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Profile of Functional Limitations and Task Performance Among People With Early- and Middle-Stage Parkinson Disease

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Background. Overall functional ability declines over time in people with Parkinson disease (PD). Established benchmarks are needed to allow clinicians and researchers to facilitate meaningful interpretation of data.

Objective. The purposes of this study were: (1) to report typical values for standard measures of functional ability commonly used in intervention studies and clinical practice with individuals in the early and middle stages of PD and (2) to describe the profile of functional limitations using the Hoehn and Yahr (H&Y) stages of disease and Unified Parkinson's Disease Rating Scale (UPDRS) motor scores.

Design. Cross-sectional data were obtained from 5 different studies.

Methods. Three hundred thirty-nine patients were evaluated for disease severity (UPDRS motor score); functional capacity (Continuous Scale Physical Functional Performance Test [CS-PFP]); balance and gait (Functional Reach Test [FRT], Timed "Up & Go" Test [TUG], 360-degree turn, Six-Minute Walk Test [6MWT], and Two-Minute Walk Test); and basic functional activities (supine-to-stand task, stand-to-supine task, and functional axial rotation [FAR]).

Results. The mean UPDRS motor score for the sample was 39.2 (SD=12.93). At each stage of PD (from least to most involved), scores on functional measures indicated a significant and progressively reduced functional status. Limitations began early in the disease for the CS-PFP and FAR. Losses in performance were consistent across all stages of disease for the CS-PFP, FRT, 6MWT, and FAR. Several measures demonstrated meaningful losses of function only in later stages of disease. Findings extend current appreciation of functional limitations that begin early in PD and can guide the choice of functional outcome measures at different stages of disease severity.

Limitations. Data were obtained only from participants in H&Y stages 1 through 3 and only for some of the performance measures typically used.

Conclusions. The findings demonstrate that functional loss occurs at different points in the disease process, depending on the task under consideration. The resulting profile of functional limitations provides benchmarks that clinicians and researchers can use to interpret and monitor status of patients.

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Overall ability to function declines over time in people with Parkinson disease (PD). Shulman and colleagues,[1] using the Unified Parkinson's Disease Rating Scale (UPDRS), were the first to examine functional differences by stage of PD. Because performance of basic functional activities is critical to maintaining independence and staving off disability, considerable effort has been directed toward investigating the effectiveness of physical intervention strategies for maintaining functional ability, despite the progressive nature of the disease. Based on the accumulated evidence, it is clear that early physical intervention can have positive benefits for these individuals.[2-5] Although the UPDRS is the gold standard for quantifying response to interventions,[6,7] this scale does not adequately describe the patient's difficulties with physical function and participation and may be less responsive to rehabilitation interventions than to more specific measures of function. For this reason, a variety of performance measures have been used with people who have PD to examine response to exercise. Often

included are measures of gross physical mobility[8] (eg, supine-to-stand maneuver), balance[9] (eg, Functional Reach Test [FRT],[10] Timed "Up & Go" Test [TUG][11]), and walking[12] (eg, Six-Minute Walk Test [6MWT][13]). However, ranges of typical values for these measures in patients with PD are lacking in the literature. There is a need for established benchmarks to allow clinicians and researchers to compare their data with points of reference, thus facilitating more meaningful interpretation.

This article reports typical values, by disease severity, for a variety of standard measures of function commonly used in exercise intervention studies and clinical practice. The profile of functional limitations at particular stages of disease severity is described based on both Hoehn and Yahr (H&Y) stages of disease, which is particularly useful for physical

therapist clinicians, and UPDRS scores, the gold standard for researchers and neurologists. A greater appreciation of functional limitations associated with different stages of disease progression may guide timely initiation of rehabilitation interventions, with the goal of delaying functional decline. Established benchmarks can inform selection of measures for longitudinal tracking of function for people with PD.

Method
Samples
The data in this report are from 3 studies conducted by Schenkman and colleagues at Duke University[8,14] and the University of Colorado (unpublished) and from 2 studies conducted at Boston University by Ellis and colleagues[15] and Tickle-Degnen and colleagues.[16] Many of the measurements obtained in the 5

The Bottom Line

What do we already know about this topic?

Several measures of physical function are available to clinicians and researchers to assess walking, balance, and general mobility in people with Parkinson disease. Despite the wide use of these measures, there is little information to guide the interpretation of the findings.

What new information does this study offer?

This study provides typical values for standard measures of walking, balance, and general mobility in people with Parkinson disease and describes the profile of functional limitations in relation to disease severity. This information provides established benchmarks to help clinicians and researchers interpret their findings when administering these measures.

If you're a patient, what might these findings mean for you?

Your physical therapist may administer physical performance tests to measure your walking ability, balance, and general mobility. The information presented in this article will help your physical therapist choose appropriate measures and compare your performance to the performance of other people with Parkinson disease.

Table 1.
Characteristics of the Sample and Comparison Across Sites[a]

Variable	Total Sample	Ellis et al[15] and Tickle-Degnen et al[16]	Schenkman and Colleagues[8,14,unpublished data]	P
Sample size, n	339	183 (54.0%)	156 (46.0%)	
Age (y)				
Mean (SD)	66.1 (9.34)	65.3 (8.91)	67.0 (9.77)	.102
Range	37–92	37–83	46–92	
Sex (male), n (%)	238 (70.2%)	131 (71.6%)	107 (68.6%)	.609
Education (highest degree), n (%)				
< High school	5 (2.0%)	0 (0.0%)	5 (3.6%)	
High school	53 (20.7%)	24 (20.7%)	29 (20.7%)	
Professional certificate	11 (4.3%)	5 (4.3%)	6 (4.3%)	<.001
Associate's degree	20 (7.8%)	2 (1.7%)	18 (12.9%)	
Bachelor's degree	71 (27.7%)	22 (19.0%)	49 (35.0%)	
Graduate degree	96 (37.5%)	63 (54.3%)	33 (23.6%)	
Race, n (%)				
Asian or Pacific Islander	4 (1.6%)	2 (1.7%)	2 (1.4%)	
Black (not of Hispanic origin)	4 (1.6%)	2 (1.7%)	2 (1.4%)	1.000
White (not of Hispanic origin)	248 (96.8%)	112 (96.6%)	136 (97.2%)	
UPDRS total				
Mean (SD)	39.2 (12.93)	40.9 (12.18)	36.2 (13.71)	.006
Range	6.0–86.5	6.0–74.0	8.5–86.5	
UPDRS motor				
Mean (SD)	25.2 (9.56)	25.3 (9.28)	25.0 (10.08)	.804
Range	2.0–59.5	2.0–50.0	5.5–59.5	
UPDRS ADL				
Mean (SD)	11.8 (5.23)	13.2 (4.88)	9.3 (4.88)	<.001
Range	1.0–27.0	2.0–27.0	1.0–25.0	
Hoehn and Yahr scale, n (%)				
Stages 1–1.5	10 (2.9%)	4 (2.2%)	6 (3.9%)	
Stage 2	138 (41.2%)	80 (43.7%)	58 (38.2%)	.558
Stage 2.5	104 (31.1%)	53 (29.0%)	51 (33.6%)	
Stage 3	83 (24.8%)	46 (25.1%)	37 (24.3%)	
Time since diagnosis (y)				
Mean (SD)	6.0 (5.12)	7.1 (5.67)	4.7 (3.99)	<.001
Range	0–32	0–32	0–23	
MMSE				
Mean (SD)	29.1 (1.03)	29.3 (0.96)	29.0 (1.09)	.069
Range	25–30	27–30	25–30	
PDQ-39				
Mean (SD)	27.2 (12.71)	31.5 (11.07)	21.0 (12.46)	<.001
Range	1.0–61.4	4.8–61.4	1.0–55.6	
SF-36 physical function				
Mean (SD)	68.9 (22.4)	N/A	68.9 (22.4)	N/A
Range	5–100	N/A	5–100	

