clinical tests, predicted fall risk.

Neurological gait abnormalities and risk of falls

Neurological gaits were diagnosed in 120 subjects (18.9%) at baseline. The severity of impairment was rated as mild by study clinicians in 86 (71.6%) and moderate (uses walking aid such as cane) in 33 (27.5%) of the 120 subjects with neurological gaits.[31] There was only one subject with severe gait abnormality (wheelchair) in this community-based sample, and was included in the moderately severe group for analyses.

The mean fall rate was 0.47 falls per person year; mean fall rate in subjects with neurological gaits was 0.66 falls per person year and 0.43 falls per person year in those without neurological gaits (p =0.01). Of the 244 subjects who fell during follow-up, 56 had neurological gait at baseline (sensitivity 23%, specificity 84%). Subjects with neurological gaits were more likely to fall during follow-up than those without neurological gaits (47% vs. 37%, p = 0.04). Subjects with neurological gaits were at increased risk of falls (risk ratio 1.49, 95% CI 1.11 – 2.00) after adjustments for multiple confounders in the GEE model.

The association of neurological gaits with fall risk (risk ratio 1.45, 95% CI 1.09 – 1.94) was significant even after additional adjustments for unipedal stance, repeated chair rise tests, and gait velocity in the full model. Velocity (p = 0.047) but not unipedal stance and chair rise was significant in this expanded model.

Compared to subjects without neurological gaits, those with moderately severe neurological gaits (risk ratio 1.92, 95% CI 1.20 – 3.06, p <0.001) were at increased risk of falls. The association of mild neurological gaits with fall risk was not significant (risk ratio 1.38, 95% CI 0.98 – 1.94, p = 0.06).

Gait subtypes

The neurological gait subtypes included 42 unsteady (35%), 15 hemiparetic (13%), 9 frontal (8%), 10 Parkinsonian (8%), 23 neuropathic (19%), and 12 spastic (10%) gaits. Six subjects (5.0%) were diagnosed other rare gait subtypes that included waddling gait due to proximal myopathy (n = 2), cautious gait due to fear of falling (n = 3), and slow gait without any distinguishing features (n = 1). In this secondary analysis, unsteady (risk ratio 1.52, 95% CI 1.04 – 2.22) and neuropathic gaits (risk ratio 1.94, 95% CI 1.07 – 3.52) predicted risk of falls (Table 2).

Sensitivity analyses

Non-neurological gaits were mostly due to musculoskeletal causes such as arthritis as reported previously in this cohort [31], and was not associated with increased fall risk (risk ratio 0.91, 95% CI 0.66 – 1.26). The association of neurological gaits with falls (risk ratio 1.53, 95% CI 1.12 – 2.08, p = 0.006) remained even when subjects with primary diagnosis of non-neurological gaits were excluded. Associations of individual neurological gait subtypes with falls were strengthened when subjects with non-neurological gaits were excluded (data not shown).

The interaction between Blessed scores[3] and neurological gait status was suggestive but not significantly associated with fall risk ($p = 0.16$). On the other hand, significant interactions were seen between Blessed scores and frontal ($p = 0.01$) as well as unsteady gaits ($p = 0.03$).

We also examined injurious falls, which may be less prone to recall bias. Injuries occurred in 47% of the falls. The injurious fall rate was 0.24 per person year. Women were at higher risk for injurious falls than men (risk ratio 1.70, 95% CI 1.23 – 2.37). Neurological gaits predicted risk of injurious falls (risk ratio 1.80, 95% CI 1.23 – 2.64) in the fully adjusted models.

DISCUSSION

In this prospective study of a large, well-characterized cohort of community residing older adults, presence of neurological gaits diagnosed on routine clinical examination was a strong predictor of future fall risk. Older adults with neurological gaits at baseline had a 49% increased risk for falls over a mean follow-up period of 20 months compared to subjects without neurological gaits. The association between gait and risk of falls remained robust even after adjusting for several potential confounders as well as traditional tests of mobility and balance. The increased risk of falls associated with moderately severe gait impairment suggests a possible dose response effect. Among individual subtypes, unsteady and neuropathic gaits were associated with increased fall risk. To our knowledge, this is the first systematic study to demonstrate the role of abnormal neurological gaits overall as well as a range of specific subtypes as predictors of falls in older adults. Our findings are supported by previous studies that have reported increased fall risk with individual subtypes such as neuropathic gaits.[7,8, 11]

