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Predictors of future falls in Parkinson's disease

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DISCLOSURES

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ABSTRACT

Background

Falls are a major health and injury problem for people with Parkinson's disease (PD). Despite the severe consequences of falls, a major unresolved issue is the identification of factors that predict the risk of falls in individual PD patients. The primary aim of this study was to prospectively determine an optimal combination of functional and disease-specific tests to predict falls in individuals with PD.

Methods

One-hundred and one people with early stage PD undertook a battery of neurological and functional tests in their optimally medicated state. The tests included Tinetti, Berg, Timed Up and Go, Functional Reach and the Physiological Profile Assessment of falls risk: the latter assessment includes physiological tests of visual function, proprioception, strength, cutaneous sensitivity, reaction time and postural sway. Falls were recorded prospectively over six months.

Results

Forty-eight percent of participants reported a fall and 24% more than one fall. In the multivariate model, a combination of the UPDRS total score, total freezing of gait score, occurrence of symptomatic postural orthostasis, Tinetti total score and extent of postural sway in the anterior-posterior direction produced the best sensitivity (78%) and specificity (84%) for predicting falls. From the UPDRS items, only the rapid alternating task category was an independent predictor of falls. Reduced peripheral sensation and knee extension strength in fallers contributed to increased postural instability.

Conclusions

Falls are a significant problem in optimally medicated early stage PD. A combination of both disease-specific and balance- and mobility-related measures can accurately predict falls in individuals with PD.

INTRODUCTION

There is a high occurrence of falls in PD (40-70%)[1] which occur during daily activities and when patients are optimally medicated.[2] Falls lead to injuries,[3] fear of falling,[4] reduced mobility and a concomitant development of weakness,[5, 6] deterioration of fitness, loss of independence, increased risk of nursing home admission,[7] and reduced survival.[8] This impacts upon the health care system and the broader community.[9, 10] Consequently there is a need to identify falls risk predictors relevant to PD as this is critical for prescribing appropriate treatments and interventions.

Currently there are limitations in falls risk assessments for people with neurological disease.[11] Although "generic" falls risk tests have been developed for the general elderly population, it is uncertain whether these measures are equally sensitive for people with PD, whose hallmark characteristic balance and gait deficits are unique.[2]

Seven prospective studies[12-18] have produced inconsistent findings in their search for clinically useful falls risk factors. Possible risk factors included disease duration, dementia, symmetrical disease onset, loss of arm swing,[18] prior falls and disease severity,[12-14] abnormal posture, freezing of gait, frontal impairment, poor balance and leg weakness.[17] The most robust clinical predictor was two or more falls in the previous year[1] but this is of limited use for treatment planning and ideally intervention should occur before the first fall has occurred.

The aim of this study was to prospectively determine falls risk factors, the effectiveness of different functional tests and disease-specific clinical assessments to predict falls, and to develop a multivariate predictive model.

METHODS

We used an observational cohort design to assess Parkinson's disease patients on a series of clinical and functional tests at baseline. Participants were then followed up for 6 months while they reported their daily incidence of falls using monthly calendars.

Participants

One-hundred and thirty people with a diagnosis of Parkinson's disease were recruited from community support groups and neurology clinics in South-East Queensland from March 2002 until December 2006. Participants were independently living in the community and were required to be able to walk without the use of any aids. A cohort size of 100 people was determined to provide sufficient sample size based on previous prospective studies of falls in PD.[14, 18]

Standard Protocol Approvals, Registrations, and Patient Consents.

Ethics approval for this study was received from the Queensland University of Technology Human Research Ethics Committee. All participants gave informed consent to participate in accordance with Queensland University of Technology ethics guidelines, consistent with the Declaration of Helsinki.

INSERT TABLE 1 ABOUT HERE.

Assessments

Demographic data including height, weight, body mass index and current medications were recorded. Participants were assessed on the Mini Mental State Exam (MMSE),[19] the freezing of gait (FOG) questionnaire,[20] the Schwab and England (S&E) activities of daily living scale.[21] The UPDRS was assessed for each subscale: I mentation, behaviour, mood, II

activities of daily living, III motor function, IV complications of therapy. A measure of postural instability and gait disability (PIGD) was derived from the UPDRS (sum of items 13-15, 27-30).

