Articles

Functional Aspects of Gait in Essential Tremor: A Comparison with Age-Matched Parkinson's Disease Cases, Dystonia Cases, and Controls

Elan D. Louis[1,2*] & Ashwini K. Rao[3,4]

[1] Department of Neurology, Yale School of Medicine, Yale University, New Haven, CT, USA, [2] Department of Chronic Disease Epidemiology, Yale School of Public Health, Yale University, New Haven, CT, USA, [3] Program in Physical Therapy, Department of Rehabilitation & Regenerative Medicine, College of Physicians and Surgeons, Columbia University, New York, NY, USA, [4] GH Sergievsky Center, College of Physicians and Surgeons, Columbia University, New York, NY, USA

Abstract

Background: An understanding of the functional aspects of gait and balance has wide ramifications. Individuals with balance disorders often restrict physical activity, travel, and social commitments to avoid falling, and loss of balance confidence, itself, is a source of disability. We studied the functional aspects of gait in patients with essential tremor (ET), placing their findings within the context of two other neurological disorders (Parkinson's disease [PD] and dystonia) and comparing them with age-matched controls.

Methods: We administered the six-item Activities of Balance Confidence (ABC-6) Scale and collected data on number of falls and near-falls, and use of walking aids in 422 participants (126 ET, 77 PD, 46 dystonia, 173 controls).

Results: Balance confidence was lowest in PD, intermediate in ET, and relatively preserved in dystonia compared with controls. This ordering reoccurred for each of the six ABC-6 items. The number of near-falls and falls followed a similar ordering. Use of canes, walkers, and wheelchairs was elevated in ET and even greater in PD. Several measures of balance confidence (ABC-6 items 1, 4, 5, and 6) were lower in torticollis cases than in those with blepharospasm, although the two groups did not differ with respect to falls or use of walking aids.

Discussion: Lower balance confidence, increased falls, and greater need for walking aids are variably features of a range of movement disorder patients compared to age-matched controls. While most marked among PD patients, these issues affected ET patients as well and, to a small degree, some patients with dystonia.

Keywords: Essential tremor, Parkinson's disease, dystonia, gait, balance, ataxia, function

Citation: Louis ED, Rao AK. Functional aspects of gait in essential tremor: a comparison with age-matched Parkinson's disease cases, dystonia cases, and controls. Tremor Other Hyperkinet Mov 2015; 5. doi: 10.7916/D8B27T7J

Introduction

There is a growing appreciation of the presence of gait and balance problems in patients with essential tremor (ET), who demonstrate a mild degree of ataxia.[1–5] Although these problems are often mild, in some patients, they are marked.[6] While the objective metrics of this gait and balance disorder have been the focus of considerable study, less attention has been devoted to the functional aspects of this gait difficulty in ET. What do patients experience? How does the problem affect daily activities? The issue is important and has wider ramifications. Individuals with balance disorders often deliberately restrict physical activity, travel, and social commitments to avoid the potential consequences.[7,8] They may reduce or eliminate normal daily activities, thereby lessening their quality of life, in order to avoid the potential for falls. In this way, loss of balance confidence, itself, is a potential source of disability.[7] There are surprisingly few data on functional gait in ET, and none directly comparing ET to Parkinson's disease (PD) or dystonia cases.

In the current study, our primary focus was on the functional aspects of gait and balance—balance confidence, falls and near-falls, and use of walking aids (canes, walkers, and wheelchairs) in ET. As a useful exercise, we placed these findings in ET within the larger context of

several other groups. Therefore, we compared ET patients to: 1) age-matched patients with a second movement disorder, PD, in which gait and balance problems are well recognized and of considerable severity[9,10]; 2) age-matched patients with another movement disorder, dystonia, which is without reported gait problems (i.e., a disease control); and 3) age-matched controls. The hypothesis was that ET patients would exhibit a level of functional gait impairment that was less than that seen in PD, greater than that seen in dystonia, and significantly greater than that seen in controls. We also further stratified ET cases based on a range of disease characteristics of *a priori* interest (e.g., greater total tremor score, presence of cranial tremor), hypothesizing that these would co-vary with extent of functional gait difficulty.

Methods

Participants

Participants were prospectively enrolled in a clinical-epidemiological study of ET, which compared them to diseased controls (PD and dystonia) and normal controls, at the Neurological Institute, Columbia University Medical Center (CUMC), USA (2009–2014).[11] The study was designed to assess a wide range of clinical features as well as the role of environmental toxins in disease etiology. ET, PD, and dystonia cases were identified from a computerized billing database at the Center for Parkinson's Disease and Other Movement Disorders at the Neurological Institute, with a search conducted of all patients seen within the past 3 years. Each case had received a diagnosis of ET, PD, or dystonia from their treating neurologist at the Institute and lived within 2 hours' driving distance of CUMC. One of the authors (E.D.L.) reviewed the office records of all selected patients; patients with diagnoses or physical signs consistent with other movement disorders were excluded. At the time of the record review, the location of dystonia (torticollis, blepharospasm, writer's cramp, combination or other locations) was extracted (dystonia cases), as was the most recent Hoehn and Yahr score[12] (PD cases).