The increased risk of falls seen with neurological gaits is mutifactorial. Fall risk may result from diseases affecting the neuro axis from the periphery to the cortical motor centers. Mild Parkinsonian signs are common in community residing older adults and may contribute to fall risk.[17] Other mostly clinic based samples have reported higher fall rates in patients with Parkinson's disease.[11] Fall risk in these studies may relate to severity of disease, which is usually worse in clinic samples than in community based cohorts.[17] We restricted our examination of Parkinsonian signs to gait, and it is possible that other Parkinsonian features such as tone or postural instability may better predict falls. We reported a higher prevalence of history of falls at cross-section in subjects with Parkinsonian gaits compared to frontal gaits [1], but did not find an association with incident falls in this study. Subjects with hemiparetic or Parkinsonian gaits are more likely to receive rehabilitation or pharmacological interventions that may reduce fall risk. However, we did not have information on rehabilitation interventions. Our results were unchanged when adjusted for medications that may influence fall risk.[13] Cerebrovascular disease and strokes are associated with increased risk of falls in other elderly cohorts.[8,12] We have reported that unsteady gaits predict risk of vascular dementia [32], suggesting a vascular etiology for this subtype.

While we reported that abnormal gaits are a marker for early cognitive decline [32], the interaction between neurological gaits overall and Blessed scores was suggestive but not significant. However, subjects with frontal or unsteady gaits were at higher risk of falls in the presence of cognitive impairment.

Several limitations need to be noted. This nested cohort study was necessarily restricted to subjects who received gait and fall assessments since 2004, but subjects seen previously were not differentially excluded. This is a community based sample but was not recruited as a representative population sample. However, demographic characteristics of this cohort were similar to that of older adults in our county. While we have reported good reliability of our gait classification [30–32], individual gait subtypes may be misclassified. Moreover, subjects may develop abnormal gaits during follow-up. The findings reported with individual neurological gaits shed light on relative risks of falls in different neurological diseases. However, there was a low prevalence of many gait subtypes in this community based sample reducing power. Hence, our secondary analysis using individual gait subtypes should be considered exploratory and verified in other population and clinic samples. As the underlying disease pathology for different gaits may vary, we did not pool the less common gait subtypes for analyses. Despite its widespread use in clinical practice [20,31], there are no universally accepted gait classifications. Unlike our gait classification, the reliability and validity of most descriptive classifications have not been verified and subtypes overlap. For instance, marche a petit pas, cautious gait, and apractic gait are used to describe gait abnormalities that share clinical features such as slowness, short steps, or wide base with frontal gaits.[1,20,31] Information on individual medication classes was not available. We did not examine fear of falling. Though adjusted for multiple confounders, our results may be influenced by unmeasured confounders such as environmental factors.

Poor recall of falls is linked to cognitive impairment and longer assessment intervals.[9] The short intervals and high interview completion rates help reduce errors in our study. Our contact interval was longer than studies where monthly fall calendars were used, but similar or shorter than those using telephone interviews.[4,6,27] A more detailed fall collection method was not used as falls were not the primary outcome in our parent study. Hence, it is likely that we may have underestimated effects. Adjusting for cognitive status or studying injurious falls as the outcome did not change our results. Some individual variables did not significantly predict fall risk (Table 1) [8], though the associations were in the right direction. Differences in populations, fall collection methods, clinical assessment techniques, and definitions used for risk factors may account for differing results.[8,25] While attrition is a concern in any longitudinal study, we had almost complete follow-up over the study period reducing bias. We expect that different fall outcomes such as first ever fall (though this outcome is more prone to recall bias) may differ in strength of associations with different neurological gaits, and is an issue we are investigating in our ongoing studies. This will have implications for developing gait assessments and interventions in the future.

As expected for a condition like falls with multiple contributing factors [2,8,25], neurological gaits had high specificity (and risk ratio) but lower sensitivity in predicting falls. Slow gait (defined as velocity < 70 cm/sec) at baseline also had low sensitivity (18%) and high specificity (85%) in predicting falls in this cohort. Gait assessment alone will not identify all fallers, but it does identify a large group at high risk and potentially amenable to preventive intervention.