[a] UPDRS=Unified Parkinson's Disease Rating Scale, MMSE=Mini-Mental State Examination, PDQ-39=39-item Parkinson's Disease Questionnaire, SF-36=36-Item Short-Form Health Survey questionnaire, N/A=not applicable.

Functional Limitations and Task Performance in Early- and Middle-Stage Parkinson Disease

Table 2.
Functional Measure Characteristics[a]

Measure	Description of Items	Estimated Time to Administer (Preparation Time), Mean (SD)	Selected Examples of Published Scores for Adults Who Were Healthy	Clinically Important Score Indicators
Overall functional capacity				
CS-PFP[20]	15-item functional test battery that quantifies performance of actual tasks important for living independently. Items span low effort (eg, donning and removing a jacket, pouring jug of water into a cup), medium effort (eg, sweeping floor of set amount of cat litter, transferring laundry from washer to dryer), and high effort (eg, carrying groceries for 70 m, walking up and down bus platform carrying weighted luggage). Total score ranges from 0 to 100. See referenced article for details.	60 (15) min	Mean (SD)[21]: 70.9 (11.4); 45–54 y (n=23) 63.2 (10.4); 55–64 y (n=21) 58.7 (12.5); 65–74 y (n=33)	57; cutoff indicator between functional independence and dependence[22]
Balance and gait activities				
FRT[10]	Distance an individual is willing to reach forward with unilateral upper extremity extended (without stepping forward)	10 (<5) min	Mean (SD)[48]: 15.9 (0.2) in; 40–49 y, women (n=95) 15.0 (0.2) in; 50–59 y, women (n=93) 14.5 (0.2) in; 60–69 y, women (n=90) Mean (SD)[10]: 15.0 (2.2) in; 41–69 y, men (n=22) 13.8 (2.2) in; 41–69 y, women (n=28) 13.2 (1.6) in; 70–87 y, men (n=20) 10.5 (3.5) in; 70–87 y, women (n=14)	10 in; cutoff for indicator of increased fall risk in older adults[39] 12.5 in; cut-off for indicator of increased fall risk for people with PD (H&Y scores: 1–4)[48]
TUG[11]	Time required to rise from a chair, walk 3 m (10 ft), turn, walk back to the chair, and sit down	5 (<5) min	Mean (SD)[25] (self-selected pace): 10.09 (2.60) s; 65–69 y (n=66) 10.40 (2.11) s; 70–74 y (n=59) 10.61 (2.30) s; 75–79 y (n=50) Mean (SD)[48] (quickly and safely as possible): 6.24 (0.67) s; 40–49 y, women (n=95) 6.44 (0.17) s; 50–59 y, women (n=93) 7.24 (0.17) s; 60–69 y, women (n=90)	13.5 s; cutoff for indicator of increased fall risk in older adults[27] 7.95 s; cutoff for indicator of increased fall risk in people with PD (H&Y scores: 1–4)[39]
360° turn, standing[29]	Time and number of steps required for a person to make a 360° turn (right and left directions tested)	5 (<5) min	No data available	No data available
2MWT[30]	Distance a person can walk in 2 minutes at fastest comfortable pace	2 (<5) min	Mean (SD)[30]: 185.3 (25.8) m; 51–76 y (n=12)	No data available
6MWT[13]	Distance a person can walk in 6 minutes at fastest comfortable pace	6 (<5) min	Mean (range)[33]: 560 (511–609) m; 60–69 y, men (n=582) 505 (460–549) m; 60–69 y, women (n=1,176) 530 (482–578) m; 70–79 y, men (n=661) 490 (442–538) m; 70–79 y, women (n=1,426)	350 m; cutoff associated with increased mortality and 50 m; minimal clinically important change for a variety of cardiopulmonary diagnoses[32]
Basic functional activities				
Supine-to-stand and stand-to-supine tasks[8]	Time required to transition from supine to standing and standing to supine on a bed	5 (<5) min	No data available	No data available
FAR[35]	Degree of rotation a participant is able to achieve with trunk, measured in a sitting position with hips stabilized	10 (5) min	Mean (SD)[b]: 117.0 (14.2)°; 40–59 y, men (n=22) 127.8 (10.4)°; 40–59 y, women (n=18)	No data available

a CS-PFP=Continuous Scale Physical Functional Performance Test, FRT=Functional Reach Test, PD=Parkinson disease, H&Y=Hoehn and Yahr scale, TUG=Timed "Up & Go" Test, 2MWT=Two-Minute Walk Test, 6MWT=Six-Minute Walk Test, FAR=functional axial rotation.
b Unpublished data.

studies overlapped; however, not all measurements were collected in all studies, and thus the sample size for each variable differs. The order and length of testing varied among studies; however, sessions typically were between 2 and 2.5 hours long, and all measures were administered on the same day. Specific details are provided in the primary articles.[8,14-16] All data were collected in the *medication "on" state*, which was defined as the time when the patient reported optimal effect of his or her PD medications (typically within an hour of medication intake). For those patients who participated in randomized, controlled exercise intervention studies,[8,15,16] only baseline data were used.

Participants were in H&Y stages 1 through 3,[17] lived in the community, and ambulated independently, representing a relatively wide range of individuals in the early and middle stages of PD. Participants were excluded if they had musculoskeletal, neuromuscular (other than PD), or cardiovascular disorders that would interfere with ability to exercise. Participants also were excluded if they had a Mini-Mental State Examination score of less than 24. Characteristics of the sample are shown in Table 1. The study cohorts of Schenkman et al[8] were similar with respect to age, race, and sex distributions to those of Ellis et al,[15] except that the latter sample included a significantly higher proportion of patients with a graduate-level education. Clinically, the cohorts were similar with regard to H&Y stage and UPDRS motor scores. The study by Ellis et al,[15] however, included patients with significantly longer disease duration and higher UPDRS total, UPDRS ADL, and 39-item Parkinson's Disease Questionnaire (PDQ-39) scores.[18] Quality-of-life scores, characterized with the 36-Item Short-Form Health Survey questionnaire (SF-36)[19] and PDQ-39, were consistent with mild to moderate disease severity.