Balance, gait and falls risk were assessed using the following widely used functional tests: Tinetti,[22] Berg,[23] Timed Up and Go (TUG),[24] Functional Reach[25] and the Physiological Profile Assessment (PPA).[26] The Tinetti is a qualitative test comprised of two sub-scales, which relate to clinical balance and gait, which are combined into a total score. Similarly, the Berg Balance Scale assesses balance during common, everyday tasks, such as turning, single leg support, reaching and whilst picking up an object from the floor. For the TUG test, participants arose from a chair, walked three metres, turned around, walked back to the chair and sat down. The PPA assessment includes physiological tests of visual function (visual acuity and contrast sensitivity), lower-limb proprioception and cutaneous sensitivity, knee and ankle strength, hand and foot reaction time, and postural sway while standing on a firm and foam surface with eyes open and closed. All assessments were undertaken when participants were in their optimally-medicated state.

Falls Assessment

A fall was defined as unintentionally coming to the ground or some lower level not as a result of a major intrinsic event (e.g. stroke) or overwhelming hazard.[27, 28] Retrospective falls were obtained from a questionnaire which asked whether participants had experienced a fall in the previous 12 months. Following the initial assessment each participant was given a set of monthly falls calendars to complete and return over a six month period using envelopes with prepaid postage. Participants recorded each fall, where it occurred, and whether they had

sustained any injuries. If participants failed to complete their monthly calendars they were sent reminders by mail and received follow-up phone calls.

Statistical Analysis

Independent samples *t*- tests were used to examine mean differences between fallers and non-fallers on continuous variables. The chi-square (χ^2) test was used to assess associations between categorical variables. Receiver Operating Characteristic (ROC) analyses were performed to determine the sensitivity and specificity of each variable in predicting fallers. The cut-off value of the test which yielded the "best" sensitivity and specificity was selected as the point which simultaneously maximised both on the ROC curve. An accuracy based on the proportion of cases correctly classified using this cut-off was calculated.

A restricted set of variables that were different between fallers and non-fallers ($p<0.01$) was entered into a logistic regression model. Predicted probabilities from the logistic regression equation were examined using ROC analyses to investigate the efficacy of the classification function.[29] A leave-one-out cross-validation was performed to examine the likely efficacy of the model if tested on a different sample.[30]

The relationship between falls and individual items of the UPDRS was examined by averaging symptom scores over different body parts[1] and including this as a single regressor in a logistic regression.[1, 12] Odds ratios and 95% confidence intervals were calculated.

RESULTS

From the 130 people with a diagnosis of Parkinson's disease who volunteered for the project, seven withdrew before attending the testing session, eleven were excluded for medical reasons (previous surgery 8, diabetes 1, previous diagnosis of dementia 1, uncertain PD medication 1), one used a cane for walking, five did not complete the baseline tests and five did not complete the six month follow-up falls calendars.

One-hundred and one people (68 males, 33 females, 66.4±8.2 yrs) completed all baseline assessments and follow-up falls calendars. These participants were predominantly early stage, had average disease duration since diagnosis of 6.1±4.4 yrs, a Unified Parkinson's Disease Rating Score (UPDRS) of 32.8±13.4, and a Hoehn and Yahr score of 2.1±0.8 (Table 1). More participants were of the akinetic-rigid subtype (77.1%) than the tremor-dominant (19.5%) or mixed subtypes (3.4%) as determined from the UPDRS scores.[31]

Falls

In the six-month follow up period, 48% of participants reported a fall and 24% of participants were recurrent fallers (> 1 fall). Forty two percent of participants reported falling in the previous year.

Comparison between Non-Fallers and Fallers

Fallers had longer disease duration and increased disease severity based on the UPDRS (II, III, Total) and the derived PIGD score (Table 1). From the UPDRS IV (complications of therapy) dyskinesia was more often present in fallers than non-fallers. Fallers had a greater incidence of symptomatic orthostasis and sleep disturbance. Fallers scored lower on the S&E activities of daily living scale and had higher scores on the FOG questionnaire.

Fallers performed more poorly than non-fallers for the Tinetti (Balance, Gait, Total), Berg Balance, and Timed Up and Go tests (Table 2). There were no significant differences in falls risk as determined by the PPA. However, the component physiological tests of the PPA revealed that fallers had significantly poorer peripheral sensation, knee extension strength and had greater anterior-posterior postural sway when standing on a firm surface compared to non-fallers.

Increased touch thresholds were correlated with increased postural sway (eyes open r=.277, p=.006; eyes closed r=.293, p=.003) when all participants were considered. Similarly, increased L-Dopa medications were correlated with increased postural sway (eyes open r=.224, p=.026; eyes closed r=.239, p=.018). However, these correlations were not evident for the separate faller or non-faller groups.

