

# Falling risk factors in Parkinson's disease

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**Abstract.** *Objective:* to identify falling risk factors that are potentially modifiable among individuals who have idiopathic Parkinson's disease.

*Design:* a between group comparison of 19 fallers and 21 nonfallers who have Parkinson's disease, across an array of variables that have been identified as falling risk factors among the elderly and among those who have Parkinson's disease.

*Results:* several variables were demonstrated significantly to distinguish fallers: disease duration and severity; dyskinesias associated with the use of dopaminergic agents; freezing; postural instability; depression; fear of falling; impaired fine motor control and motor planning in the feet; decreased proximal strength and muscular endurance in the legs; and a higher level of disability.

*Conclusions:* several of these variables can be viewed a potentially modifiable during a future intervention trial that aims to reduce falls in those who have Parkinson's disease using multidimensional risk factor modification.

Keywords: Falling, risk factors, Parkinson's disease

## 1. Introduction

Falling risks and events in individuals who have Parkinson's disease must be understood within the context of falling among the general elderly population. While identification of falling risk factors, and modification of these risk factors in efforts to reduce falls have been well studied among the general elderly population, these require further investigation among those who

have Parkinson's disease. The approaches to falling risk factor modification among the general elderly can be applied as models to reduce falls among those who have Parkinson's disease. Before these models can be tested in individuals with Parkinson's disease, more consensus needs to be achieved in defining falling risk factors in Parkinson's disease that are pragmatically modifiable.

### 1.1. Falling in the elderly

Falling is a significant public health problem among elderly people living both in the community and in long term care institutions in the United States and worldwide. At least 30% of otherwise healthy elderly

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Table 1  
Falling risk factors in the elderly [9,11,12,16,27,33,34,44,46,51,59,65]

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<i>Intrinsic risk factors:</i>
Mobility impairment including compromised lower limb strength, gait and balance
Orthostasis
Polypharmacy (taking > 3 medications particularly cardiovascular, hypnotic/sedative, neuroleptic, anticholinergic, anticonvulsant, and serotonin-reuptake inhibiting agents)
History of cervical spine disease, stroke, arthritis, and heart failure
Not participating in regular exercise or outside housework
Proprioceptive/peripheral sensory deficits
Special sensory (visual and hearing) deficits
Foot disorders
Cognitive deficits
<i>Extrinsic risk factors:</i>
Non-level surfaces (e.g., stairs, outdoors)
Unfamiliar environments
Poor lighting
Objects on the floor/insecure floor coverings
Low beds/toilets/chairs
Improper footwear
Improper use of assistive devices (e.g., canes, walkers)

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fall annually resulting in at least 15 million falls. Falls result in major injury up to 15% of the time, including fractures (75% of these injuries), head trauma, severe soft tissue injuries, and joint dislocations [51,64,65]. Up to 2% of falls result in hip fractures, or at least one quarter of a million new hip fractures annually [51, 64,65]. The costs of medical and health services to treat the consequences of falls, and time lost from work because of their consequences, are estimated to be at least \$50 million annually [18]. The consequences of falls are common precipitants for change of residential site from living in the community to living in a nursing home, particularly if an elderly person lives alone at the time of the fall. Falling episodes among elderly people who reside within nursing homes occur three times as often as falls among community based elderly [59].

Factors that increase the risk of falling among community and institutionally based elderly have been well described, and are summarized in Table 1 [9,11,12,16, 27,33,34,44,46,51,59,64,65]. These risk factors have been categorized as intrinsic, that is, within or part of the individual or "host", and as extrinsic or environmental [9]. As the number of falling risk factors for an elderly individual increase, there are consistent and expected increased falling episodes [65].

Recurrent falls, that is, occurring more than one time annually, is particularly problematic among the elderly. Recurrent falling is an independent risk factor for increasing disability and death within 2 years [27,67]. Recurrent falls indicate multiple chronic conditions acting cumulatively to accelerate the risks of falling and death from their consequences [17]. Recurrent falls can result in fear of falling or a "post-falling anxiety

syndrome" and associated reduction in mobility, de-conditioning, and further escalation of falling risks [17, 27,65,67].

### 1.2. *Falling in Parkinson's disease*

Falling in individuals who have Parkinson's disease is common. It is estimated that up to 70% of those with Parkinson's disease fall annually, and 13% fall more than once weekly [37,70]. Parkinson's disease-specific falling risk factors have been identified. Several of these risk factors overlap with those that are defined for the general elderly population. However, several of these Parkinson's disease-specific risk factors are idiosyncratically associated with this aging related neurodegenerative disease process. Moreover, there continues to be a lack of consensus in the literature as to which intrinsic risk factors are modifiable when considering preventative therapeutic interventions. Falling risk factors for those with Parkinson's disease are summarized in Table 2 [2,28,37,56,70].