Functional Measures

Measures of function were grouped into 3 categories: (1) overall functional capacity, (2) balance and gait, and (3) basic functional activities. Table 2 summarizes information related to administration and interpretation of these functional tests. Where available, data are provided from older adults who were healthy for comparison.

Overall functional capacity was measured using the Continuous Scale Physical Functional Performance Test (CS-PFP).[20-22] This standardized test of physical function was developed and validated on a large sample of older adults ranging from those living in assisted living environments to elite athletes.[20] Fifteen tasks are performed serially, providing a more realistic measure of overall capacity to carry out functional activities in the home setting than typically used single-task measures (eg, balance and gait measures). Performance would be expected to be better if a task is measured in isolation than if the task is measured in combination with 14 other tasks because of the physiological demands of continuous function. A higher score indicates greater functional capacity. On completion of the test, participants rated their perceived exertion[23] for the entire test.

Balance was measured using a variety of tests with established validity and reliability. For the FRT,[10,24] participants performed 2 practice trials followed by 3 test trials, which were averaged. For the TUG,[11,25-27] participants completed 1 practice trial followed by 2 test trials, which were averaged.[28] For the 360-degree turn in standing, participants performed one practice trial followed by 2 test trials, which were averaged.[8,29]

Gait function was assessed by means of the Two-Minute Walk Test (2MWT) and the 6MWT. The 2MWT required 2 practice walks due to an initial training effect.[30] Data from the third trial were analyzed. The 6MWT, originally developed as a measure of cardiovascular endurance,[31] has been applied to adults who were healthy and individuals with a variety of disorders, including PD.[31-34] Data were obtained from a single trial.

Basic functional activities included measures of supine-to-stand time, stand-to-supine time, and functional axial rotation (FAR). Time required to lie supine on a bed from a standing position and to return to standing from the supine position was recorded following a single test.[8] For the FAR measure,[35] data were averaged from 2 trials to each side (left and right). No significant difference was detected between FAR to the right and the left ($P=.49$); only data for FAR to the more limited side (worse measure) are reported.

PD Symptoms and Severity

Parkinson disease was diagnosed in each patient by a neurologist with fellowship training in movement disorders, with the exception of the small sample from Duke University, in which a general neurologist made the diagnosis. Severity of PD was measured using the UPDRS motor and total scores and the modified H&Y scale.[6] The on-state UPDRS and modified H&Y scores (scores when medications were most effective) were determined by a movement disorder specialist or by another professional trained by the study's movement disorder specialist. The UPDRS motor score provides a measure of severity of signs and symptoms (eg, bradykinesia, rigidity, tremor) of PD. The modified H&Y scale describes disease severity more broadly, with stages 1 to 2 indicating mild disease, stages 2.5 to 3 indicating moderate

disease, and stages 4 to 5 indicating severe disease.[36]

Data Analysis

Means, quartiles, standard deviations, and ranges of physical function and quality-of-life measures were calculated. Demographic and disease stage data were tabulated using 2-way contingency tables with counts and relative frequencies. Comparisons among groups (ie, H&Y stage or UPDRS scores) were made using Wilcoxon rank sum tests for quantitative measures and chi-square and Fisher exact tests for count data. Data then were displayed graphically, categorized in 2 ways. Modified H&Y stage of disease was grouped into stages 1 to 1.5, 2, 2.5, and 3. The UPDRS motor scores were grouped as follows: 1 to 15, 15.5 to 30, 30.5 to 45, and 45.5 to 60. Linear trends in performance measures were evaluated using linear regression. In order to test for a linear trend, new variables were created that were equal to the numerical categories of either UPDRS motor or H&Y scores (eg, 1, 2, 3, 4). These variables were included in the regression models, and the coefficients were interpreted as continuous covariates would be interpreted (eg, as a change in the outcome for a one-unit change in the category of UPDRS). The Cohen f statistic was used to report effect sizes of the estimated linear trends. An effect size of 0.15 is generally considered small, 0.4 medium, and 0.6 large.[37] All data analyses was performed using SAS/BASE and SAS/STAT software, version 9.2 of the SAS System for Windows.*

Results

Characteristics of the Sample

The full database comprised 339 participants (Tab. 1). Of these, 156 were from the studies by Schenkman and

colleagues[8,14,unpublished data] and 183 were from studies by Ellis et al[15] and Tickle-Degnen et al.[16] Age was normally distributed (mean=66.1 years, SD=9.3, range=37–92). The sample was 70.6% male and 96.9% white, 98.0% had graduated from high school, and 73.0% had earned a higher degree. Mean years since diagnosis of PD was 6.0 (SD=5.12), with 78.5% of the participants diagnosed within the previous 10 years; a few of the participants (2.9%) had the disease for more than 20 years.

Using the modified H&Y scale, half of the sample (56%) had moderate disease (H&Y stages 2.5 or 3) (Tab. 1). The mean UPDRS total score was 39.2 (SD=12.93, range= 6–86.5). The mean UPDRS motor score was 25.2 (SD=9.56, range= 2–59.5). In contrast to the H&Y scores, UPDRS motor scores were nearly normally distributed.

Physical Functional Ability

Overall functional capacity. We examined overall functional capacity, as measured by the CS-PFP, in relation to both UPDRS motor score and H&Y stage (Tab. 3; Fig. 1; eFig. 1, available at ptjournal.apta.org). The mean scores dropped by approximately 10 points between categories of UPDRS motor score, with the exception of the last stage, in which they dropped by 20 points. A similar pattern was seen for the H&Y stages. Despite the consistently lower CS-PFP scores, the RPE remained relatively constant (between 11 and 12) until a UPDRS motor score of 45 had been reached, after which it rose sharply to a median of 14 for participants with UPDRS motor scores of 45.5 to 60.

Balance and gait. For the FRT (Tab. 3; Fig. 2; eFig. 2, available at ptjournal.apta.org), whether examining the mean or median score,

there was an approximately 6-in[†] drop in reach across levels of disease severity. For the TUG, whether examining the mean or median score, values at all stages of severity (H&Y or UPDRS motor) were greater than 8 seconds. The TUG times (mean and median) were at least 2.5 seconds longer at the highest level of disease severity (H&Y stage 3, UPSRS motor score=45.5–60) compared with the lowest levels of disease severity (H&Y stage 1–1.5, UPDRS motor score=0–15).