Control subjects were recruited for the same study during this time period. Controls were identified using random digit telephone dialing within a defined set of telephone area codes that were represented by neurological cases (e.g., 212, 201, 203, 516, 718, and 914) within the New York Metropolitan area. There was one group of controls for all neurological disease cases (ET, PD, and dystonia). Controls were frequency-matched to ET cases based on current age (5-year intervals).

The CUMC Internal Review Board approved all study procedures. Written informed consent was obtained upon enrollment.

Study evaluation

A trained research assistant conducted an in-person evaluation in the subjects' homes or at the medical center. Subjects were not asked to withhold use of their daily medications. During the evaluation, the assistant administered a demographic and medical history questionnaire, and data on all current medications were collected. This included a listing of all medications with potential effects on gait (e.g., primidone, topiramate, benzodiazepines). The presence of self-reported visual problems (e.g., macular degeneration), neuropathy, and orthopedic problems (e.g., arthritis, joint replacement) was noted. To briefly assess cognition, the assistant administered the Folstein Mini-Mental State Examination (MMSE, range 0–30 [no impairment]).[13] During the assessment, the assistant administered the six-item Activities of Balance Confidence (ABC-6) Scale.[14] The scale asks participants to self-rate their confidence in performing functional activities without losing balance or becoming unsteady during a range of situation-specific activities (e.g., reaching on tiptoes for an object, stepping on or off an escalator). The ABC has been shown to have excellent utility in evaluating balance-related confidence, and scores for each item, as well as the total score, range from 0 (not confident at all) to 100 (completely confident). The ABC-6 Scale has been validated against the parent ABC questionnaire, which consists of 16 items. During the assessment, we also asked participants to indicate how many falls they had had during the past year. Falls were defined as "an event which results in a person coming to rest inadvertently on the ground or supporting surface, and other than as a consequence of a violent blow, loss of consciousness or sudden onset of paralysis." We, and others have defined fallers as those who have had more than two falls in the previous year.[15] We also asked about the number of near-falls (i.e., when subjects felt they were going to fall but did not actually fall) they had had in the past year, and whether during that period they used a walking aid (cane, walker, wheelchair) regularly in the house or when outside of the house.

Careful validation of the ET diagnosis is an important feature of all clinical and epidemiological research on ET. Therefore, during the assessment, a videotaped neurological examination was also performed on all ET cases. This included one test for postural tremor and five for kinetic tremor (pouring, using spoon, drinking, finger–nose–finger maneuver, drawing spirals) performed with each arm (12 tests in total). A neurologist specializing in movement disorders (E.D.L.) used a reliable and valid clinical rating scale, the Washington Heights–Inwood Genetic Study of ET (WHIGET) Tremor Rating Scale, to rate postural and kinetic tremor during each test: 0 (none), 1 (mild), 2 (moderate), 3 (severe). These ratings resulted in a total tremor score (range = 0–36), which is an assessment of postural and kinetic tremor.[16] The finger–nose–finger maneuver included 10 repetitions per arm, and intention tremor was defined as present when tremor amplitude increased during visually guided movements towards the target.[17] Rest tremor was evaluated 1) while the patient was seated with arms fully supported by their legs, 2) while the patient was standing with arms at rest by their side and then while walking. Rest tremor was rated as present or absent.

On videotaped examination, several types of cranial tremor were assessed. Jaw and voice tremors were coded as present or absent while cases were seated facing the camera. Jaw tremor was assessed while the mouth was stationary (closed), while the mouth was slightly open, during sustained phonation, and during speech. Voice tremor was assessed during sustained phonation, while reading a prepared paragraph, and during speech. Neck tremor in ET was coded as present or absent and was distinguished from dystonic tremor by the

absence of twisting or tilting movements of the neck, jerk-like or sustained neck deviation, or hypertrophy of neck muscles; it was distinguished from titubation by its faster speed and the absence of accompanying truncal titubation or ataxia while seated or standing.[18]

Diagnoses

As noted above, diagnoses of ET were re-confirmed by E.D.L. using the videotaped neurological examination as well as WHIGET diagnostic criteria (moderate or greater amplitude of kinetic tremor [tremor rating ≥ 2] during three or more tests or a head tremor, in the absence of PD, dystonia, or another cause).[16] The WHIGET criteria have been used routinely in Dr. Louis's epidemiological studies of ET and are used by other tremor investigators in the USA and internationally.[19–22] The diagnosis of dystonia was confirmed using published diagnostic criteria, as described.[23] The diagnosis of PD was confirmed using published diagnostic criteria, as also described.[24]

Final selection of sample for analysis

Dystonia and PD cases were younger than ET cases and controls. In order to frequency-match based on age, which is an important confounding variable, we excluded the 58 PD cases and 76 dystonia cases who were ≤ 65 years of age, resulting in a final sample of 126 ET cases, 77 PD cases, 46 dystonia cases, and 173 controls, all of whom were age-matched with one another.