The utility of deconstructing clinical gait into clinically observable components such as speed, steadiness, or base to refine current gait assessments for falls should be examined. We recently reported that quantitative gait parameters such as gait velocity and variability in swing and stride predicted fall risk in the same cohort.[29] Slow gait is a key feature of many neurological gait subtypes. We had also reported that when adjusted for gait velocity the relationship between abnormal gait (non-neurological or neurological gaits) and falls was not significant.[29] However, in the current analysis that focuses on neurological gaits, the association with falls was significant even when adjusted for velocity and other performance measures such as unipedal stance and chair rise supporting an independent role for neurological gaits as a fall predictor. Current fall guidelines recommend a multiple risk assessment approach; including history of previous falls, cognition, balance, and medications will make the detection of persons at risk for falls more sensitive.[2,8,25]

Gait evaluation is already a standard element of the neurological examination. Hence, our findings will not result in additional commitment of time or effort for clinicians or patients but provides guidance in interpreting observations that are already being made. Furthermore, gait evaluation is quick and does not require specialized equipment as for quantitative gait assessment. Our findings show that identification of neurological gaits in clinical settings serves not only diagnostic purposes but also aids in prognostication of falls. All clinicians that assess older adults can utilize gait information to identify high risk older adults to institute fall prevention strategies such as gait and balance training or home modifications especially if their examination also reveals cognitive impairment. Given the high personal and societal costs of falls[21,22], these gait markers for falls should be further studied to improve current fall risk assessments and tested as possible intervention targets.

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Table 1

Baseline variables compared by gait status and incident fall risk.

Variables	Neurological gait (n = 120)	Normal or non-neurological gaits (n = 512)	P-value*	Incident falls Risk Ratio (95% CI)
Age, year (mean ± SD)	82.6 ± 5.4	80.1 ± 5.3	<0.001	1.03 (1.00 – 1.05)
Female, %	53	64	0.019	1.22 (0.96 – 1.56)
Education, year (mean ± SD)	13.6 ± 3.5	13.9 ± 3.4	0.267	1.01 (0.98 – 1.04)
Illness index (mean ± SD)	1.6 ± 1.3	1.2 ± 1.0	0.001	0.98 (0.90 – 1.07)
Parkinson's disease, %	2.6	0.4	0.018	1.71 (0.64 – 4.54)
Strokes, %	19.1	5.2	<.0001	0.91 (0.60 – 1.40)
Diabetes, %	22.6	16.0	0.091	1.02 (0.72 – 1.43)
Hypertension, %	69.8	58.8	0.028	0.96 (0.74 – 1.21)
Medication count (mean±SD)	5.3 ± 4.0	5.0 ± 3.7	0.390	0.99 (0.97 – 1.02)
Fall previous year, %	39	29	0.035	1.18 (0.91 – 1.53)
Disability score, (mean ± SD)	1.3 ± 1.8	0.6 ± 1.0	<0.001	1.12 (1.04 – 1.21)
Gait velocity, cm/sec (mean ± SD)	77.2 ± 23.9	96.5 ± 22.7	<0.001	0.99 (0.98–0.99)
Blessed test (mean ± SD), range 0–32	2.4 ± 2.3	2.2 ± 2.4	0.55	1.02 (0.97 – 1.06)

** Risk ratios are for univariate (unadjusted) associations of clinical variables at baseline with incident fall risk derived using the GEE models described in Methods.

* p-values are for comparisons of variables by gait status at baseline.

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Table 2

Neurological gaits and subtypes: association with fall risk.

Gait subtypes	N (n = 632)	Risk ratio (95% CI)*	p-value
Neurological (overall)	120	1.49 (1.11 – 2.00)	0.007
Hemiparetic	15	0.92 (0.47 – 1.80)	0.81
Frontal	9	1.59 (0.72 – 3.50)	0.25
Parkinsonian	10	0.90 (0.36 – 2.22)	0.82
Unsteady	42	1.52 (1.04 – 2.22)	0.03
Spastic	12	1.20 (0.47 – 3.11)	0.69
Neuropathic	23	1.94 (1.07 – 3.52)	0.03
Other rare subtypes**	6	2.11 (0.97 – 4.63)	0.06

*Risk ratios adjusted for age, sex, education, illness index, number of medications, falls in the previous year, Blessed test scores, and disability score.

**Other rare subtypes included waddling gait, cautious gait, and slow gait.