For the 360-degree turn (Fig. 2, eFig. 2), whether using the median or mean time, participants who were most involved (H&Y stage 3) took approximately twice as long to complete the task as those who were least involved (H&Y stages 1, 1.5, and 2), with mean time ranging from 3.32 to 7.34 seconds. Only about 2 seconds discriminated between participants who were least and most involved when measured with the UPDRS motor scores. In terms of number of steps, there was a difference of approximately 4 steps between participants who were least and most involved using either the H&Y stages or UPDRS motor scores.

Data from the 6MWT and 2MWT are shown in Table 3, Figure 2, and eFigure 2. Examining changes in 6MWT scores by H&Y stages, the median walk distance was 562 m for participants who were least involved and 389 m for those who were most involved, a difference of 173 m. The majority of this difference occurred between H&Y stages 2 and 2.5, with a difference of 100 m observed between median values. Mean scores showed a similar pattern. Examining 6MWT distance by UPDRS motor scores, the median score was approximately 200 m less for participants who were most involved compared with those who were least

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† 1 in=2.54 cm.

Table 3.
Overall Functional Capacity (Continuous Scale Physical Functional Performance Test [CS-PFP]), Basic Functional Activity, Balance, and Gait Measures Presented by Hoehn and Yahr Stage and Unified Parkinson's Disease Rating Scale (UPDRS) Motor Score

Measure		Hoehn and Yahr Stage						UPDRS Motor Score					
		1–1.5	2	2.5	3	Linear Trend	Cohen f	0–15	15.5–30	30.5–45	45.5–60	Linear Trend	Cohen f
CS-PFP total		n=100						n=97					
	Mean	62.90	54.74	42.44	28.67	F value: 33.78	0.33	59.88	48.23	42.61	20.93	F value: 23.86	0.24
	SD	13.40	12.76	16.04	14.58	P<.0001		11.50	15.09	15.45	10.21	P<.0001	
	Min	50.20	29.80	7.30	9.20			42.30	17.20	11.20	9.20		
	Q1	52.30	47.10	34.30	21.90			49.80	37.20	31.90	9.20		
	Median	58.27	56.22	41.73	27.13			56.29	48.25	42.07	26.55		
	Q3	72.90	61.60	51.10	35.60			71.40	59.25	57.50	27.10		
	Max	80.80	78.20	73.70	57.50			80.80	78.20	68.60	27.10		
CS-PFP RPE		n=100						n=97					
	Mean	11.8	11.0	11.6	12.7	F value: 3.32	0.02	11.0	11.1	12.0	13.7	F value: 5.94	0.05
	SD	1.0	1.9	1.7	1.5	P=.0715		1.7	2.0	1.3	0.6	P=.0168	
	Min	11.0	6.0	8.0	9.0			8.0	6.0	9.0	13.0		
	Q1	11.0	10.0	11.0	13.0			10.0	10.0	11.0	13.0		
	Median	11.5	11.0	12.0	13.0			11.0	11.5	12.0	14.0		
	Q3	12.5	12.0	13.0	13.0			13.0	13.0	13.0	14.0		
	Max	13.0	15.0	15.0	14.0			14.0	15.0	15.0	14.0		
FRT (in)		n=152						n=97					
	Mean	16.07	14.28	12.13	10.79	F value: 46.00	0.30	14.96	13.15	11.85	8.73	F value: 17.58	0.17
	SD	1.60	2.58	2.88	2.95	P<.0001		2.20	2.93	3.35	4.53	P<.0001	
	Min	13.33	6.70	6.00	3.50			10.80	6.50	3.80	3.50		
	Q1	15.50	12.70	10.30	9.20			12.70	11.25	10.20	3.50		
	Median	16.33	14.40	12.20	11.00			15.00	13.50	11.30	11.00		
	Q3	16.80	15.80	14.00	12.50			16.80	15.70	14.20	11.70		
	Max	18.20	19.20	17.30	16.70			19.20	18.20	18.50	11.70		
TUG (s)		n=136						n=133					
	Mean	8.40	9.21	11.18	10.89	F value: 10.56	0.07	8.78	9.85	10.34	11.78	F value: 7.77	0.05
	SD	1.15	2.06	3.78	3.59	P=.0015		1.05	2.27	2.95	3.52	P=.0061	
	Min	6.61	5.54	7.48	6.21			6.61	6.38	5.54	8.48		
	Q1	8.21	7.86	9.30	8.48			8.21	8.32	9.02	9.22		
	Median	8.64	9.25	10.31	11.13			8.80	9.48	9.83	11.66		
	Q3	8.82	9.97	11.67	12.08			9.66	10.72	11.41	12.08		
	Max	9.73	18.14	31.57	20.92			10.61	17.72	20.92	17.44		

(Continued)

Table 3.
Continued

Measure		Hoehn and Yahr Stage						UPDRS Motor Score					
		1–1.5	2	2.5	3	Linear Trend	Cohen f	0–15	15.5–30	30.5–45	45.5–60	Linear Trend	Cohen f
360° turn time, worst (s)		n=150						n=95					
	Mean	3.33	3.91	4.81	7.34	F value: 45.98	0.30	3.05	4.00	4.24	5.18	F value: 13.93	0.14
	SD	0.98	1.37	1.58	3.60	P<.0001		0.58	1.06	1.41	0.32	P=.0003	
	Min	2.22	2.43	2.53	2.94			2.22	2.45	2.59	4.95		
	Q1	2.90	3.03	3.74	5.26			2.55	3.32	3.07	4.95		
	Median	3.11	3.62	4.68	6.87			2.90	3.82	3.86	5.18		
	Q3	3.51	4.18	5.67	8.42			3.61	4.44	4.93	5.40		
	Max	5.11	10.82	9.53	19.82			4.27	7.68	7.78	5.40		
360° turn steps, worst		n=150						n=95					
	Mean	6.33	7.55	8.66	11.04	F value: 38.42	0.25	6.26	7.88	8.89	10.25	F value: 15.53	0.15
	SD	0.93	1.96	2.66	3.61	P<.0001		0.90	2.30	2.46	0.35	P=.0002	
	Min	5.00	5.00	5.00	5.50			5.00	5.50	5.50	10.00		
	Q1	5.50	6.00	7.00	8.50			5.50	6.50	7.50	10.13		
	Median	6.50	7.00	8.00	10.75			6.00	7.00	8.00	10.25		
	Q3	6.88	8.00	9.50	12.00			7.00	8.63	10.50	10.50		
	Max	7.50	14.00	16.50	24.50			8.00	16.50	13.50	10.50		
6MWT distance (m)		n=150						n=97					
	Mean	579.02	545.60	460.24	397.81	F value: 50.40	0.33	573.91	515.55	501.54	392.33	F value: 9.29	0.09
	SD	70.40	93.62	107.09	104.02	P<.0001		53.90	104.07	120.10	42.76	P=.0030	
	Min	511.90	307.24	175.00	209.70			505.40	302.80	214.60	367.00		
	Q1	522.60	503.90	373.10	323.10			536.20	439.65	432.20	367.00		
	Median	561.90	562.10	464.20	388.90			567.60	516.30	527.40	368.30		
	Q3	629.60	605.60	534.10	471.15			598.10	599.45	605.60	441.70		
	Max	686.20	762.20	634.10	635.00			686.20	762.20	651.10	441.70		
6MWT gait speed (m/s)		n=150						n=97					
	Mean	1.61	1.52	1.28	1.10	F value: 50.49	0.33	1.59	1.43	1.39	1.09	F value: 9.29	0.09
	SD	0.20	0.26	0.30	0.29	P<.0001		0.15	0.29	0.33	0.12	P=.0030	
	Min	1.42	0.85	0.49	0.58			1.40	0.84	0.60	1.02		
	Q1	1.45	1.40	1.04	0.90			1.49	1.23	1.20	1.02		
	Median	1.56	1.56	1.29	1.08			1.58	1.44	1.47	1.02		
	Q3	1.75	1.68	1.48	1.31			1.66	1.67	1.68	1.23		
	Max	1.91	2.12	1.76	1.76			1.91	2.12	1.81	1.23		