### 1.3. *Falling prevention in the elderly:*

#### *Multidimensional risk factor modification*

Tinetti and colleagues [35,57,65–68] have applied a successful model for primary and secondary prevention of falling risks and episodes in the elderly. This model [65,66] proposes that targeted interventions must be linked to specific risk factors that are modifiable in order to be effectively preventive. These investigators operationalized such an approach during one of the FICSIT (Fragility and Injuries: Cooperative Studies

Table 2  
Intrinsic falling risk factors in Parkinson's disease [2,28,37,56,70]

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Older age
Higher disease severity
Polypharmacy (use of > 3 medications), particularly use of cardiovascular medications
Hallucinations/confusion associated with use of dopaminergic medications
Sleep disturbances (vivid dreams, nightmares) associated with use of dopaminergic medications
Dyskinesias associated with use of dopaminergic medications
Orthostasis
Mobility impairments (compromised gait and balance)
Postural disturbances (compromised balance)
Rigidity
Bradykinesia
Freezing
Impaired hand and foot agility/fine motor function
Decreased arm swing during gait
Inability to arise from a chair (proximal leg, core and trunk muscular weakness)
Visual impairments
Daily use of alcohol
Affective disturbances (depression, anxiety)
Cognitive impairments

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Table 3  
Falling risk factors and associated interventions utilized during the FICSIT primary prevention trials [66]

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Orthostasis: ankle pumps; sleep with the head of the bed elevated; control hypertension with minimal medication dosing
Sedative use: change to shorter acting benzodiazepines or use non-pharmacologic interventions to regulate sleep disturbances
Polypharmacy: minimize, simplify, restrict
Transfer impairment: transfer training, grab bars, raised toilet seat
Mobility impairment: lower limb strengthening, gait training, balance training
Environmental hazards: make appropriate modifications such as removing "throw rugs" and installing grab bars and transfer benches in the bath tub
FICSIT = Fragility and Injuries: Cooperative Studies of Intervention techniques

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of Intervention Techniques) trials. This primary prevention trial targeted healthy, ambulatory, community based elderly subjects who had at least one falling risk factor. The recruited subjects were randomized into intervention (multidimensional risk factor reduction;  $n = 153$ ) and control (social visits;  $n = 148$ ) groups who were followed longitudinally for one year. The intervention encompassed a standardized menu of treatments that linked specific falling risk factors with selected falling preventive strategies. Although the treatment menu was standardized, it allowed for individualized preventive strategies to be operationalized, by advanced practice nurses and physical therapists during home visits, as determined by the risk factor profile of each subject [66]. The risk factors and their associated preventive strategies applied are summarized in Table 3 [66].

During the one year of prospective observation in this study by Tinetti and colleagues [66], 35% of the treatment subjects and 47% of the control subjects sustained at least one fall ( $p < 0.04$ ). The adjusted incidence ratio for falling in the intervention group relative to the control group was 0.69 ( $p < 0.05$ ). It was estimated in this study that for every one unit reduction in an iden-

tified falling risk factor, there was an 11% decrease in falls. A cost benefit analysis revealed that the average cost of each fall that was prevented was about \$2000 by early 1990 financial estimates [57]. Thus, multidimensional risk factor modification as operationalized by Tinetti and colleagues is a successful model that can be tested in disease-specific groups with high falling risk such as those with Parkinson's disease.

#### 1.4. Defining modifiable falling risk factors in Parkinson's disease

For falling risk factor reduction to be effective within this proposed model, the preventive interventions must be linked to specific risk factors that are modifiable. This assumes that there is some consensus within the literature as to which falling risk factors are salient and thus should be subjected to treatment across populations who have Parkinson's disease. Consensus, then, can be achieved with more refined definition of the idiosyncratic falling risk factors in Parkinson's disease. Moreover, it cannot be assumed that those risk factors that are salient and modifiable in the elderly popula-

tion are similarly important for those with Parkinson's disease particularly when these risk factors will be potentially subjected to treatment strategies intended to reduce them. Thus, we conducted a study of falling risk factors in our outpatient population at the Parkinson's Disease Research, Education, and Clinical Center (PADRECC) based at the Philadelphia Veterans' Affairs Medical Center (PVAMC), with the intention of defining risk factors that can be viewed as modifiable during a future intervention trial. We hypothesized that an idiosyncratic profile of falling risk factors can be defined in patients with Parkinson's disease, and that these risk factors can be identified using clinical history-taking, a medical record review, and a physical examination, that is, data collection tools that are clinically accessible and integrated into the usual care of outpatients with Parkinson's disease. Moreover, we postulated that these risk factors will contribute to establish some consensus among falling risk factors already defined in this literature, and that modifiable falling risk factors will emerge that potentially will be amenable to primary and secondary preventive interventions.

## 2. Methodology

### 2.1. Sample

We recruited a convenience sample of 40 male patients who were diagnosed with idiopathic Parkinson's disease at the PADRECC. These subjects were referred for Rehabilitation Medicine consultation by neurologists and advanced practice nurses because of compromised gait, balance and/or postural control. Based on clinical history that was verified by a spouse or another family member, 19 of the subjects were categorized as fallers defined as having more than one fall within the year prior to consultation, and 21 of the subjects were categorized as nonfallers reporting only one or no falls within the previous year. These group assignments were verified by an independent rating on Item #13 of the Unified Parkinson's Disease Rating Scale (UPDRS) [19]. Group comparisons of mean values using between group t-tests of the fallers and the nonfallers demonstrated that these groups were matched ( $p > 0.05$ ) for age, education, global cognitive status and global functional status, but not for disease duration or severity. These data are summarized in Table 4.

### 2.2. Procedures

Data were collected during patient interview, outpatient medical record review and physical examination. All subjects were examined on their usual medications.

#### 2.2.1. Patient interview

During the patient *interview*, the following factors were probed: history of falling; (yes/no) fear of falling (yes/no); rapid "on-off" phenomena associated with the use of dopaminergic agents (yes/no); history of visual problems (yes/no); participation in regular exercise (yes/no); and participation in outside house work (yes/no).