Statistical analyses

Demographic characteristics across the four groups were compared using analysis of variance, chi-square tests, and Kruskal–Wallis tests. The main outcome variables (i.e., the six items on the ABC-6, number of falls, number of near-falls) were not normally distributed (all Kolmogorov–Smirnov test p values <0.05). Therefore, these were assessed using non-parametric tests.

To examine differences by group, we first used a nonparametric test, the Jonckheere–Terpstra test of ordered alternatives. The Jonckheere–Terpstra test is useful when the alternative hypothesis includes *a priori* ordering, as was the case in our study. We hypothesized that the PD patients would have the most gait and balance difficulty, followed by ET, and then dystonia and controls, in that order. Second, we also compared each disease group to controls (i.e., ET vs. controls, PD vs. controls, dystonia vs. controls) using Mann–Whitney tests. As dystonia is a heterogeneous condition, we compared the two largest groups of dystonia cases (torticollis and blepharospasm) to one another and to controls (Mann–Whitney tests). There was no *a priori* hypothesis. In an additional set of analyses, we further stratified ET cases based on a range of disease characteristics of *a priori* interest, including total tremor score, tremor duration, presence vs. absence of intention tremor, presence vs. absence of rest tremor, and presence vs. absence of cranial (jaw, voice, or neck) tremor. In these stratified analyses, total tremor score was split based on the mean (21.0) into lower (<21) vs. higher (≥ 21) categories, and symptom (i.e., tremor) duration was split on the mean (33.0) into lower (<33) vs. higher (≥ 33) categories. Given the small sample size within many of the strata (e.g., those with intention

tremor, those with rest tremor) and the small effect sizes, formal statistical comparisons were not performed. The main analyses involved a small number (n = 11) of pre-specified comparisons, all of which were of *a priori* interest; therefore, correction for multiple comparisons was not necessary. In a sensitivity analysis, we assessed the potential effects of medications by removal of ET cases on medications with potential effects on gait (e.g., primidone, topiramate, benzodiazepines).

Results

The 422 participants were similar in terms of age and race, although there were gender differences, with more males among the PD cases (Table 1). The prevalence of self-reported visual problems, neuropathy, and orthopedic problems (e.g., arthritis, joint replacement) was similar across groups (Table 1), as was the MMSE score (Table 1). As expected, symptom duration was longer in ET cases than PD cases. The total tremor score in ET cases was 21.0 ± 6.2. The Hoehn and Yahr score was 1 or 2 in 91% of PD cases.

As hypothesized, balance confidence was lowest in PD cases, intermediate in ET cases, and relatively preserved in dystonia cases compared with controls (Table 1). Indeed, this ordering reoccurred for each of the six ABC-6 items (Table 1). The number of near-falls and falls, as well as the number of fallers, followed a similar ordering (Table 1). Use of canes, walkers, and wheelchairs was elevated in ET cases and even greater in PD cases (Table 1). In all cases, the difference between PD cases and controls was significant (Table 1). This was the case for some but not other variables in the ET vs. controls analyses (Table 1).

The dystonia cases included 27 (58.7%) with torticollis, 13 (28.3%) with blepharospasm, 1 (2.2%) with writer's cramp, and the remaining 5 (10.9%) with dystonia in several sites. Several measures of balance confidence (ABC-6 items 1, 4, 5, and 6) were lower in the torticollis cases than in those with blepharospasm, although the two groups did not differ with respect to falls or use of walking aids (Table 2).

In a sensitivity analysis, we assessed the potential effects of medications. Indeed, we had collected data on all medications with potential effects on gait (e.g., primidone, topiramate, benzodiazepines). Forty-three (34.1%) ET cases were taking one or more of these medications. Removal of these 43 ET cases did not change the results—the trends noted above remained evident and significant. We further stratified ET cases based on a range of disease characteristics of *a priori* interest, including total tremor score, tremor duration, presence vs. absence of intention tremor, presence vs. absence of rest tremor, and presence vs. absence of cranial tremor (Table 3). More severe tremor, presence of rest tremor, and presence of cranial tremor seemed to co-vary with measures of balance confidence, falls and near-falls, and use of walking aids (Table 3). However, differences in age across strata complicate the interpretation of these data (Table 3).

Only 9% of the PD cases had Hoehn and Yahr scores ≥ 3; these had lower balance confidence, more near-falls and falls, and greater use of walking aids than did their counterparts with Hoehn and Yahr scores of 1 or 2 (data not shown), although the small number of PD