INSERT TABLE 2 ABOUT HERE.

Sensitivity and Specificity of Clinical Tests

Despite the significant difference between fallers and non-fallers in many of the measures and the significant relationship with falls, there were large variations in the precision (sensitivity and specificity) with which each measure was able to predict falls. Table 3 shows the outcomes of the ROC analysis for the disease-specific and functional test measures in predicting falls.

INSERT TABLE 3 ABOUT HERE.

Of the disease specific measures, the UPDRS total score provided the best measure of sensitivity (74%) and specificity (63%) followed by the FOG questionnaire (Sensitivity 75%, Specificity 59%). Both of these measures had a similar accuracy (66-67%). Moderate precision was achieved by the UPDRS subscales (UPDRS II, III, PIGD) and disease duration. The individual UPDRS items that were significantly associated with falls were hand movements, rapid alternating tasks, leg agility and rising from a chair (Figure 1). When all UPDRS items were simultaneously included as a multivariate model in the logistic regression, only the rapid alternating tasks were associated with falls (Exp(B)=2.244, p=0.031, 95%CI=1.076-4.680).

INSERT FIGURE 1 ABOUT HERE.

For the functional tests of balance, mobility and falls risk, similar precision of falls prediction was achieved by the Tinetti gait, TUG and PPA tests with sensitivities of 65-69%, specificities of 62-69% and accuracies of 63-68%. Of the significant component tests of the PPA, the postural sway on a firm surface provided the best precision with a sensitivity of 66%, specificity of 68% and accuracy of 67%.

Logistic Regression Model

To ensure that there was no redundancy in the variables used the UPDRS total and Tinetti total scores were used rather than their component scores. The more objective UPDRS total score was used as a measure of disease severity in preference to disease duration. Other variables included were the FOG total score, symptomatic postural orthostasis, and postural sway with eyes open on a firm surface. This multivariate model produced a sensitivity of 78% and specificity of 84% (Figure 2a). The leave-one-out validation resulted in a

sensitivity of 72% and specificity of 76% (Figure 2c). The addition of previous falls as a variable in this model made only slight changes to the sensitivity (77%) and specificity (82%) in the negative direction. Similar sensitivities (78%) and specificities (84%) were obtained if either the UPDRS II or III scores were substituted for the UPDRS total score.

INSERT FIGURE 2 ABOUT HERE.

Prediction of Falls in Previous Non-Fallers

Of the 59 participants who had not previously fallen, 17 (29%) went on to fall in the following six months. For this group there were no significant differences between fallers and non-fallers for any of the demographic or disease specific measures. There were also no differences on performance of any of the clinical tests. Only the PPA component measures of anterior-posterior postural sway when standing on a firm and foam surface with eyes open showed a significant increase for the fallers. These measures had an average sensitivity of 66% and specificity of 68%.

The application of the multivariate model to these data resulted in a sensitivity of 77% and specificity of 76% (Figure 2b). The leave-one-out validation resulted in a sensitivity of 69% and specificity of 72% (Figure 2d).

DISCUSSION

This prospective study of falls in people with PD demonstrated that both disease-specific and balance- and mobility-related measures are important for predicting falls. The multivariate model that produced the best sensitivity (78%) and specificity (84%) included UPDRS total score, total FOG score, occurrence of symptomatic postural orthostasis, Tinetti total score and extent of postural sway in the anterior-posterior direction while standing on a firm surface with eyes open.

The incidence of falls was 48% which is comparable to two previous prospective studies[14, 17] but lower than that reported by two others.[15, 18] The incidence was lower (29%) in those patients who had not previously fallen and confirms the findings of a recent meta-analysis.[1] Recurrent falls occurred in 50% of the fallers (24% of all participants). Fallers were predominantly of the akinetic-rigid subtype rather than the tremor dominant subtype which is in agreement with previously reported trends.[1]

The high incidence of falls is particularly notable given that participants were predominantly early stage PD, independently living in the community, did not use walking aids and had good functional mobility. Although there were no differences between fallers and non-fallers in measures of cognitive impairment as determined by the MMSE and UPDRS I scores, two fallers has MMSE scores less than 24, which is regarded as a cut-off for dementia. Cognitive impairment has previously been identified as an independent predictor of falls in PD.[17, 18]

Both faller and non-faller groups had a wide range of L-Dopa intake, which was also evident in an earlier study.[18] Increased L-Dopa medications were also slightly but significantly correlated with increased postural sway on the firm surface when all subjects were considered. Importantly, however, there were differences in symptomatic postural

hypotension which can be expected if L-Dopa medications were strongly linked to falls. Postural hypotension has also been associated with falls risk in PD.[14, 17]