#### 2.2.2. Medical record review

During the *medical record review*, the following factors were identified: age (years); level of education (years); disease duration (months since symptom/sign onset and since diagnosis); disease severity (Modified Hoehn and Yahr Staging) [19]; global functional status (Schwab and England Activities of Daily Living Scale-%) [19]; a medical history of (yes/no for each entity) alcohol use, stroke, cardiovascular disease, diabetes mellitus, arthritis, peripheral neuropathy, glaucoma, macular degeneration, cataracts; medication history [total number of medications used daily; total number of medications to treat Parkinson's disease used daily; use of cardiovascular (yes/no), anticholinergic (yes/no), hypnotic/sedative (yes/no), or neuroleptic (yes/no) agents]; global cognitive status (Mini-Mental Status Examination score) [20]; and visual perceptual/organizational functions [The Clock Drawing Test, ability to complete overlapping pentagrams on the MMSE (able/unable to complete)] [20,45].

The *medical record review* additionally recorded data from the Unified Parkinson's Disease Rating Scale (UPDRS) [26] including the motor score (Items #18 to #31); the dyskinesia score (Items #32 to #35); motor fluctuation score (Items #36 to #39); as well as individual items such as depression score (Item #3), the presence of sleep disturbance (Item #41-yes/no) and symptomatic orthostasis (Item #42-yes/no). The UPDRS was also used to create Parkinson's disease-specific impairment and disability subscales using selected items that would cumulatively provide measures of these concepts that reflect World Health Organization definitions of impairment (anatomical or physiological disturbances as manifest by disease-related symptoms and signs) and disability/activity participation (integrative functional performance in everyday life activities and mobility) [36]. The UPDRS items used to create these subscales are summarized in Table 5.

Table 4  
Comparison of fallers and non-fallers who have Parkinson's disease on demographic and disease-specific factors [mean value (SD)]

	Fallers	Non-fallers	p-value
N	19	21	
Mean age (years)	71.68 (8.47)	75.14 (5.81)	0.137
Mean education (years)	12.33 (5.30)	13.72 (4.07)	0.384
*Mean disease duration (months since symptom/sign onset)	110.74 (74.07)	64.20 (48.88)	0.020
*Mean disease duration (months since diagnosis)	98.74 (76.13)	58.20 (44.10)	0.047
*Mean disease severity (Modified Hoehn and Yahr staging)	2.75 (0.55)	2.18 (0.60)	0.004
Mean global cognitive status (MMSE score)	25.83 (2.61)	27.05 (2.44)	0.985
Mean global functional status (Schwab and England score-%)	72.88 (13.51)	79.50 (11.91)	0.122
*History of falling (mean score on UPDRS Item #13)	2.05 (1.13)	0.38 (0.59)	0.001

\*Significant group difference at  $p < 0.05$  during between group t-tests; SD = standard deviation; N = sample size; MMSE = Mini-Mental Status Examination [20]; UPDRS = Unified Parkinson's Disease Rating Scale [19].

Table 5

Impairment and disability subscales created from the Unified Parkinson's Disease Rating Scale [19]

*Impairment subscale:*

Freezing when walking-Item #14  
Tremor-Item-#16  
Facial expression-Item #19  
Tremor at rest-Item #20  
Action or postural tremor of hands-Item #21  
Rigidity-Item- #22  
Posture-Item #28  
Postural Stability-Item #30  
Body bradykinesia and hypokinesia-Item #31  
Subscale score

*Disability subscale:*

Speech-Item #5  
Swallowing-Item #7  
Handwriting-Item #8  
Cutting food and handling utensils-Item #9  
Dressing-Item-#10  
Hygiene-Item-#11  
Turning in bed-Item #12  
Walking-Item #15  
Speech-Item #18  
Arising from chair-Item #27  
Gait-Item #29  
Subscale score

# = number.

### 2.2.3. Physical examination

During the *physical examination*, potential risk factors were assessed in three categories: motor control, balance and gait. Motor control measures included probes of fine motor functioning of the feet (clumsy/not clumsy during foot tapping); motor planning of the feet (able/unable to complete a 3-step repetitive motor sequence for 5 repetitions); and lower limb proximal strength and muscle endurance (number of unsupported sit to stand maneuvers able to complete up to 5) [29]. Balance measures included observing whether the Romberg maneuver [6], side-by-side stance, semi-

tandem stance and tandem stance could be maintained without assistance for up to 10 seconds [29]; walking in tandem for up to 10 feet [29]; and performing the multidimensional Functional Reach task, backward and forward (inches) [55,56]. Measures of gait included observing timed performance during the Timed Get Up and Go (TGUG) task under single and dual task conditions (seconds). The secondary tasks utilized during 2 separate dual task trials were a secondary cognitive task (verbal fluency/semantically guided word retrieval), and a secondary motor task (carrying a full glass of water) [10,69]. Finally, the gait measures included an endurance test, consisting of a 2-minute walk test on a measured course (feet).

### 2.3. Statistical analyses

Group comparisons between the fallers and non-fallers for each variable were performed to observe if specific risk factors could distinguish the subjects with Parkinson's disease who were fallers. Between group t-tests were applied for interval and ordinal measures, and the chi-square test was applied for categorical measures. A confidence level of 95% or a p-value of 0.05 was used to determine significant differences between the groups for each variable.