Table 1. Demographic and Clinical Characteristics of 422 Participants

	Controls	Dystonia	ET	PD	Significance
n	**173**	**46**	**126**	**77**	
Age (years)	74.1 ± 9.0	73.2 ± 4.2	75.7 ± 8.3	74.4 ± 4.2	p = 0.19 [5]
Female gender[1]	106 (61.6)	34 (73.9)	65 (52.0)	36 (47.4)	p = 0.01 [6]
Caucasian[1]	151 (89.3)	42 (91.3)	119 (95.2)	68 (89.5)	p = 0.32 [6]
Symptom duration (years)	NA	18.5 ± 13.8	33.0 ± 19.5	9.1 ± 11.0	p <0.001 [7]
Macular degeneration[1]	13 (7.6)	2 (4.3)	2 (1.6)	5 (6.6)	p = 0.13 [6]
Neuropathy[1]	17 (9.9)	2 (4.3)	14 (11.3)	8 (10.7)	p = 0.59 [6]
Orthopedic problems[1]	106 (61.3)	34 (73.9)	76 (60.3)	40 (53.3)	p = 0.16 [6]
Mini-mental State Examination	28.6 ± 1.7 (29.0)	28.3 ± 1.9 (29.0)	28.7 ± 1.6 (29.0)	28.3 ± 2.0 (29.0)	p = 0.46 [7]
ABC1 (Confidence when you stand on your tiptoes and reach for something)	72.2 ± 31.6 (90)	76.4 ± 25.2 (90)	64.8 ± 31.7 (72.5) [3]	61.8 ± 34.5 (70) [3]	p = 0.002 [8]
ABC2 (Confidence when you stand on a chair and reach for something)	62.5 ± 35.6 (75)	63.0 ± 34.8 (70)	53.5 ± 35.1 (60) [3]	43.5 ± 33.2 (40) [3]	p <0.001 [8]
ABC3 (Confidence when you are bumped into by people as you walk)	75.7 ± 28.4 (90)	74.4 ± 24.0 (80)	69.7 ± 31.7 (80)	61.1 ± 34.1 (70) [3]	p = 0.001 [8]
ABC4 (Confidence when you step onto or off an escalator while holding the handrail)	81.8 ± 25.2 (90)	75.6 ± 28.5 (90)	75.8 ± 28.4 (90) [4]	68.7 ± 32.0 (80) [3]	p = 0.001 [8]
ABC5 (Confidence when you step onto or off an escalator while holding onto parcels)	63.8 ± 36.6 (80)	58.0 ± 38.0 (70)	54.6 ± 35.2 (60) [3]	47.3 ± 34.3 (50) [3]	p <0.001 [8]
ABC6 (Confidence when you walk outside on icy sidewalks)	46.9 ± 33.9 (50)	42.5 ± 33.4 (40)	39.7 ± 31.5 (30) [4]	36.5 ± 30.8 (37.5) [3]	p <0.001 [8]
ABC-6 total score	67.2 ± 27.5 (76.7)	65.0 ± 25.5 (68.3)	59.7 ± 27.7 (65.4) [3]	53.1 ± 28.9 (54.1) [3]	p <0.001 [8]
Number of near-falls in past year	5.3 ± 29.3 (0)	4.1 ± 11.0 (0)	13.2 ± 41.9 (0)	61.4 ± 120.9 (5) [3]	p <0.001 [8]
Number of falls in past year	0.6 ± 0.9 (0)	0.5 ± 1.0 (0)	1.0 ± 3.2 (0)	9.9 ± 47.5 (1) [3]	p = 0.001 [8]

Table 1. Continued

	Controls	Dystonia	ET	PD	Significance
n	**173**	**46**	**126**	**77**	
Number of fallers in past year[2]	9 (5.2)	2 (4.3)	12 (9.5)	21 (27.3) [3]	p <0.001 [6]
Use of walking aid (in home)					p <0.001 [6]
No	164 (94.8)	46 (100)	115 (91.3)	56 (72.7)	
Cane	4 (2.3)	0 (0.0)	5 (4.0)	7 (9.1)	
Walker	5 (2.9)	0 (0.0)	4 (3.2)	12 (15.6)	
Wheelchair	0 (0.0)	0 (0.0)	2 (1.6)	2 (2.6) [3]	
Use of walking aid (outside of home)					p <0.001 [6]
No	143 (82.7)	42 (91.3)	103 (81.7)	44 (57.1)	
Cane	25 (14.5)	4 (8.7)	13 (10.3)	17 (22.1)	
Walker	5 (2.9)	0 (0.0)	7 (5.6)	11 (14.3)	
Wheelchair	0 (0.0)	0 (0.0)	3 (2.4)	5 (6.5) [3]	

Values are mean $\pm$ standard deviation (median) or number (percentage).

Abbreviations: ABC, Activities of Balance Confidence; ET, Essential Tremor; NA, Not Applicable; PD, Parkinson's Disease.

[1]Data missing on <1% of subjects.

[2]As in prior analyses, we and others have defined fallers as those who have had more than two falls in the previous year.[14]

[3]Significantly different from controls (p <0.05, Mann–Whitney test).

[4]Marginally significantly different from controls (p <0.10, Mann–Whitney test).

[5]Analysis of variance comparing all four groups.

[6]Chi-square test comparing all four groups.

[7]Kruskal–Wallis test comparing all four groups.

[8]Jonckheere–Terpstra rank order test of four groups.

cases with higher Hoehn and Yahr scores does not allow for statistical testing.