The individual UPDRS items that were significantly related to falls included rapid movement sequencing tasks of upper (hand movements) and lower limbs (leg agility) as well as rising from a chair. The strongest independent predictor arising from the multivariate UPDRS model, however, was that of rapid alternating tasks of the upper limbs. This suggests that impairments in sequencing and coordination of multi-joint movements may represent a specific falls risk factor that has not been recognized previously. Importantly, the difficulty in performing these sequencing tasks occurs in the arms rather than the legs. The upper extremities normally play a minimal role in the maintenance of postural stability and this factor may therefore indicate a higher-level cognitive deficit. People with PD have difficulties in movement sequencing tasks.[32] Changes in the pre-supplementary and supplementary motor area, regions implicated in the control of movement sequences, have also been reported for PD.[33, 34] Deficits in the initiation and timing of repetitive upper limb movements have also been associated with freezing of gait and considered a manifestation of akinesia.[35] In contrast to healthy elderly, people with PD have difficulty in movement anticipation, coordination and timing which are critical for ensuring the correct sequencing of postural reactions and for ensuring postural stability.[36] These results are in contrast to the significance of individual items of speech, gait and postural stability reported previously,[1] which were considered to be related to axial motor features.

The majority of the functional tests in this study, which are commonly used to determine postural stability and falls risk in older people, showed differences between fallers and non-fallers. The exceptions were the functional reach test and the PPA test. The magnitudes of

these differences were small, however, and they achieved only moderate sensitivity and specificity. This probably renders them unviable as individual screening tools for detecting PD individuals at risk of falls, particularly when they are in the early stage of the disease and are active and independently living in the community.

The lack of difference for the overall falls risk score derived from the PPA was surprising given that it is designed to provide a disease independent assessment of falls risk.[26] This is probably because the tests and falls risk equations have been derived for older people at risk of multiple falls. However, several of its component tests revealed significant differences between fallers and non-fallers and highlight the importance of assessing potential contributing physiological falls risk factors.[17] The difference in touch thresholds between fallers and non-fallers indicates that a reduction in peripheral sensation could be associated with the increased postural instability that was observed in fallers. Increased touch thresholds[37] and cutaneous denervation[38] have been reported for people with PD. This indicates that there is a deficit in peripheral and central mechanisms involved in sensation and perception. Decreased leg strength is also a potential risk factor for falls in PD,[17] as has been reported for community dwelling older people[39], and may be an important modifiable factor for falls prevention programs. An important finding was the difference in postural sway when standing on a firm surface with eyes open. In this situation participants have full availability of sensory cues yet, despite this, fallers still swayed more than non-fallers. Increased postural sway has been reported for retrospective[40] and prospective[17] PD falls studies. Community dwelling older people at risk of falls perform worse when standing on a foam surface. It appears that a combination of decreased peripheral somatosensory information and decreased leg strength may have contributed to the increased postural instability particularly as this occurred in the absence of any differences in visual function.

Practically, the test battery is easy to implement and takes only a short time to administer. The UPDRS is a routine clinical assessment and the UPDRS II or III score can be substituted for the UPDRS total score. The FOG questionnaire takes only 5 minutes and could be completed by the patient prior to their appointment. The Tinetti takes approximately 5 minutes to complete and the measure of postural sway on a firm surface less than two minutes. These latter tests could be completed by an allied health professional.

CONFLICTS OF INTEREST

The authors have no conflicts of interest.

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FIGURE CAPTIONS

Figure 1 short title: UPDRS odds ratios.

Figure 1: Odds ratios and 95% confidence intervals for the individual components of the UPDRS for individual items (top) and all items combined (bottom).

Figure 2 short title: Multivariate model ROC.

Figure 2: Receiver operating curves for multivariate model using (A) the whole sample; (B) sub-sample who had not previously fallen; (C) whole sample leave-one-out validation; (D) sub-sample leave-one-out validation.