## 3. Results

### 3.1. Demographic and lifestyle risk factors

Among the factors categorized as *demographic and lifestyle risk factors*, no significant groups differences were observed for age, education level, living arrangement, participation in regular exercise, and participa-

Table 6

Group comparison of lifestyle and medical historical falling risk factors between fallers and non-fallers who have Parkinson's disease (# subjects)

Risk factors	Fallers	Non-fallers	p-value
N	19	21	
<i>Lifestyle Factors</i>			
Living arrangement (alone/with others)	1/18	1/20	$p = 0.263$
Regular exercise participation (yes/no)	8/11	8/13	$p = 0.921$
Outside housework participation (yes/no)	5/14	8/13	$p = 0.173$
<i>Medical Historical Factors</i>			
Alcohol use (yes/no)	1/18	0/21	$p = 0.263$
Stroke (yes/no)	1/18	2/19	$p = 0.580$
Heart disease (yes/no)	10/9	6/15	$p = 0.069$
Diabetes mellitus (yes/no)	10/9	6/15	$p = 0.789$
Arthritis (yes/no)	3/16	3/18	$p = 0.641$
Peripheral neuropathy (yes/no)	2/17	4/17	$p = 0.540$
Visual impairment (yes/no)	3/16	6/15	$p = 0.379$
Cataracts (yes/no)	2/17	7/14	$p = 0.119$
Glaucoma (yes/no)	0/19	2/19	$p = 0.189$
Macular degeneration (yes/no)	1/18	0/21	$p = 0.263$

# = number.

tion in outside housework. Among *medical historical factors*, no significant group differences were observed for use of alcohol, history of stroke, heart disease, diabetes mellitus, arthritis, peripheral neuropathy, general visual impairment, and specific aging related diseases of vision (cataracts, glaucoma, macular degeneration). These findings are summarized in Tables 4 and 6.

### 3.2. Medication use risk factors

Among *medication use risk factors*, no significant group differences were observed between fallers and non-fallers for total number of medications used; total number of medications used to treat Parkinson's disease; and use of cardiovascular/anti-hypertensive (yes/no), anticholinergic (yes/no), and hypnotic/sedative medications (yes/no). None of the subjects were using neuroleptic agents. When observing for dopaminergic medication side effects and tolerance, fallers demonstrated a significantly higher score on the dyskinesia score (UPDRS Item #32–35) [ $p < 0.019$ ] indicating significantly higher prevalence of medication-induced dyskinesias. However, no significant group differences were observed for the presence of rapid motor fluctuations as measured by the motor fluctuation score (UPDRS Items #36–39) and self-report of “rapid on-off” phenomenon (yes/no). These findings are summarized in Table 7.

### 3.3. Parkinson's disease-specific impairment risk factors

Among Parkinson's disease-specific factors, a longer duration of disease (months since symptom onset [ $p < 0.02$ ], months since diagnosis [ $p < 0.05$ ]), and a higher disease severity (Modified Hoehn and Yahr Staging [ $p < 0.003$ ]) distinguished fallers. Among Parkinson's disease-specific clinical signs, fallers were distinguished by scoring significantly higher on measures of freezing (UPDRS Item #14 [ $p < 0.005$ ]) and postural instability (UPDRS Item #30 [ $p < 0.02$ ]) indicating that they experienced significantly more freezing episodes, and a significantly higher degree of postural instability in response to the “pull” test, respectively. No significant group differences were observed between fallers and non-fallers on the impairment subscale score or on other UPDRS items that were included to create this subscale (Table 5), as well as on the UPDRS motor score (Items #18–31). Moreover, no significant group differences were observed for categorical measures of sleep disturbance [UPDRS Item #41 (yes/no)], and for symptomatic experience of orthostasis [UPDRS Item #42 (yes/no)]. These findings are summarized in Tables 4 and 8.

### 3.4. Psychological and cognitive risk factors

Among *psychological factors*, fallers were distinguished on measures of depression and fear of falling, in that the fallers scored significantly higher on a measure of depression (UPDRS Item #3 [ $p < 0.006$ ]) indicating significantly more common experience of neurovegetative symptoms of depression, and reported fear of falling (yes/no) [ $p < 0.004$ ] significantly more frequently. Among *cognitive factors*, no group differences were observed on global measures of cognition (MMSE), as well as on more specific probes of visuo-perception [the Clock Drawing test; ability to copy the overlapping pentagrams on the MMSE]. These findings are summarized in Tables 4 and 9.

### 3.5. Disability risk factors

Among *disability factors*, while the fallers and non-fallers were matched on a measure of global functional status (Schwab and England Activities of Daily Living Scale), a significant group difference was observed on the disability subscale created from selected UPDRS items [ $p < 0.003$ ]. Fallers scored significantly higher on this subscale indicating a higher level of functional

Table 7  
Group comparison of medication use falling risk factors between fallers and nonfallers who have Parkinson's disease [Mean (SD) for ordinal and interval measures, and # subjects for categorical measures]

	Fallers	Nonfallers	p-value
N	19	21	
<i>Medication Factors</i>			
Total # medications	5.84 (2.46)	6.19 (3.14)	$p = 0.700$
# anti-Parkinson medications	2.11 (0.94)	2.05 (1.02)	$p = 0.854$
Cardiovascular agents (yes/no)	12/7	10/11	$p = 0.949$
Anticholinergics (yes/no)	1/19	1/20	$p = 0.884$
Hypnotic/sedatives (yes/no)	2/17	1/20	$p = 0.433$
Neuroleptics (yes/no)	0/19	0/21	
*Dyskinesia score			
(UPDRS Items #32–35)	0.95 (1.35)	0.14 (0.40)	$p < 0.019$
Motor fluctuation score			
(UPDRS Items #36–39)	0.95 (1.35)	0.43 (1.36)	$p = 0.235$
Rapid "on-off" experience (yes/no)	4/15	1/20	$p = 0.273$

\*Significant group differences at  $p \leq 0.05$ ; SD = standard deviation; # = number; N = sample size; UPDRS = Unified Parkinson's Disease Rating Scale.

disability (Table 5). Six of 11 of the UPDRS items that were used to comprise the disability subscale demonstrated a significantly higher level of functional disability for fallers: handwriting [ $p < 0.05$ ], hygiene [ $p < 0.02$ ], turning in bed [ $p < 0.01$ ], walking [ $p < 0.008$ ], speech [ $p < 0.05$ ], and arise from chair [ $p < 0.03$ ]. These findings are summarized in Tables 4 and 10.