Discussion

In the current study, 422 participants, including three age-matched neurological disease groups and one group of age-matched controls, underwent an evaluation of a number of functional aspects of gait, which included evaluations of balance confidence, falls and near-falls, and use of various walking aids. While these functional aspects of gait were the most impaired in PD cases, many of these same aspects of gait were impaired, although to a lesser degree, in ET cases. Indeed, compared to age-matched controls, balance confidence in ET cases was significantly diminished across a range of diverse settings, including standing on tiptoes to reach for something, standing on a chair to reach for something, stepping on or off an escalator, and walking on icy sidewalks. ET cases were intermediate between PD cases and age-matched controls in terms of their need for walkers and

wheelchairs. Overall, these functional aspects of gait were relatively preserved in dystonia cases; however, when this group was further divided into those with torticollis vs. those with blepharospasm, there was some functional gait impairment in the former. The reason for this finding is not clear but the involvement of axial musculature in these patients could translate into some mild difficulty with gait and balance.

Additional subdivision of ET cases indicated that more severe tremor, presence of rest tremor, and presence of cranial tremor seemed to co-vary with measures of balance confidence, falls and near-falls, and use of walking aids; however, differences in age across strata complicate the interpretation of these data. We have previously demonstrated that ET cases with cranial tremor have the most difficulty with tandem gait.[18]

Quantification of objective metrics of gait and balance is worthwhile because it provides information on mechanisms that may underlie gait and balance impairments. Studying the functional aspects of gait and balance difficulty provides a more patient-centered perspective on

Table 2. Characteristics of Dystonia Cases Compared with Controls

	Controls	Dystonia–Blepharospasm	Dystonia– Torticollis
N	**173**	**13**	**27**
Age (years)	74.1 ± 9.0	74.2 ± 4.4	73.2 ± 4.1
Female gender[1]	106 (61.6)	10 (76.9)	20 (74.1)
Caucasian[1]	151 (89.3)	10 (76.9)	27 (100) [4]
Symptom duration	NA	24.3 ± 16.3	17.5 ± 14.0
ABC1 (Confidence when you stand on your tiptoes and reach for something)	72.2 ± 31.6 (90)	88.1 ± 15.5 (90)	67.0 ± 27.0 (70) [5]
ABC2 (Confidence when you stand on a chair and reach for something)	62.5 ± 35.6 (75)	66.8 ± 40.4 (90)	57.4 ± 33.0 (60)
ABC3 (Confidence when you are bumped into by people as you walk)	75.7 ± 28.4 (90)	77.7 ± 24.2 (90)	70.3 ± 24.7 (80)
ABC4 (Confidence when you step onto or off an escalator while holding the handrail)	81.8 ± 25.2 (90)	88.5 ± 17.7 (100)	71.0 ± 28.9 (80) [3,5]
ABC5 (Confidence when you step onto or off an escalator while holding onto parcels)	63.8 ± 36.6 (80)	77.5 ± 31.8 (90)	50.7 ± 35.2 (50) [4,5]
ABC6 (Confidence when you walk outside on icy sidewalks)	46.9 ± 33.9 (50)	52.9 ± 29.3 (40)	34.1 ± 32.1 (20) [4,6]
ABC-6 total score	67.2 ± 27.5 (76.7)	75.2 ± 23.7 (80.0)	58.8 ± 25.1 (58.3) [4,5]
Number of near-falls in past year	5.3 ± 29.3 (0)	4.6 ± 14.3 (0)	2.3 ± 4.3 (0)
Number of falls in past year	0.6 ± 0.9 (0)	0.6 ± 1.5 (0)	0.4 ± 0.8 (0)
Number of fallers in past year[2]	9 (5.2)	1 (7.7)	1 (3.7)
Use of walking aid (in home)			
No	164 (94.8)	13 (100)	27 (100)
Cane	4 (2.3)	0 (0)	0 (0)
Walker	5 (2.9)	0 (0)	0 (0)
Wheelchair	0 (0.0)	0 (0)	0 (0)
Use of walking aid (outside of home)			
No	143 (82.7)	10 (76.9)	27 (100)
Cane	25 (14.5)	3 (23.1)	1 (3.7)
Walker	5 (2.9)	0 (0)	0 (0)
Wheelchair	0 (0.0)	0 (0)	0 (0)

Values are mean ± standard deviation (median) or number (percentage).
Abbreviations: ABC, Activities of Balance Confidence; NA, Not Applicable.
[1]Data missing on <1% of subjects.
[2]As in prior analyses, we and others have defined fallers as those who have had more than two falls in the previous year.[14]
[3]Significantly different from controls (p <0.05, Mann–Whitney test).
[4]Marginally significantly different from controls (p <0.10, Mann–Whitney test).
[5]Significantly different from dystonia cases with blepharospasm (p <0.05, Mann–Whitney test).
[6]Marginally significantly different from dystonia cases with blepharospasm (p <0.10, Mann–Whitney test).