Table 1. Demographic and disease statistics

		Prospective Falls			
	All Patients (n = 101)	**Non-Fallers (n = 53)**	**Fallers (n = 48)**	**Test**	**p-value**
Age (yrs)	66.4 (8.2); 43 - 84	66.9 (8.4); 49 - 82	65.8 (8.0); 43 - 84	1	0.480
Gender (male)	67.3%	37.6%	29.7%	2	0.325
MMSE	28.0 (1.9); 21 - 30	28.2 (1.7); 24 - 30	27.7 (2.1); 21 - 30	1	0.265
Previous Falls	1.9 (10.3); 0 - 100	0.3 (0.9); 0 - 6	3.8 (15.5); 0 - 100	1	0.157
Height (cm)	168.3 (8.2); 149.8 - 188.3	168.2 (7.7); 149.8 - 181.0	168.4 (8.8); 151.6 - 188.3	1	0.873
Weight (kg)	72.5 (13.5); 43.4 - 112.9	71.3 (13.2); 43.4 - 104.7	73.8 (13.9); 43.8 - 112.9	1	0.363
BMI (kg/m^2)	25.6 (4.6); 17.8 - 42.5	25.2 (4.2); 17.8 - 38.5	26.1 (5.0); 18.1 - 42.5	1	0.320
Disease Duration (yrs)	6.1 (4.4); 0.5 - 21.3	4.9 (3.3); 0.5 - 14.0	7.3 (5.2); 0.7 - 21.3	1	**0.007****
Activities of Daily Living	82.1 (9.4); 50 - 100	84.5 (7.8); 70 - 100	79.6 (10.4); 50 - 98	1	**0.014***
Freezing of Gait	4.8 (4.9); 0 - 21	3.1 (3.4); 0 - 12	6.8 (5.6); 0 - 21	1	**<0.001****
Levodopa dose (mg/day)	661.3 (485.2); 0 - 3328	607.9 (301.1); 0 - 1530	723.0 (632.9); 0 - 3328	1	0.264
Dopamine agonist use	43.6%	15.6%	22.7%	2	0.100
Hoehn & Yahr	2.1 (0.8); 1.0 - 4.0	2.0 (0.8); 1.0 - 3.5	2.3 (0.7); 1.0 - 4.0	1	0.053
UPDRS I	2.4 (2.1); 0 - 10	2.1 (1.8); 0 - 6	2.7 (2.3); 0 - 10	1	0.169
UPDRS II	10.2 (5.2); 1 - 26	8.5 (4.1); 1 - 18	12.0 (5.8); 1 - 26	1	**0.002****
UPDRS III	18.7 (9.2); 3.5 - 43.0	16.4 (8.8); 3.5 - 41.5	21.3 (9.1); 4.0 - 43.0	1	**0.012***
UPDRS Total	32.8 (13.4); 11.0 - 66.5	28.5 (12.6); 12.0 - 65.5	37.5 (12.7); 11.0 - 66.5	1	**0.001****
UPDRS IV					
Dyskinesia present	32.1%	11.9%	20.2%	2	**0.037***
Off state occurrence	43.4%	20.5%	22.9%	2	0.263
Symptomatic orthostasis	18.1%	2.4%	15.7%	2	**<0.001****
Sleep disturbance	38.1%	14.3%	23.8%	2	**0.021***
PIGD	4.0 (2.8); 0 - 11	3.1 (2.2); 0 - 9	4.9 (3.1); 0 - 11	1	**0.002****
PD Sub-type					
TDT	19.5%	14.9%	4.6%		
ART	77.1%	36.8%	40.3%	2	0.084
MT	3.4%	1.1%	2.3%		

Data are mean (SD) and ranges or absolute numbers and percentages. ** p<0.01 * p<0.05. Test 1 = independent samples t-test; Test 2 = χ2 test