### 3.6. Motor control, balance and gait risk factors

Among *motor control and balance factors*, fallers were distinguished by their significantly worse performance on measures of fine motor control [ $p < 0.028$ ] and motor planning [ $p < 0.005$ ] of the feet, and lower limb proximal strength and repetitive muscle endurance [ $p < 0.02$ ]. No significant group differences were observed on balance measures including the Romberg test; ability to maintain side-by-side, semi-tandem and tandem stances; ability to walk in tandem; and the Functional Reach test, forward and backward. Among measures of gait speed and endurance, no significant group differences between fallers and non-fallers were observed during the Timed Get Up and Go test under single and dual task conditions, and on a measure of walking endurance. These findings are summarized in Table 11.

### 3.7. Summary of results

An idiosyncratic falling risk factor profile that is Parkinson's disease-specific has emerged from data collected during clinical history-taking, medical record review and physical examination. The Parkinson's

disease-specific falling risk factor profile defined from our analyses (significant differences between fallers and non-fallers at  $p \leq 0.05$ ) include: longer disease duration; higher disease severity; more frequent experience of dyskinesias associated with taking dopaminergic medications; more frequent experience of freezing of gait; a higher degree of postural instability; more frequent experience of symptoms of depression; more frequent reporting of fear of falling; a higher level of disability; more impairment with fine motor control and motor planning of the feet; and weaker proximal lower limb strength and repetitive muscle endurance. Among these factors, disease duration is not modifiable. Disease severity and level of disability present as factors associated with higher falling risk, and potentially as outcome measures for interventions that aim to reduce falling risks and episodes. Dyskinesias, freezing, postural instability, depression, fear of falling, and impaired lower limb fine motor control, motor planning, strength and muscle endurance present as potentially modifiable using a variety of specific preventive interventions.

## 4. Discussion

An idiosyncratic falling risk factor profile that is Parkinson's disease specific has been defined in this study. Many of these risk factors present pragmatically as modifiable during a future intervention trial. Moreover, several of these have been articulated in the evolving literature (Table 2) that has identified Parkinson disease-specific falling risk factors including dyskinesia-

Table 8  
Group comparisons of Parkinson's disease-specific impairment falling risk factors between fallers and nonfallers who have Parkinson's disease [Mean (SD) for ordinal measures, and # subjects for categorical measures]

	Fallers	Nonfallers	p-value
N	19	21	
<i>Impairment Factors</i>			
<i>(UPDRS Items)</i>			
UPDRS motor score			
(Items #18-31)	31.47 (13.92)	23.56 (11.20)	$p = 0.080$
Impairment subscale score:	15.61 (5.16)	13.64 (7.12)	$p = 0.329$
*Freezing (Item #14)	2.21 (1.36)	0.81 (0.59)	$p < 0.004$
Tremor (Item #16)	1.11 (0.88)	1.00 (0.84)	$p = 0.699$
Facial expression (Item #19)	1.66 (0.78)	1.45 (0.67)	$p = 0.376$
Resting tremor (Item #20):			
Face/Lips/Hands	0.08 (0.25)	0.14 (0.48)	$p = 0.605$
Right hand	0.55 (0.83)	0.81 (1.12)	$p = 0.420$
Left hand	0.21 (0.38)	0.57 (0.87)	$p = 0.104$
Right foot	0	0.14 (0.66)	$p = 0.348$
Left foot	0	0.29 (0.72)	$p = 0.090$
Action tremor (Item #21):			
Right	0.03 (0.12)	0.24 (0.54)	$p = 0.102$
Left	0.18 (0.38)	0.10 (0.30)	$p = 0.415$
Rigidity (Item #22):			
Neck	1.29 (1.22)	1.00 (0.94)	$p = 0.402$
Right arm	0.84 (0.91)	0.98 (0.90)	$p = 0.643$
Left arm	0.84 (0.96)	0.76 (0.80)	$p = 0.775$
Right leg	0.87 (1.10)	0.88 (0.92)	$p = 0.969$
Left leg	0.87 (1.10)	0.69 (0.78)	$p = 0.556$
Posture (Item #28)	1.79 (0.90)	1.30 (0.82)	$p = 0.085$
*Postural Stability			
(Item #30)	1.66 (0.80)	1.07 (0.73)	$p < 0.020$
Bradykinesia (Item #31)	1.58 (0.75)	1.57 (0.55)	$p = 0.971$
<i>Other Impairment Factors</i>			
Sleep disturbance			
(Item #41) (yes/no)	7/12	10/11	$p = 0.366$
Orthostasis			
(Item #42) (yes/no)	7/12	7/14	$p = 0.100$

\*Significant group differences at  $p \leq 0.05$ ; SD = standard deviation; # = number; N = sample size; UPDRS = Unified Parkinson's Disease Rating Scale.

sias, freezing, postural disturbances, affective disturbances (depression, anxiety), and impaired lower limb fine motor control (agility) and strength (ability to arising from a chair). However, this study did not identify several other modifiable falling risk factors articulated in the literature including hallucinations and sleep disturbances associated with the use of dopaminergic agents, orthostasis, rigidity, bradykinesias, visual impairments, daily use of alcohol and cognitive impairments [2,28,37,56,70].