Table 3. Gait and Balance in ET Cases Stratified Based on Different Clinical Characteristics

	TTS*		Tremor Duration*		Intention Tremor*		Rest Tremor*		Cranial Tremor*	
	Lower	Higher	Shorter	Longer	No	Yes	No	Yes	No	Yes
n	58	57	69	50	100	21	102	19	57	63
Age (years)	72.7 ± 7.7	79.1 ± 7.4	74.2 ± 8.1	77.9 ± 8.2	75.3 ± 8.3	77.3 ± 7.9	75.1 ± 8.1	77.8 ± 8.2	72.7 ± 7.0	78.0 ± 8.5
ABC1	69.3 ± 29.7	60.9 ± 32.8	64.8 ± 33.0	64.3 ± 29.5	64.1 ± 30.9	69.5 ± 30.8	67.1 ± 30.1	51.6 ± 35.3	69.0 ± 30.5	59.7 ± 31.6
ABC2	61.6 ± 33.1	45.8 ± 35.4	51.8 ± 37.3	55.3 ± 30.8	53.9 ± 33.7	54.1 ± 39.5	56.5 ± 34.3	38.2 ± 35.1	55.5 ± 36.3	50.9 ± 33.9
ABC3	72.9 ± 29.5	67.9 ± 32.5	68.5 ± 31.8	73.3 ± 29.4	71.8 ± 28.7	63.8 ± 39.7	71.1 ± 30.2	64.0 ± 38.0	73.0 ± 31.5	66.1 ± 31.3
ABC4	78.9 ± 24.7	74.9 ± 29.6	78.2 ± 26.6	75.0 ± 28.3	76.9 ± 26.5	75.7 ± 30.5	77.5 ± 26.9	69.7 ± 32.9	78.1 ± 27.2	73.5 ± 28.6
ABC5	57.5 ± 35.0	51.8 ± 34.1	56.4 ± 35.3	53.6 ± 34.3	55.2 ± 34.2	55.2 ± 35.7	56.3 ± 34.3	46.2 ± 36.4	62.2 ± 31.8	47.2 ± 35.7
ABC6	44.2 ± 31.9	36.6 ± 30.9	38.5 ± 31.0	42.1 ± 32.3	39.9 ± 30.0	40.7 ± 36.8	41.8 ± 30.9	29.0 ± 32.3	44.5 ± 30.1	35.1 ± 32.2
ABC total	64.1 ± 25.6	56.3 ± 27.9	59.7 ± 27.7	60.6 ± 26.7	60.3 ± 25.8	59.8 ± 31.7	61.7 ± 26.4	49.8 ± 30.8	63.7 ± 26.8	57.8 ± 27.0
Number of near-falls in past year	11.1 ± 28.6	17.3 ± 55.0	11.7 ± 46.6	16.6 ± 37.7	12.1 ± 42.6	20.2 ± 43.2	8.1 ± 22.7	43.5 ± 90.1	8.1 ± 21.2	18.9 ± 55.3
Number of falls in past year	0.7 ± 1.3	1.1 ± 4.0	1.2 ± 3.7	0.9 ± 2.6	1.0 ± 3.2	0.5 ± 0.9	0.9 ± 2.1	1.8 ± 6.8	1.3 ± 4.6	0.8 ± 1.3
Number of fallers in past year**	6 (10.3)	5 (8.8)	7 (10.1)	5 (10.0)	10 (10.0)	1 (4.8)	11 (10.8)	1 (5.3)	5 (8.8)	7 (11.1)
Use of walking aid (in home)										
No	56 (96.6)	50 (87.7)	64 (92.8)	46 (92.0)	94 (94.0)	18 (85.7)	96 (94.1)	15 (78.9)	54 (94.7)	56 (88.9)
Cane	1 (1.7)	3 (5.3)	2 (2.9)	2 (4.0)	3 (3.0)	1 (4.8)	2 (2.0)	2 (10.5)	1 (1.8)	3 (4.8)
Walker	1 (1.7)	3 (5.3)	3 (4.3)	1 (2.0)	2 (2.0)	2 (9.5)	3 (2.9)	1 (5.3)	1 (1.8)	3 (4.8)
WC	0 (0.0)	1 (1.8)	0 (0.0)	1 (2.0)	1 (1.0)	0 (0.0)	1 (1.0)	1 (5.3)	1 (1.8)	1 (1.6)

Table 3. Continued

	TTS*		Tremor Duration*		Intention Tremor*		Rest Tremor*		Cranial Tremor*	
	Lower	Higher	Shorter	Longer	No	Yes	No	Yes	No	Yes
n	58	57	69	50	100	21	102	19	57	63
Use of walking aid (outside of home)										
No	50 (86.2)	47 (82.5)	58 (84.1)	41 (82.0)	85 (85.0)	17 (81.0)	87 (85.3)	14 (73.7)	51 (89.5)	49 (77.8)
Cane	7 (12.1)	4 (7.0)	5 (7.2)	6 (12.0)	9 (9.0)	2 (9.5)	9 (8.8)	2 (10.5)	4 (7.0)	7 (11.1)
Walker	1 (1.7)	4 (7.0)	5 (7.2)	2 (4.0)	4 (4.0)	2 (9.5)	5 (4.9)	1 (5.3)	1 (1.8)	5 (7.9)
WC	0 (0.0)	2 (3.5)	1 (1.4)	1 (2.0)	2 (2.0)	0 (0.0)	1 (1.0)	2 (10.5)	1 (1.8)	2 (3.2)