Table 2. Functional balance, mobility and falls risk tests

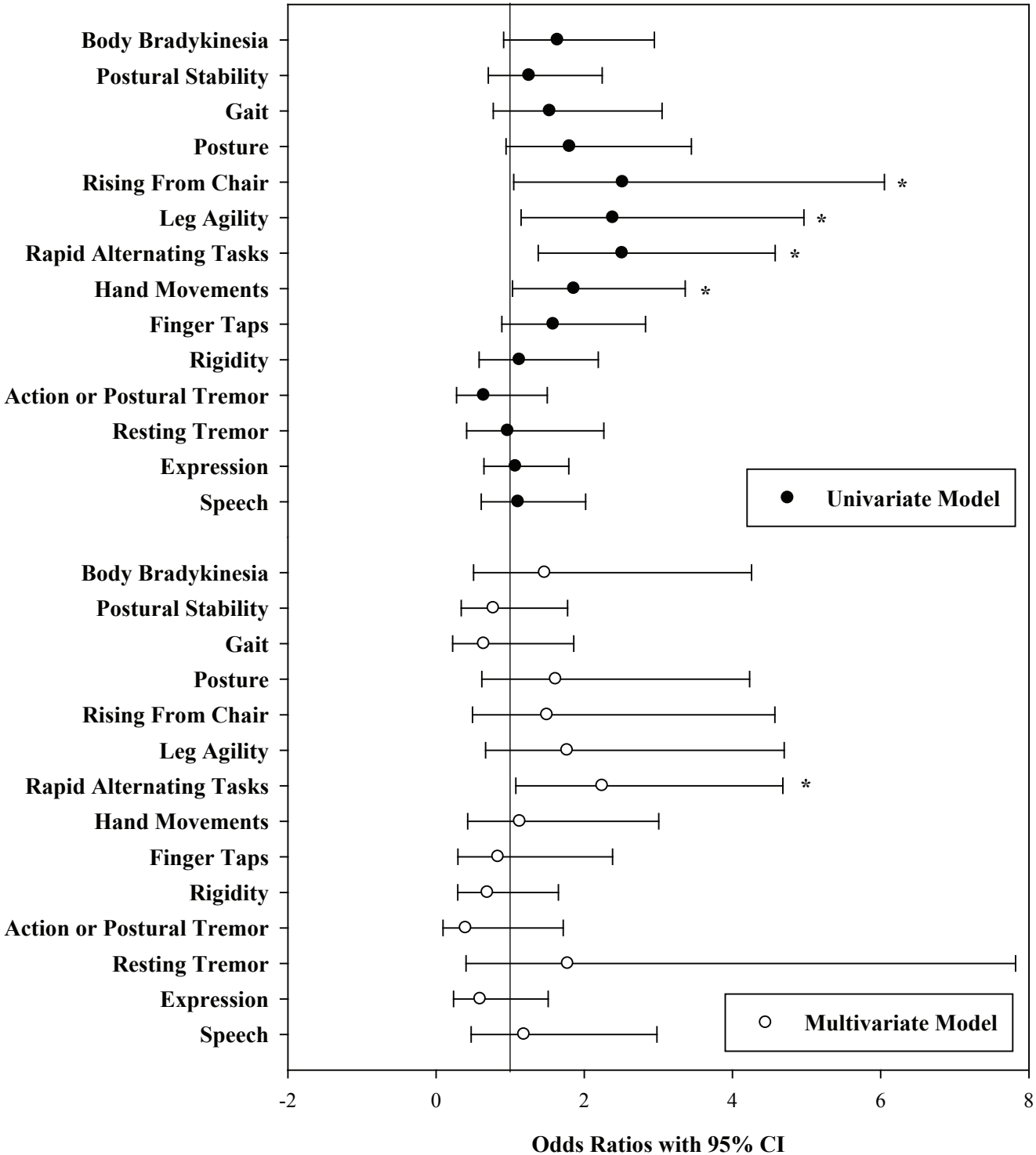
		Prospective Falls		
	All Patient (n = 101)	**Non-Fallers (n = 53)**	**Fallers (n = 48)**	**p-value**
Tinetti				
Balance	15.0 (1.2); 11 – 16	15.5 (0.7); 13 - 16)	14.5 (1.4); 11 - 16	**<0.001****
Gait	10.9 (1.4); 5 – 12	11.3 (0.8); 10 - 12)	10.4 (1.7); 5 - 12	**0.002****
Total	25.9 (2.2); 18 – 28	26.8 (1.1); 24 – 28	24.9 (2.7); 18 - 28	**<0.001****
Berg Balance Scale	53.6 (2.8); 42 – 56	54.2 (1.9); 46 – 56	52.8 (3.4); 42 - 56	**0.013***
Functional Reach (cm)	27.6 (6.2); 12.7 - 44.5	27.7 (5.1; 12.7 - 41.9	27.6 (7.2); 14.0 - 44.5	0.964
Timed Up & Go (s)	10.1 (2.7); 5.0 - 19.0	9.4 (2.2); .0 - 19.0	10.8 (3.0); 5.0 - 18.0	**0.010***
Physiological Profile Assessment Falls Risk	1.4 (1.0); -1.0 - 4.9	1.2 (1.0); -0.4 - 4.9	1.5 (0.9); -1.0 - 3.5	0.164
Component Tests of Physiological Profile Assessment				
Vision				
Visual Acuity: High Contrast	0.0 (0.1); -0.2 - 0.5	0.0 (0.1); -0.2 - 0.3	0.0 (0.1); -0.2 - 0.5	0.461
Visual Acuity: Low Contrast	0.3 (0.2); -0.1 - 0.8	0.3 (0.2); 0.0 - 0.8	0.3 (0.2); -0.1 - 0.8	0.250
Contrast Sensitivity: Melbourne Edge Test	20.1 (1.9); 16 – 24	20.3 (2.0); 17 – 24	20.0 (1.8); 16 - 23	0.427
Peripheral Sensation				
Touch	5.1 (1.6); 2 – 8	4.8 (1.5); 2 – 8	5.4 (1.6); 2 - 8	**0.045***
Vibration	39.8 (20.2); 3.6 - 86.1	39.1 (17.3); 5.9 - 76.0	40.6 (23.2); 3.6 - 86.1	0.742
Proprioception	2.4 (1.4); 0.3 - 8.2	2.3 (1.2); 0.3 - 5.5	2.4 (1.6); 0.3 - 8.2	0.631
Strength (kg)				
Knee flexion	13.2 (5.3); 2.5 - 26.0	13.6 (5.8); 2.5 - 25.4	12.8 (4.7); 3.8 - 26.0	0.452
Knee extension	30.3 (13.9; 9.0 - 83.3	33.0 (16.1); 9.0 - 83.3	27.4 (10.3); 10.4 - 53.1	**0.045***