In assessing this study in the context of this literature as summarized in Table 2, several observations can be made: 1) no singular study has been all-encompassing for identifying every and all risk factors, however there is considerable consistency and overlap among these studies; 2) every study has utilized small sample sizes of subjects who have Parkinson's disease to identify

the articulated risk factors, thus their generalizability may be limited; 3) when considered together, these studies do begin to define some consensus that an idiosyncratic falling risk factor profile that is Parkinson's disease-specific exists. Thus, further refinement of these falling risk factors needs to continue to be accomplished through similar identification of risk factors among other populations of subjects who have Parkinson's disease, using larger sample sizes and more sophisticated analytic techniques, such as predictive modeling, that can assist in prioritizing what modifiable risk factors should be targeted for interventions. While more refined identification and prioritization of falling risk factors in Parkinson's disease continues to be important, these processes should not preclude applying what we already know during planning and executing risk factor modification intervention trials, us-

Table 9

Group comparisons of psychological and visuo-perceptual falling risk factors between fallers and nonfallers who have Parkinson's disease [Mean (SD) for ordinal measures and # subjects for categorical variables]

	Fallers	Nonfallers	p-value
N	19	21	
<i>Psychological Factors</i>			
*Depression			
(UPDRS Item #3)	0.71 (0.69)	0.19 (0.40)	$p < 0.006$
*Fear of falling (yes/no)	7/12	0/21	$p < 0.004$
<i>Cognitive Factors</i>			
Visuoperception:			
Clock drawing score	3.22 (0.88)	3.50 (0.88)	$p = 0.521$
Overlapping pentagrams (unable/able to complete)	6/13	4/17	$p = 0.438$

\*Significance group differences at  $p \leq 0.05$ ; SD = standard deviation; # = number; N = sample size; UPDRS = Unified Parkinson's Disease Rating Scale.

ing or "testing" the models that have been applied successfully for reducing falling risks and episodes in the general elderly population.

#### 4.1. Planning falling risk factor modification in Parkinson's disease

To begin to identify interventions directed toward modifying the identified falling risk factors, a fundamental understanding of mobility impairments in Parkinson's disease must be appreciated. Mobility impairments in Parkinson's disease encompass those of impaired gait or locomotion, and impaired balance or postural control. Within these mobility impairments, five components can be defined as contributing to their compromise: 1) impaired sensory-motor integration; 2) impaired visual compensatory systems; 3) impaired visuospatial perception; 4) motor blocks; and 5) postural stability.

##### 4.1.1. Impaired sensory-motor integration

It is hypothesized that impaired central processing of peripheral sensory, primarily proprioceptive, feedback that directs motor control, underpins the gait and balance difficulties in those who have Parkinson's disease [14,15,63,72]. The visual and auditory systems, then, become the important compensatory sensory mechanisms that are used to provide more feedback centrally to direct locomotion and to optimize balance [4]. Several gait laboratory and clinical studies have demonstrated that gait and balance can be enhanced in those who have Parkinson's disease by applying therapeutic techniques during gait and balance training that explicitly utilize visual and auditory cue-

ing [4,40,43,47,63,71]. These studies define an idiosyncratic therapeutic approach that should be taken during falling risk factor modification in Parkinson's disease when considering reducing several risk factors including impaired postural stability and impaired lower limb fine and gross motor control.

##### 4.1.2. Impaired visual compensatory systems

Several aspects of the visual system have been reported to be compromised in Parkinson's disease. These include: impaired saccadic eye movements or conjugate eye movements necessary to engage a visual target in space; bradykinesia of the extraocular muscles; impaired temporal sensitivity; impaired motion detection; dopamine depletion of the retinal amacrine cells that control formation of visual images; and impaired color perception [32,58]. Visual acuity is generally to be reported as unimpaired except when associated with aging relating diseases of vision (cataracts, glaucoma, macular degeneration). The use of enhanced visual and auditory sensory systems during gait and balance training, as discussed above, emerges as essential during falling risk factor modification to compensate for these visual processing difficulties observed in Parkinson's disease.

##### 4.1.3. Impaired visuospatial perception

Several components of this cognitive domain have been reported to be impaired in Parkinson's disease including: object and facial recognition; judgment of direction and distance; spatial orientation and attention; and appreciating the relationships of objects to one another in space as well as a spatial composite or "whole" [13,31,39,50,52]. Visuo-perceptual impairments are ubiquitous in those who have dementia associated with Parkinson's disease, and some investigators have hypothesized that a disproportionate impairment in visuoperception is the distinguishing feature of this dementia [50]. Again, the uses of organized visual cueing mechanisms are underscored when considering compensatory strategies to reduce falling risk factors within this cognitive domain. The ultimate success of these cueing strategies may depend on the integrity of fundamental visual attentional and procedural learning systems.

#### 4.2. Motor blocks

Motor blocks or freezing of gait, are idiosyncratically associated with Parkinson's disease and its related Parkinson-plus syndromes. Motor blocks are poorly

Table 10  
Group comparisons of disability falling risk factors between fallers and nonfallers who have Parkinson's disease [Mean (SD) for ordinal measures]

	Fallers	Nonfallers	p-value
N	19	21	
<i>Disability Factors (UPDRS Items)</i>			
*Disability subscale score:	15.95 (5.02)	10.60 (5.56)	$p < 0.003$
Speech (Item # 5)	1.63 (1.06)	1.12 (0.89)	$p = 0.106$
Swallowing (Item #7)	0.63 (0.90)	0.62 (0.81)	$p = 0.963$
*Handwriting (Item #8)	2.32 (1.20)	1.62 (0.97)	$p < 0.050$
Cutting food (Item #9)	1.11 (0.95)	0.98 (0.75)	$p = 0.631$
Dressing (Item #10)	1.37 (0.83)	1.12 (0.84)	$p = 0.350$
*Hygiene (Item #11)	0.97 (0.86)	0.43 (0.60)	$p < 0.024$
*Turning in bed (Item #12)	1.45 (1.12)	0.67 (0.73)	$p < 0.011$
*Walking (Item #15)	1.76 (0.88)	1.00 (0.84)	$p < 0.008$
*Speech (Item #18)	1.71 (1.03)	1.17 (0.66)	$p < 0.051$
*Arise from chair (Item #27)	1.47 (1.09)	0.81 (0.77)	$p < 0.030$
Gait (Item #29)	1.53 (0.74)	1.12 (0.71)	$p = 0.081$

\*Significant group differences at  $p \leq 0.05$ ; SD = standard deviation; # = number.