Values are mean ± standard deviation (median) or number (percentage).
NA = not applicable.
WC = Wheelchair.
*Data missing on < 10% of subjects
**As in prior analyses, we and others have defined fallers as those who had had >2 falls in the previous year [14].

these issues, which supplies information on specific problems that may result from gait and balance impairments. While functional aspects of gait have been well studied in patients with PD, there are relatively few data in ET, despite a growing awareness of the gait and balance issue in ET.[2] An understanding of the functional aspects of the gait disorder in ET is needed in order to design rehabilitation strategies that are targeted at specific issues pertinent to this disorder, and as outcomes of rehabilitation treatment. At the moment, such strategies have yet to be proposed.

We have published several prior reports on functional balance problems in patients with ET. In one report,[25] we administered the ABC-6 to a group of 132 ET cases who were brain donors and 48 controls. Hence, on average, the ET cases had significantly more advanced disease than those in the current study.[25] They were also on average more than a decade older than the cases and controls we now report, making it difficult to compare the results across these two studies. In that study, we did not assess each individual item in the ABC-6; nor did we assess near-falls or use of walking aids.[25] Furthermore, that study was restricted to ET cases and controls, and did not include participants with PD or dystonia.[25] The ABC-6 total score in cases and controls in that study was lower than that we report here, and this was likely a function of the highly advanced age of those participants. In an earlier paper,[26] we had sampled a smaller group of 59 ET cases and 82 controls from the same study of environmental epidemiology of neurological disorders. That report did not examine each ABC-6 item individually and did not include participants with dystonia or PD. In that study, the ABC-6 total score was slightly higher in ET cases and controls than that reported here; however, that sample was younger than the current sample by several years. There is surprisingly little in the way of other data on functional gait in ET, and none directly comparing ET to PD or dystonia cases. One study administered the ABC to 30 patients with ET, demonstrating that those with head tremor had lower balance confidence than the 28 controls.[3] A study of 13 severe ET cases who had undergone deep brain stimulation surgery indicated lower ABC scores in the ET cases than in 13 controls.[27]

The results of this study should be interpreted within the framework of several limitations. First, the mean age of our participants was in the mid-70s. Additional studies on younger participants would allow one to assess whether the trends we observed can be generalized to younger individuals. Second, more than 90% of the PD cases had a Hoehn and Yahr score that was less than 3; PD cases with more advanced disease stages are expected to have more gait and balance difficulty than those enrolled here. However, it is important to note that the assessment of balance for the Hoehn and Yahr score was assigned based on a pull test rather than a more nuanced and detailed assessment of balance. Hence, PD cases with a Hoehn and Yahr score of 1 or 2 in this study reported balance difficulties on more detailed assessments. Third, it is possible that cognitive difficulty in some of the study subjects could have lessened the validity of their responses to questions about falls.

Lower balance confidence, increased falls, and greater need for walking aids are variably features of a range of movement disorder patients compared to age-matched controls. While most marked among PD patients, these issues affected ET patients as well and, to a small degree, some patients with dystonia.

References

1. Singer CJ, Sanchez-Ramos J, Weiner WJ. Gait abnormality in essential tremor. *Mov Disord* 1994;9:193–196, http://dx.doi.org/10.1002/mds.870090212.

2. Arkadir D, Louis ED. The balance and gait disorder of essential tremor: what does this mean for patients? *Ther Adv Neurol Disord* 2013;6:229–236, http://dx.doi.org/10.1177/1756285612471415.

3. Parisi SL, Héroux ME, Culham EG, Norman KE. Functional mobility and postural control in essential tremor. *Arch Phys Med Rehabil* 2006;87:1357–1364, http://dx.doi.org/10.1016/j.apmr.2006.07.255.

4. Kronenbuerger M, Konczak J, Ziegler W, et al. Balance and motor speech impairment in essential tremor. *Cerebellum* 2009;8:389–398, http://dx.doi.org/10.1007/s12311-009-0111-y.

5. Rao AK, Uddin J, Tillman A, Louis ED. Cognitive motor interference during dual-task gait in essential tremor. *Gait Posture* 2013;38:403–409, http://dx.doi.org/10.1016/j.gaitpost.2013.01.006.

6. Louis ED, Galecki M, Rao AK. Four essential tremor cases with moderately impaired gait: how impaired can gait be in this disease? *Tremor Other Hyperkinet Mov (N Y)* 2013 Nov 4;3, http://dx.doi.org/10.7916/D8QV3K7G.

7. Marchetti GF, Whitney SL, Redfern MS, Furman JM. Factors associated with balance confidence in older adults with health conditions affecting the balance and vestibular system. *Arch Phys Med Rehabil* 2011;92:1884–1891, http://dx.doi.org/10.1016/j.apmr.2011.06.015.