		Ankle dorsiflexion	14.3 (5.6); 1.7 – 27	14.8 (6.1); 1.7 - 27.0	13.7 (5.2); 4.0 - 25.0	0.355
Reaction Time (ms)						
		Hand	301.0 (75.0); 189.0 - 578.3	306.6 (77.2); 208.6 - 578.3	294.9 (72.9); 189.0 - 572.0	0.439
		Foot	378.5 (90.2); 225.0 - 651.8	384.5 (100.1); 247.5 - 629.6	372.0 (78.7); 225.0 - 651.8	0.487
Balance (mm)						
	Firm Surface:	Eyes Open – AP	17.5 (8.4); 6 – 46	14.8 (7.1); 6 – 41	20.4 (8.8); 8 - 46	**0.001****
		– ML	15.5 (13.1); 1 – 80	13.1 (9.2); 1 – 42	18.2 (16.2); 1 - 80	0.057
		Eyes Closed – AP	23.1 (14.0); 6.5 - 99.0	20.1 (12.0); 6.5 - 63.0	26.5 (15.3); 10 - 99	**0.022***
		– ML	17.7 (16.0); 1 – 97	15.5 (9.8); 2 – 38	20.1 (20.7); 1 - 97	0.170
	Foam Surface:	Eyes Open – AP	30.5 (13.0); 12.5 - 78.0	28.3 (12.5); 12.5 – 69.0	33.0 (13.3); 16 - 78	0.079
		– ML	32.6 (20.6); 4 – 142	29.9 (22.4); 4 – 142	35.7 (18.1); 6.5 - 85.0	0.170
		Eyes Closed – AP	54.2 (25.1); 13 – 145	51.9 (23.5); 13 – 145	56.7 (26.7); 22 - 125	0.371
		– ML	46.6 (25.7); 5 – 143	43.4 (20.5); 5 – 92	50.0 (30.2); 5.5 - 143.0	0.227

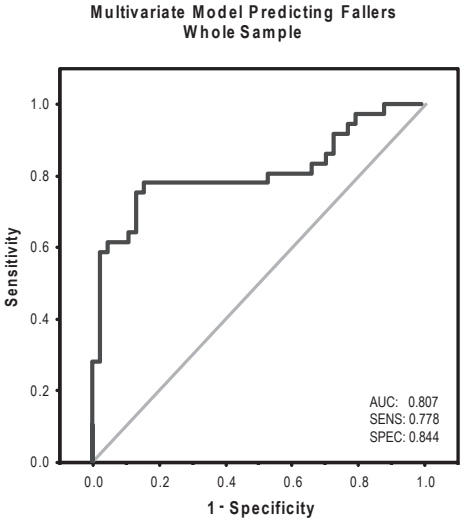
Data are mean (SD) and ranges or absolute numbers and percentages. ** p<0.01 * p<0.05.