Table 11  
Group comparisons of motor control, balance and gait falling risk factors between fallers and nonfallers who have Parkinson's disease [Mean (SD) for ordinal and interval measures, and # patients for categorical measures]

Fallers	Nonfallers	p-value
N	19	21
<i>Motor control factors</i>		
*Fine motor control-feet (clumsy/not clumsy):		
Total (right + left)	18/38	11/42 $p < 0.028$
*Motor planning-feet (unable/able to complete task):		
Total (right + left)	22/38	9/42 $p < 0.005$
*Lower limb strength/endurance (# sit/stands completed)	2.69 (2.44)	4.41 (1.66) $p < 0.023$
<i>Balance factors</i>		
Romberg score	0.69 (1.01)	0.65 (0.79) $p = 0.898$
Side-by-side/semi-tandem/tandem stance score	1.40 (1.12)	1.07 (1.16) $p = 0.431$
Tandem walking (feet)	7.58 (4.91)	6.13 (4.12) $p = 0.411$
Functional reach-forward (inches)	10.13 (2.94)	11.59 (2.76) $p = 0.151$
Functional reach-backward (inches)	8.38 (2.00)	9.12 (2.29) $p = 0.329$
<i>Gait factors</i>		
TGUG-single task (seconds)	28.07 (16.69)	20.33 (3.75) $p = 0.079$
TGUG-dual task/cognitive (seconds)	35.72 (22.83)	25.29 (7.83) $p = 0.093$
TGUG-dual task/motor (seconds)	21.86 (5.91)	22.05 (4.21) $p = 0.925$
Cardiopulmonary endurance (feet)	340.71 (123.48)	369.46 (70.72) $p = 0.429$

\*Significant group differences at  $p \leq 0.05$ ; SD = standard deviation; # = number; N = sample size; TGUG = Timed Get Up and Go.

understood phenomena. They are viewed as clinically distinct and not as a manifestation of bradykinesia. Freezing is associated with longer disease duration and higher disease severity, thus it is not surprising that it emerges as a falling risk factor in Parkinson's disease in this study. Freezing is often resistant to dopaminergic agents and may worsen when use of these agents occurs over extended periods of time [1,3,22–26,38,41, 72]. Abnormal adrenergic neurotransmission has been partially implicated in the pathophysiology of freezing: treatment with deprenyl, a monoamine oxidase inhibitor, was reported to decrease freezing during one

double blind, cross-over trial [23]. Freezing of gait has been clinically classified according to what the sensory and environmental demands are during locomotion: start hesitation when initiating gait; gait arrests when approaching obstacles or terminal objects such as chairs; gait arrests when walking through narrow spaces such as doorways; gait arrests during turning; and gait arrests when walking in open space. Interrupting freezing episodes is problematic and difficult to study. One commonly used, poorly understood and inconsistently successful strategy involves the use of sensory (tactile or visual) cueing such as tapping on the

Table 12

Proposed treatment menu that links Parkinson's disease-specific falling risk factors with focused treatment intervention that aim to reduce falling risks and episodes

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*Risk factor: Treatment intervention*

*Dyskinesias and sleep disturbances associated with the use of dopaminergic medications:* modify dosing amount and dosing frequency of these agents to minimize these side effects; selective use of low dose, low potency neuroleptics at bedtime to control vivid dreams/nightmares and regulate sleep

*Orthostatic hypotension:* adequate medical management of heart disease and hypertension with minimal dosing amounts and frequency of use of cardiovascular medications; lower limb strength and muscle endurance training to enhance venous return; venous compression stockings; change position slowly from lying to sitting and sitting to standing during functional mobility training; maintain optimal hydration status

*Freezing:* behavioral strategies that support controlling the conditions that predispose to motor blocks such as taking wider turns during turning, stopping/re-establishing posture/stepping out to re-initiate gait, using tactile and visual imagery "tricks" to re-initiate gait, and using assistive devices during gait that provide continuous proprioceptive feedback and support fluid motion such as rollator (4-wheeled) or rolling (2-wheeled) walkers

*Functional mobility difficulties in axial movements, transfers, and walking:* gait training that includes focusing attention on pacing and proper gait mechanics; gait training using external visual and auditory cues; gait training under a variety of dual task conditions such as walking and talking, and walking while performing a concurrent upper limb functional motor task; proximal lower limb strengthening/flexibility/muscle endurance training

*Compromised posture and postural stability:* balance training during static, dynamic and provocative conditions; aquatics programs; core/trunk/axial muscle group strengthening and flexibility

*Depression and post-fall anxiety syndrome:* screening and medical treatment of depression and anxiety; functional mobility training in "threatening" environments that includes repetition and rehearsal; psychotherapy; support groups

*Compromised lower limb fine motor control/agility and motor planning:* coordination training using external visual and auditory cues; dancing

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leg or stepping over a laser beam generated from the base of a walker or cane, to interrupt the motor block and initiate or continue with locomotion [1,3,22–26, 38,41,72].