8. King LA, Priest KC, Nutt J, et al. Comorbidity and functional mobility in persons with Parkinson disease. *Arch Phys Med Rehabil* 2014;95:2152–2157, http://dx.doi.org/10.1016/j.apmr.2014.07.396.

9. Ebersbach G, Sojer M, Valldeoriola F, et al. Comparative analysis of gait in Parkinson's disease, cerebellar ataxia and subcortical arteriosclerotic encephalopathy. *Brain* 1999;122:1349–1355, http://dx.doi.org/10.1093/brain/122.7.1349.

10. Hiorth YH, Larsen JP, Lode K, Pedersen KF. Natural history of falls in a population-based cohort of patients with Parkinson's disease: an 8-year prospective study. *Parkinsonism Relat Disord* 2014;20:1059–1064, http://dx.doi.org/10.1016/j.parkreldis.2014.06.023.

11. Louis ED, Factor-Litvak P, Michalec M, Jiang W, Zheng W. Blood harmane (1-methyl-9H-pyrido[3,4-b]indole) concentration in dystonia cases vs. controls. *Neurotoxicology* 2014;44:110–113, http://dx.doi.org/10.1016/j.neuro.2014.06.010.

12. Hoehn MM, Yahr MD. Parkinsonism: onset, progression and mortality. *Neurology* 1967;17:427–442, http://dx.doi.org/10.1212/WNL.17.5.427.

13. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975;12:189–198, http://dx.doi.org/10.1016/0022-3956(75)90026-6.

14. Peretz C, Herman T, Hausdorff JM, Giladi N. Assessing fear of falling: can a short version of the Activities-specific Balance Confidence Scale be useful? *Mov Disord* 2006;21:2101–2105, http://dx.doi.org/10.1002/mds.21113.

15. Beauchet O, Annweiler C, Allali G, Berrut G, Herrmann FR, Dubost V. Recurrent falls and dual task-related decrease in walking speed: is there a relationship? *J Am Geriatr Soc* 2008;56:1265–1269, http://dx.doi.org/10.1111/j.1532-5415.2008.01766.x.

16. Louis ED, Pullman SL. Comparison of clinical vs. electrophysiological methods of diagnosing of essential tremor. *Mov Disord* 2001;16:668–673, http://dx.doi.org/10.1002/mds.1144.

17. Louis ED, Frucht SJ, Rios E. Intention tremor in essential tremor: prevalence and association with disease duration. *Mov Disord* 2009;24:626–627, http://dx.doi.org/10.1002/mds.22370.

18. Louis ED, Rios E, Rao AK. Tandem gait performance in essential tremor: clinical correlates and association with midline tremors. *Mov Disord* 2010;25:1633–1638, http://dx.doi.org/10.1002/mds.23144.

19. Dogu O, Sevim S, Camdeviren H, et al. Prevalence of essential tremor: door-to-door neurologic exams in Mersin Province, Turkey. *Neurology* 2003;61:1804–1806, http://dx.doi.org/10.1212/01.WNL.0000099075.19951.8C.

20. Inzelberg R, Mazarib A, Masarwa M, Abuful A, Strugatsky R, Friedland RF. Essential tremor prevalence is low in Arabic villages in Israel: door-to-door neurological examinations. *J Neurol* 2006;253:1557–1560, http://dx.doi.org/10.1007/s00415-006-0253-5.

21. Gasparini M, Bonifati V, Fabrizio E, et al. Frontal lobe dysfunction in essential tremor: a preliminary study. *J Neurol* 2001;248:399–402, http://dx.doi.org/10.1007/s004150170181.

22. Farrer M, Gwinn-Hardy K, Muenter M, et al. A chromosome 4p haplotype segregating with Parkinson's disease and postural tremor. *Hum Mol Genet* 1999;8:81–85, http://dx.doi.org/10.1093/hmg/8.1.81.

23. Fahn S. Concept and classification of dystonia. *Adv Neurol* 1988;50:1–8, http://dx.doi.org/10.1212/WNL.50.5_Suppl_5.S1.

24. Hughes A, Ben-Shlomo Y, Daniel SE, Lees AJ. What features improve the accuracy of clinical diagnosis in Parkinson's disease: a clinicopathologic study. *Neurology* 1992;42:1142–1146, http://dx.doi.org/10.1212/WNL.42.6.1142.

25. Rao AK, Gilman A, Louis ED. Balance confidence and falls in nondemented essential tremor patients: the role of cognition. *Arch Phys Med Rehab* 2014;95:1832–1837, http://dx.doi.org/10.1016/j.apmr.2014.04.001.

26. Louis ED, Rao AK, Gerbin M. Functional correlates of gait and balance difficulty in essential tremor: balance confidence, near misses and falls. *Gait Posture* 2012;35:43–47, http://dx.doi.org/10.1016/j.gaitpost.2011.08.002.

27. Earhart GM, Clark BR, Tabbal SD, Perlmutter JS. Gait and balance in essential tremor: variable effects of bilateral thalamic stimulation. *Mov Disord* 2009;24:386–391, http://dx.doi.org/10.1002/mds.22356.