Table 3. ROC analyses

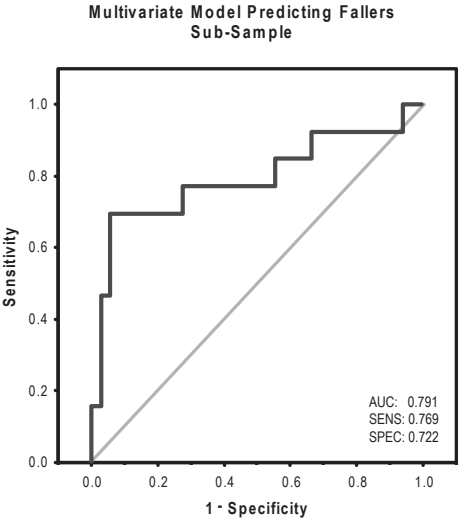
	Accuracy (%)	Area Under Curve	Sensitivity	Specificity
Demographics				
Age	0.46	0.45	0.50	0.43
Previous falls	0.71	0.72	0.59	0.79
Disease Specific Measures				
Disease Duration	0.61	0.63	0.63	0.62
Activities of Daily Living	0.56	0.63	0.62	0.50
Freezing of Gait	0.67	0.73	0.75	0.59
Levodopa dose	0.61	0.52	0.54	0.51
Hoehn &Yahr	0.55	0.61	0.88	0.35
UPDRS I	0.53	0.57	0.48	0.61
UPDRS II	0.63	0.68	0.64	0.67
UPDRS III	0.63	0.67	0.64	0.60
UPDRS Total	0.66	0.70	0.74	0.63
PIGD	0.60	0.67	0.66	0.62
Functional Tests				
Tinetti				
Balance	0.68	0.71	0.65	0.66
Gait	0.64	0.64	0.65	0.45
Total	0.71	0.72	0.67	0.59
Berg Balance Scale	0.60	0.61	0.65	0.51
Functional Reach	0.52	0.52	0.52	0.53
Timed Up & Go	0.63	0.65	0.69	0.62
Physiological Profile Assessment Falls Risk	0.64	0.64	0.68	0.69


Body Bradykinesia
Postural Stability
Gait
Posture
Rising From Chair
Leg Agility
Rapid Alternating Tasks
Hand Movements
Finger Taps
Rigidity
Action or Postural Tremor
Resting Tremor
Expression
Speech
*
*
*
*
Univariate Model
Body Bradykinesia
Postural Stability
Gait
Posture
Rising From Chair
Leg Agility
Rapid Alternating Tasks
Hand Movements
Finger Taps
Rigidity
Action or Postural Tremor
Resting Tremor
Expression
Speech
*
Multivariate Model
-2
0
2
4
6
8
Odds Ratios with 95% CI

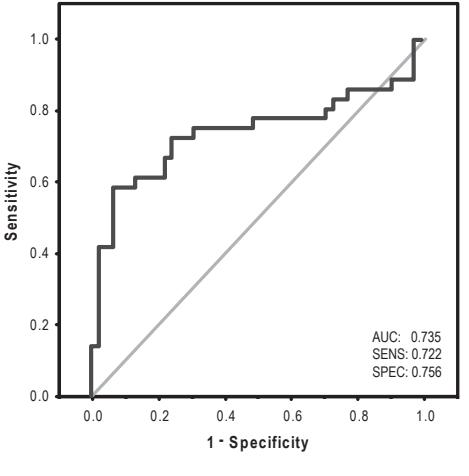
a.


Multivariate Model Predicting Fallers
Whole Sample
Sensitivity
1 - Specificity
AUC: 0.807
SENS: 0.778
SPEC: 0.844

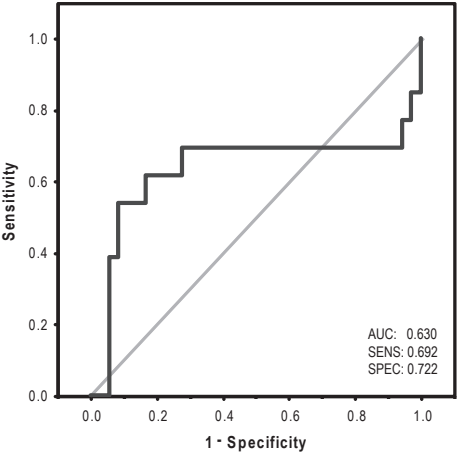
c.


Multivariate Model Predicting Fallers
Sub-Sample
Sensitivity
1 - Specificity
AUC: 0.791
SENS: 0.769
SPEC: 0.722

b.


Multivariate Model Predicting Fallers
Leave-One-Out Validation - Whole Sample
Sensitivity
1 - Specificity
AUC: 0.735
SENS: 0.722
SPEC: 0.756

d.


Multivariate Model Predicting Fallers
Leave-One-Out Validation - Sub-Sample
Sensitivity
1 - Specificity
AUC: 0.630
SENS: 0.692
SPEC: 0.722