(Continued)

Table 3.
Continued

Hoehn and Yahr Stage

Measure		1–1.5	2	2.5	3	Linear Trend	Cohen f
2MWT distance (m)	n=116						
	Mean		167.65	160.11	118.10	F value: 24.79	0.21
	SD		30.24	32.33	41.10	P<.0001	
	Min		100.40	111.30	51.80		
	Q1		148.00	141.30	88.10		
	Median		167.00	153.85	118.30		
	Q3		185.90	177.90	156.10		
	Max		229.40	287.30	196.00		
2MWT gait speed (m/s)	n=116						
	Mean		1.40	1.33	0.98	F value: 24.49	0.21
	SD		0.25	0.27	0.34	P<.0001	
	Min		0.84	0.93	0.43		
	Q1		1.23	1.18	0.73		
	Median		1.39	1.29	0.99		
	Q3		1.55	1.48	1.30		
	Max		1.91	2.39	1.63		
Supine-to-stand time (s)	n=186						
	Mean	3.35	3.36	4.68	6.42	F value: 31.95	0.17
	SD	0.92	2.02	2.01	4.16	P<.0001	
	Min	2.44	1.85	1.81	1.75		
	Q1	2.73	2.41	3.31	3.47		
	Median	2.96	2.81	4.52	4.80		
	Q3	4.47	3.81	5.41	8.39		
	Max	4.53	17.62	11.53	19.71		

UPDRS Motor Score

Measure		0–15	15.5–30	30.5–45	45.5–60	Linear Trend	Cohen f
2MWT distance (m)	n=116						
	Mean	168.86	155.86	148.22	128.40	F value: 4.94	0.03
	SD	31.70	38.67	36.27	24.46	P=.0282	
	Min	113.50	60.80	51.80	111.10		
	Q1	147.50	137.30	125.40	111.10		
	Median	162.60	150.80	154.70	128.40		
	Q3	185.30	182.45	169.50	145.70		
	Max	229.40	287.30	208.90	145.70		
2MWT gait speed (m/s)	n=116						
	Mean	1.41	1.30	1.24	1.07	F value: 4.96	0.03
	SD	0.30	0.32	0.30	0.20	P=.0279	
	Min	0.95	0.51	0.43	0.93		
	Q1	1.23	1.15	1.05	0.93		
	Median	1.36	1.26	1.29	1.07		
	Q3	1.54	1.52	1.41	1.12		
	Max	1.91	2.39	1.74	1.12		
Supine-to-stand time (s)	n=133						
	Mean	2.79	3.50	3.60	6.55	F value: 10.79	0.07
	SD	0.67	1.38	1.53	5.22	P=.0013	
	Min	1.85	1.75	1.81	2.68		
	Q1	2.41	2.59	2.37	4.22		
	Median	2.72	3.16	3.20	4.50		
	Q3	2.97	3.84	4.67	5.65		
	Max	4.53	9.78	8.66	15.69		

(Continued)

Table 3.
Continued[a]

Measure	Hoehn and Yahr Stage						UPDRS Motor Score					
	1–1.5	2	2.5	3	Linear Trend	Cohen f	0–15	15.5–30	30.5–45	45.5–60	Linear Trend	Cohen f
Stand-to-supine time (s)	n=186						n=133					
Mean	4.10	3.99	5.13	6.62	F value: 31.41	0.17	3.58	4.12	4.41	7.04	F value: 12.89	0.09
SD	0.94	1.82	1.76	3.47	P<.0001		0.75	1.27	1.89	3.00	P=.0005	
Min	2.60	1.96	2.66	2.04			2.34	1.96	2.03	2.91		
Q1	3.60	3.04	3.87	4.46			3.11	3.15	3.00	5.84		
Median	4.31	3.54	4.77	5.20			3.47	3.94	4.35	6.72		
Q3	4.80	4.58	5.98	8.44			3.91	4.69	5.15	9.00		
Max	5.03	15.93	10.00	18.34			5.25	7.82	10.00	10.72		
FAR, worst (°)	n=252						n=249					
Mean	103.50	100.56	91.34	86.50	F value: 23.43	0.09	107.61	94.69	90.24	75.00	F value: 32.62	0.13
SD	5.48	16.82	18.36	19.80	P<.0001		13.03	17.52	20.13	13.54	P<.0001	
Min	95.00	57.50	50.00	52.50			75.00	52.50	50.00	60.00		
Q1	102.50	90.00	80.00	73.75			102.50	85.00	72.50	60.00		
Median	105.00	100.00	92.50	82.50			107.50	95.00	91.25	80.00		
Q3	105.00	112.50	107.50	97.50			117.50	107.50	107.50	85.00		
Max	110.00	140.00	132.50	132.50			140.00	140.00	130.00	95.00		

[a] RPE=rate of perceived exertion, FRT=Functional Reach Test, TUG=Timed "Up & Go" Test, 6MWT=Six-Minute Walk Test, 2MWT=Two-Minute Walk Test, FAR=functional axial rotation, Min=minimum, Q1=first quartile, Q3=third quartile, Max=maximum.

involved, with the biggest difference (more than 100 m) occurring between score categories of 30 to 45 and 45 to 60. A similar pattern was seen for the mean scores.

Data for the 2MWT (Tab. 3, Fig. 2, eFig. 2) were available only from samples collected at Boston University and only for those in H&Y stages 2, 2.5, and 3. The biggest drop in distance was seen between H&Y stages 2.5 and 3, with a mean difference of about 49 m between participants who were least and most involved. Findings were similar with respect to the UPDRS motor scores.