#### 4.2.1. Postural stability

Control of posture or upright stance has been viewed as being mediated by distinct, parallel and related neural networks along with those that control gait or locomotion. Postural control is thought to be directed by proprioceptive feedback from proximal limb and axial muscle groups; locomotion is thought to be directed by proprioceptive feedback from distal limb muscle groups [14,15,21,30,63,72]. Four components of postural control have been defined: 1) background antigravity muscle tone when at rest; 2) postural adjustments or destabilization that occur before movement is initiated when anticipating movement; 3) postural adjustments during voluntary movement; 4) compensatory postural reactions in response to external provocations. The balance tests utilized in this study to probe postural control (the Romberg test, side by side/semitandem/tandem stance, functional reach) measured to some degree the first three components, and these did not emerge as falling risk factors. However, the "pull test" which is the external provocation provided during measurement of UPDRS Item #30, that is, postural instability, did emerge as a falling risk factor in this study. Thus, when planning interventions to reduce falling in Parkinson's disease, these may be

best directed toward optimizing postural control and stability when confronted with external environmental provocations.

#### 4.3. Studies that support multidimensional falling risk factor modification in Parkinson's disease

As in the general elderly population, common rehabilitation interventions such as therapeutic exercises and functional mobility training have been reported to demonstrate improvements in impairment-specific outcome measures (e.g., strength, flexibility, muscular endurance, cardiopulmonary endurance), functional status and quality of life in those who have Parkinson's disease [5,42,53,60,61]. Rarely have these types of studies used falling events as an outcome measure. The potential influence of these types of rehabilitation interventions on reducing falls can only be inferred when viewed through the model of risk factor modification. For example, improvements of lower limb muscle strength through directed therapeutic exercise reduces this impairment as a falling risk factor, and decreases disability as an associated event, but does not directly inform us whether falling episodes have decreased.

Other studies have applied more specific, multidimensional, and sometime novel treatment approaches to enhance gait and balance in Parkinson's disease. Muller and colleagues [53] utilized multidimensional treatment interventions that included: mobility training using external sensory cues; behavioral management

strategies to enhance performance of complex functional motor tasks; rehearsal of what one has learned under different learning conditions and in different contexts; muscle relaxation techniques; and social skills training. Subjects who had Parkinson's disease, after being exposed to these organized treatments during a three month intervention phase, demonstrated significant improvements in gait initiation, forward bending and motor coordination. These subjects were partially able to maintain their gains several months after the organized interventions were discontinued. Behrman and colleagues [5] used verbal instructions, repetition and rehearsal during gait training in subjects who had Parkinson's disease: significant improvement in step length, gait velocity, and arm swing after the intervention phase were demonstrated. Lökk [42] utilized daily high altitude, non-level terrain walking and educational seminars as treatment interventions: significant symptom reduction, and improvements in emotional functioning and quality of life were reported after a one week intervention phase. These improvements, however, were not maintained at eighteen week follow-up observations. Miyai and colleagues [48,49] studied the use of partial body weight-supported treadmill training in patients with Parkinson's disease. During two prospective, four week cross-over trials that compared treadmill training with traditional physical therapy in subjects who had Parkinson's disease, significant improvements were reported for gait velocity only during the treadmill training.

These studies summarized above suggest that both traditional and novel exercise-based therapeutic interventions can potentially reduce several falling risk factors identified in this study and other studies, for example, postural disturbances, affective disturbances and impaired lower limb fine and gross motor control. They provide some support for applying and testing a model of multidimensional risk factor modification to reduce falls in Parkinson's disease. These studies have not yet been executed.

#### 4.4. *Future directions*

Table 12 presents a proposed treatment menu that links specific falling risk factors with focused treatment interventions. This proposed treatment menu has adopted the model developed by Tinetti and colleagues [65,66] of multidimensional falling risk factor modification to reduce falling episodes in the community based elderly population. This model still needs to be tested in a population of patients with Parkinson's

disease both during primary preventive trials (in those without a history of falling) and during secondary preventive trials (in those who are recurrent fallers) that are prospective, randomized, and that use falling episodes as the major outcome measure. While falling risk factors in Parkinson's disease continue to require further study to develop consensus as to those that should be targeted for modification, our own data and the literature in this area of investigation has started to identify risk factors that are idiosyncratically related to Parkinson's disease.

Moreover, there are evolving lines of investigation that are applying novel treatment strategies that can be applied pragmatically during intervention trials aimed toward reduction of falls. These include mobility training using sensory cueing and other attentionally enhancing strategies to improve sensory-motor integration, and the use of partial body weight-supported treadmill training to enhance automatic lower limb motor control.

## 5. **Conclusions**

The literature on falling risk factors in Parkinson's disease (Table 2) and our own data have identified several Parkinson's disease-specific risk factors that can be linked to directed interventions during future primary and secondary intervention trials that aim to reduce falls. These risk factors include: dyskinesias and sleep disturbances associated with the use of dopaminergic medications; orthostatic hypotension; freezing; gait and other functional mobility difficulties; compromised posture and postural stability; psychological disturbances such as depression and post-falling anxiety; compromised fine motor control/agility and motor planning of the lower limbs; and compromised proximal lower limb strength and muscular endurance. These Parkinson's disease-specific risk factors identified from this study and from the literature provide a starting point from which to evaluate specific disease related interventions that may reduce falls. A menu of treatment interventions that links specific risk factors with focused treatments is proposed in Table 12.

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