Basic Functional Activities

For the supine-to-stand task, the mean time to complete the task was not substantially different until H&Y stage 2.5 or UPDRS motor score 45.5 to 60 (Tab. 3; Fig. 3; eFig. 3, available at ptjournal.apta.org). When examining the supine-to-stand task by H&Y stage, the mean time to complete the task appears to discriminate supine-to-stand times better than median times. The mean and median times for the supine-to-stand task were similar for the UPDRS motor scores. The pattern for stand to supine was similar to supine to stand, although the trend was for the mean time to be consistently slightly higher.

With respect to FAR, the mean and median values changed by approximately 20 degrees between H&Y stages 1 and 3 (Tab. 3, Fig. 3, eFig. 3). The drop in mean FAR across UPDRS motor scores was 36 degrees from lowest to highest, with a similar pattern for median values.

Discussion

These data provide expected ranges of physical function by disease severity for measures commonly used with individuals in early and middle stages of PD. We chose these measures because they capture many of the daily tasks that people with PD

commonly bring to the attention of their health care providers, such as getting in and out of bed, rising from a chair, walking, maintaining balance, and turning to look behind while driving.

The data provide clinicians and researchers with a context for interpreting functional limitations of people with PD. Clinicians also can use the data to identify individuals who perform outside of anticipated mean and median scores for specific tasks. Furthermore, these data can inform decisions regarding appropriate measures for future studies of physical intervention.

We described the data in relation to 2 different measures typically used to characterize PD severity: the UPDRS motor score and the modified H&Y scale.[6] The UPDRS is the gold standard for experimental studies and medical management; however, extensive training is required to use this measure appropriately, it is time intensive, and the scope of information gathered is beyond that required for decisions related to physical intervention. In contrast, the H&Y score provides only a coarse estimate of disease progression but is more accessible to physical therapists. For these reasons, we chose to examine physical activities in relation to both measures.

Several insights related to the level of disease severity at which functional decline begins to emerge, choice of measures at different points in the disease course, and interpretation of measures emerged from this work. The first insight is that activity limitations occur very early in PD, as indicated by the CS-PFP, becoming progressively worse as the disease advances. This finding is of importance because most measures used with people who have PD are not as clearly responsive to early limitations in activities as is the CS-PFP.
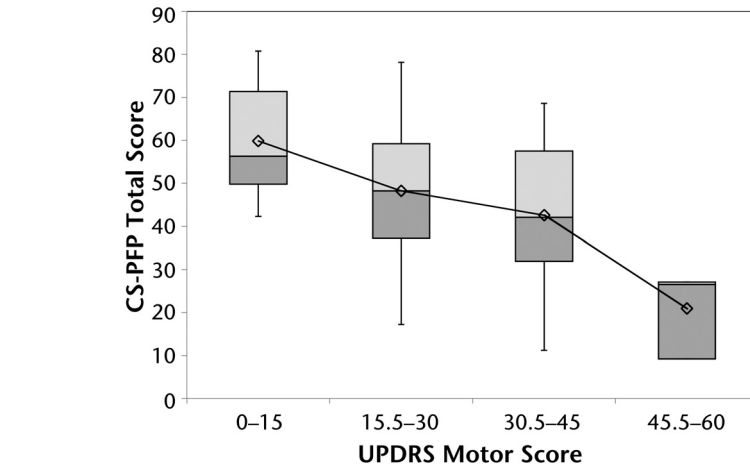
Figure 1.
Continuous Scale Physical Functional Performance Test (CS-PFP) score distribution by Unified Parkinson's Disease Rating Scale (UPDRS) motor scores. Box plot symbols: asterisk indicates outliers beyond 3 standard deviations from the mean score; diamond represents mean score; dark gray box represents distance between first quartile and median; and light gray box represents distance between median and third quartile.

Individuals with PD had lower CS-PFP scores compared with individuals who were healthy in the study by Cress and Meyer.[22] These scores represent a substantial loss of functional capacity. Those individuals with H&Y stage 3 scores (mean age=69 years) had CS-PFP scores below 30, more than 25 points lower than scores of individuals who were healthy, indicating even greater loss of capacity.

The CS-PFP is a unique measure because it quantifies capacity for performance of daily functional activities.[22] As such, this test is more likely to identify limitations that would be missed in performance of a few single tasks such as those typically used to quantify function (eg, FRT, TUG). Furthermore, the tasks included in the CS-PFP encompass a broad range of activities required for daily function.

Data from a variety of studies suggest that transition from independence to dependence occurs around a CS-PFP score of 57.[22] As evidenced by median scores, a substantial number

of participants in our data set had reached or exceeded this threshold by H&Y stage 2.5 and UPDRS motor score of 30.5 to 45. These findings are consistent with data of Shulman and colleagues[1] indicating a transition from preclinical disability and disability occurs for people with UPDRS total scores above 50.

It should be noted that the transition to disability specific to people with PD has not yet been established. Because time to complete tasks is important in scoring the CS-PFP, bradykinesia probably affects the overall scores substantially, bringing individuals to the transition point (score of 57) established for older adults, even though they may not be approaching disability. Nevertheless, these data underscore the degree to which PD affects overall physical capacity even very early in the disorder.

Of interest, most of these individuals continue to perform within a relatively constant rate of perceived exertion as evidenced by their RPE of ≤12, consistent with the range observed in older adults who are
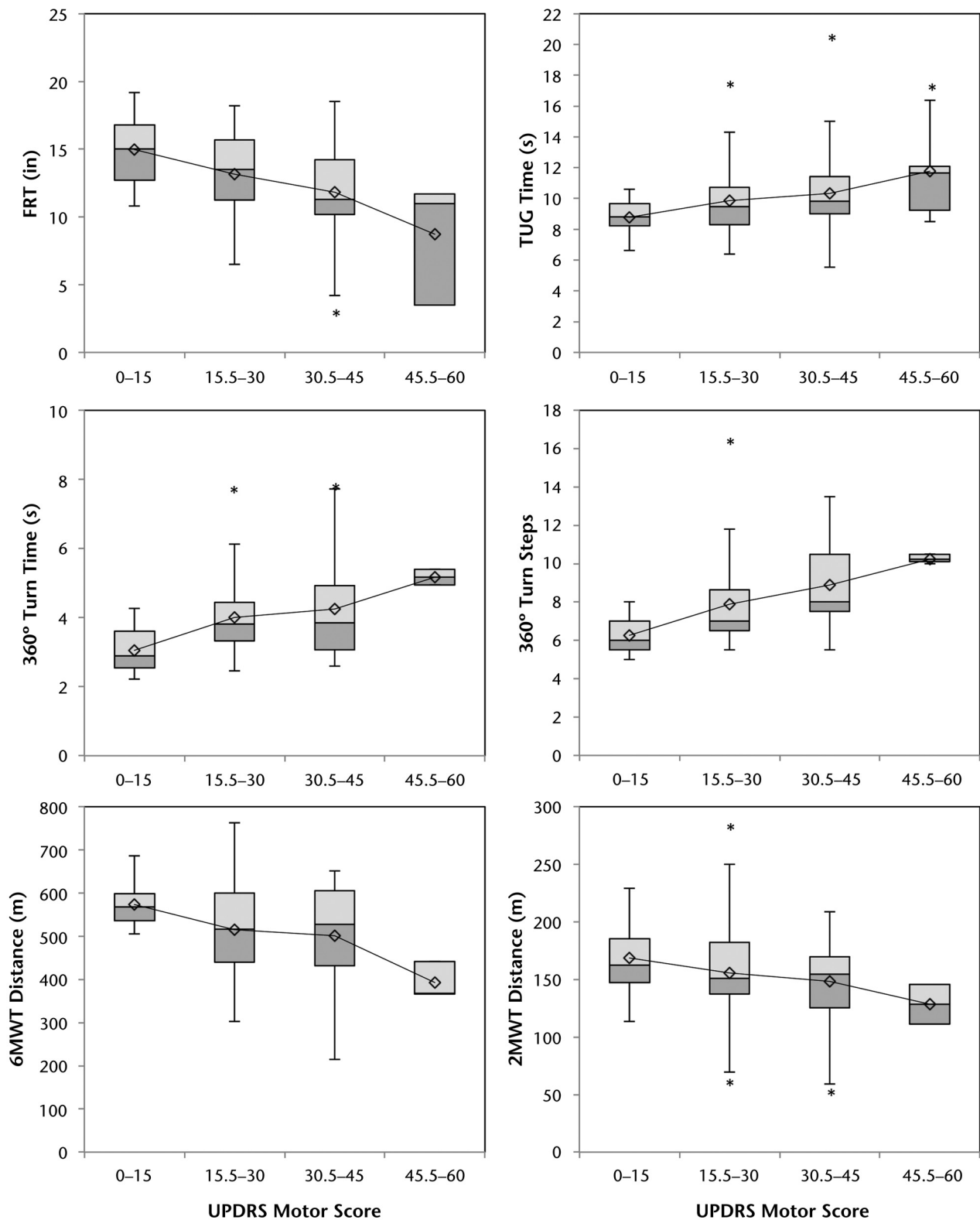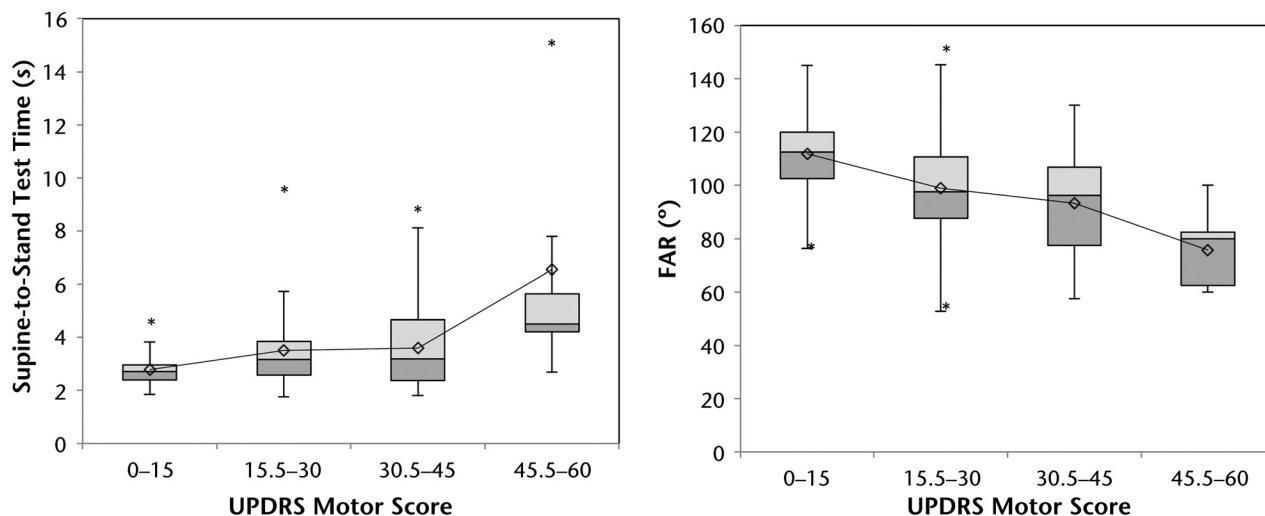
Figure 2.
Balance and gait measure score distributions by Unified Parkinson's Disease Rating Scale (UPDRS) motor scores. 6MWT=Six-Minute Walk Test, 2MWT=Two-Minute Walk Test, FRT=Functional Reach Test, TUG=Timed "Up & Go" Test. Box plot symbols: asterisk indicates outliers beyond 3 standard deviations from the mean score; diamond represents mean score; dark gray box represents distance between first quartile and median; and light gray box represents distance between median and third quartile.

Figure 3.
Supine-to-stand test and functional axial rotation (FAR) (worst side only) score distribution by Unified Parkinson's Disease Rating Scale (UPDRS) motor scores. Box plot symbols: asterisk indicates outliers beyond 3 standard deviations from the mean score; diamond represents mean score; dark gray box represents distance between first quartile and median; and light gray box represents distance between median and third quartile.

healthy. These findings suggest that people with PD adjust task performance to stay in the comfortable range. Only those individuals at higher levels of disease severity reported a high RPE during the relatively common functional activities of the CS-PFP. For example, the group with UPDRS motor scores of 45.5 to 60 had a mean RPE of 13.7 (SD=0.6), underscoring the degree of effort required for relatively simple tasks.

The only other measure in this study that detected losses early was the FAR. The mean FAR was 107 degrees (SD=8.6) for participants in H&Y stages 1 and 1.5 (mean age=55 years, SD=8.5). These individuals had substantially reduced FAR compared with a sample of adults without PD in which the mean FAR was 117.9 degrees (SD=14.2) for men and 127.8 degrees (SD=10.4) for women (data from 40 adults who were healthy, aged 40–59 years, 55% female), (unpublished data). By H&Y stage 3 (mean age=69 years,

SD=8.0), participants were 30 degrees below the expected values for individuals of similar age who are healthy. These findings have important implications for balance and function. Axial rotation is used to maximize FRT distance[38]; thus, it is likely that the substantially lower FAR for participants in H&Y stage 3 contributes to balance dysfunction in later stages of PD. Furthermore, limited ability to twist the torso to see behind has ramifications for any activity that requires such motions (eg, reaching for objects, turning to see while backing up a car).

Two other measures (FRT and 6MWT) showed a systematic decrease in values across stages of PD, although they did not detect decline in the participants with early signs of PD. Participants in the earliest stages of PD demonstrated an age-appropriate median FRT score (15–16 in), whereas those with UPDRS motor scores of 30 to 45 and H&Y stage 3 had a median reach of 11.3 in. The difference between

H&Y stages approached 2 in. To put these data into context, Dibble and Lange[39] recommended a cutoff of 12.5 in in patients with PD to predict falls (sensitivity=86%). In our sample, the following percentages of participants were below this cut-point: H&Y stage 2=11.0%, H&Y stage 2.5=51.0%, and H&Y stage 3=70.3%. These results are consistent with those of Tanji et al,[40] who also found the FRT able to distinguish between those with postural instability (H&Y stages 2.5 and 3) and those without postural instability (H&Y stage 2).

With respect to the 6MWT, the mean walk distances in our sample for participants who were least involved (H&Y stages 1–2, UPDRS motor scores=0–15) appear appropriate compared to normative values for people who are healthy.[33] A difference in mean values of nearly 200 m was observed across each UPDRS motor grouping. Our findings are consistent with those of other authors.[34,41,42] In the context of gait

speed, Perry and colleagues[43] indicated that 0.8 m/s is a cutpoint between community ambulation and limited community ambulation for people recovering from a stroke, whereas Studenski and colleagues[44] found 1.0 m/s to be a cutpoint for predicting decline in health status and function for older adults. The groups of participants in our study with H&Y stage 3 and UPDRS motor scores of 45.5 to 60 had mean and median gait speeds (around 1.0 m/s) at or near values indicating higher risk of health problems and functional compromise.

A second important insight is that the following measures begin to show impairment relatively later in disease progression, beginning in H&Y stage 3: 2MWT, TUG, supine-to-stand test, and stand-to-supine test. Both mean and median scores suggest substantial difficulty for people later in the disorder. The data indicate that the 2MWT, in contrast to the 6MWT, is not of sufficient length to pick up the endurance problems in individuals who are in the earlier stages of PD,[45] even though deficits in economy of movement have been established for those in very early stages of PD.[46]

For the TUG, scores of 10 seconds or less are generally considered normal in elderly people who are healthy.[11] Whether examining the mean or the median in our sample, there was a transition from scores below 10 seconds for participants who were less involved (H&Y stages 1, 1.5, and 2) to scores above 10 seconds for those in H&Y stages 2.5 and 3. The minimum score was 5.5 seconds, and the maximum score was 31.6 seconds. Only 22.5% of participants in H&Y stages 1, 1.5, and 2 had scores above 10 seconds for the TUG, whereas 53.8% of participants in H&Y stages 2.5 and 3 had scores above 10 seconds. With respect to UPDRS motor scores, the transition

from below to above 10 seconds occurred at UPDRS scores of 30 of 45 points for the mean (10.3 seconds) and was similar for the median (9.8 seconds). These findings suggest that limitations in the TUG are not revealed until later in the disease progression. These findings are supported by Ellis and colleagues,[45] who reported mean TUG scores of 55 seconds in a sample of patients with PD who were predominantly (64%) in H&Y stage 4.

The stand-to-supine and supine-to-stand tests can be important practical measures, as complaints of difficulty moving in bed are common among people with PD. In this study, it was only in H&Y stage 3 or UPDRS motor scores above 45 that these tests revealed limitations. These participants were twice as slow as individuals in the early stages, although the variability was large, suggesting that not all participants in H&Y stage 3 will demonstrate limitations in this area.

A third insight relates to the considerable heterogeneity and variance in performance observed in our sample, particularly in the later stages of PD. Given this variability, individuals at either end of the measurement scale can skew the mean substantially. For some measures (eg, supine-to-stand task, 360° turn), the medians indicated much greater functional limitations than the means. Based on our findings, we suggest examining both the mean and median scores. In addition, distinguishing differences in physical function by stage of disease alone may not be sufficient. Examination of subpopulations may yield less variability and more narrow profiles. For example, categorizing by dominance of symptom (eg, postural instability gait difficulty or tremor dominant) may reveal very different functional trajectories and should be investigated in future studies.

The fourth important point relates to clinical and research recommendations for selection of functional measures across stages of PD. Choice of measures will necessarily be dictated by the purpose for which they are to be used. In the clinic, physical therapists managing patients in the early stages may consider using the CS-PFP and the FAR to identify deficits in status. The 6MWT and the FRT also could be incorporated early in the disease to establish baseline status and repeated periodically thereafter to determine performance relative to elderly people who are healthy and to expected ranges in PD. The TUG, 2MWT, and supine-to-stand measure should be reserved for patients in the moderate stages.

For intervention studies, choice of measures should be determined by both stage of PD and study length. For participants in the earliest stage of PD, only the CS-PFP and FAR detected differences from age-appropriate norms. Thus, for such participants, these 2 measures have potential to detect change of functional problems in short-term studies (less than 6 months). Conversely, other measures have low potential to detect functional problems in short-term studies in which participants are in early stages of PD. Because of the lack of responsiveness of most measures for people in the earliest stages of PD, a new measure of function, the instrumented Timed "Up & Go" Test (iTUG),[47] has been developed. The iTUG appears to be especially sensitive to deficits in balance and may provide further insight into these deficits in the earliest stages of PD.

Many of the measures in addition to the CS-PFP and FAR might be appropriate for longer-term studies (eg, 12–24 months), even when people in early stages of PD are included. Examples of such measures are the FRT and 6MWT, which could add

insight into functional change as the disease progresses. The TUG, 2MWT, and supine-to-stand measure would be appropriate for studies including participants who have moderate to severe PD either at baseline or at the end of the study.

Several limitations should be acknowledged. First, most of the participants in this database were in H&Y stages 2, 2.5, and 3, with only 3% in stages 1 to 1.5. These findings were in part because people are not always diagnosed in the earliest stages of PD, and of those who are, not all are referred for exercise interventions. Second, because these data are cross-sectional (not longitudinal), we cannot make statements about change over time. Nevertheless, these data give some insight into what to expect at each point in the disease process and can help clinicians determine which deficits begin in the earliest stages as well as which measures might be of most use early in the disease process. Future investigations, utilizing change scores will be essential to further our understanding of performance in people with PD. Third, these data were derived from 5 different studies, and not all measures were performed at all sites and for all studies. Nevertheless, the sample was of sufficient size that the number of participants ranged between 100 and 252 for all measures. Finally, the participants were predominantly educated and white, with low diversity with respect to income and race, limiting ability to generalize to some extent. However the samples were recruited from 3 distinct locations across the United States, increasing generalizability from a geographical perspective.

In summary, typical values are presented relative to disease severity for standard measures of functional ability commonly used by researchers and clinicians who work with individuals in early and mid stages of PD. Findings demonstrate that functional loss occurs at different points in the disease process, depending on the task under consideration. The resulting profile of functional limitations provides benchmarks that clinicians and researchers can use to interpret and monitor status of patients.

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