

# The 9-Hole Peg Test of Upper Extremity Function: Average Values, Test-Retest Reliability, and Factors Contributing to Performance in People With Parkinson Disease

Gammon M. Earhart, PT, PhD, Jim T. Cavanaugh, PT, PhD, Terry Ellis, PT, PhD, NCS,  
Matt P. Ford, PT, PhD, K. Bo Foreman, PT, PhD, and Lee Dibble, PT, PhD, ATC

**Background and Purpose:** Pegboard tests of hand dexterity are commonly used in clinical settings to assess upper extremity function in various populations. For individuals with Parkinson disease (PD), the clinical utility of pegboard tests has not been fully evaluated. Our purpose was to examine the commercially available 9-Hole Peg Test (9HPT) using a large sample of individuals with PD to determine average values, test-retest reliability, and factors predictive of 9HPT performance.

**Methods:** A total of 262 participants with PD (67% men, Hoehn & Yahr stage =  $2.3 \pm 0.7$ ) completed the 9HPT along with a battery of other tests including the Movement Disorder Society Unified PD Rating Scale—Motor Subscale III and Freezing of Gait Questionnaire.

**Results:** Average time to complete the 9HPT was  $31.4 \pm 15.7$  s with the dominant and  $32.2 \pm 12.4$  s with the nondominant hand. Test-retest reliability of 2 trials performed with the same hand was high (dominant ICC<sub>2,1</sub> = 0.88, nondominant ICC<sub>2,1</sub> = 0.91). Women performed the test significantly faster than men, and nonfreezers significantly faster than freezers. For either hand, age, bradykinesia, and freezing of gait scores individually predicted significant portions of the variance in 9HPT time. Sex also was a significant predictor, but for the nondominant hand only. Tremor and rigidity did not predict performance.

Program in Physical Therapy, Washington University in St Louis-School of Medicine, St Louis, Missouri (G.M.E.); Department of Physical Therapy, University of New England, Portland, Maine (J.T.C.); Department of Physical Therapy and Athletic Training, Boston University, Boston, Massachusetts (T.E.); Department of Physical Therapy, School of Health Professions, University of Alabama at Birmingham, Birmingham (M.P.F.); and Department of Physical Therapy, University of Utah, Salt Lake City, Utah (K.B.F., L.D.)

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**Correspondence:** Gammon M. Earhart, PT, PhD, Program in Physical Therapy, Washington University School of Medicine, Campus Box 8502, 4444 Forest Park Blvd, St Louis, MO 63108 ([earhartg@wusm.wustl.edu](mailto:earhartg@wusm.wustl.edu)).

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**Discussion and Conclusions:** The 9HPT appears to be a clinically useful measure for assessing upper extremity function in individuals with PD. The 9HPT has advantages over previously used methods including standardization, known normative values for healthy controls, commercial availability, transportability, and ease of administration.

**Key Words:** dexterity, nine-hole peg test, Parkinson disease

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## BACKGROUND AND PURPOSE

The motor symptoms of Parkinson disease (PD) commonly affect the upper extremities.<sup>1–3</sup> Impaired upper extremity function in PD has been associated with limitations in activities of daily living and reductions in quality of life.<sup>4</sup> Although the Unified Parkinson's Disease Rating Scale (UPDRS), the gold standard tool for classifying PD severity and progression, assesses upper extremity function in several areas, it is time-consuming, subjective, and has suboptimal sensitivity.<sup>5</sup> In addition, items used to assess upper extremity function within the UPDRS may not reflect clinically relevant dexterity tasks and as such may not be ecologically valid. Other measures that might detect subtle impairment or are more responsive to change have received only limited scrutiny.<sup>6–8</sup>

Several studies have used some version of peg insertion to assess motor function. For example, a series of studies conducted by Müller et al<sup>9–11</sup> examined upper extremity function using a peg insertion task that involved placement of 25 pegs into a computerized contact board. The authors noted that peg insertion was sensitive to levodopa and other medications and related to performance on other motor tests. More recent work has utilized an 8-peg test wherein pegs were transferred from one row to another.<sup>5,12</sup> The authors of these studies noted that the peg insertion task correlated well with disease severity and duration, was sensitive for discriminating between people with PD and healthy controls, and was more sensitive than other timed tests designed to assess upper extremity function in PD. They further noted that peg tests might be particularly useful, because they require precise, coordinated finger movements, and do not rely heavily on more proximal or axial movements that could be used to compensate for deficits in fine motor dexterity. As such, they suggest that the peg test

may be a particularly useful tool for screening and also has potential utility as an outcome measure in clinical trials.

A limitation of these previous studies utilizing peg insertion tasks is that they used computerized and/or customized versions of the tests that appear to be specific to that research group. In contrast, the 9-hole peg test (9HPT) is a commercially available, standardized, well established, and reliable measure of hand function for healthy adults, with known normative values across a broad range of ages.<sup>13-15</sup> The 9HPT requires participants to quickly pick up 9 small pegs from a holding well, place them into holes on a board, and then move them back to the well. The 9HPT has the potential to serve as an easily administered and useful tool for the assessment of upper extremity function in a variety of populations including individuals with neurological conditions.<sup>16,17</sup>

To our knowledge, only a few studies have specifically evaluated the 9HPT in people with PD.<sup>6,18,19</sup> In one study, a small sample of people with PD performed the 9HPT as part of a battery of assessments administered via the Internet.<sup>18</sup> This study showed that the 9HPT could be successfully administered remotely with high intra- and interrater reliability. Another study utilized the 9HPT as an outcome measure in a study of home exercises and noted improvements in 9HPT performance in the exercise group.<sup>19</sup> The results of these studies were limited by small sample sizes, and factors that might have contributed to 9HPT performance were not evaluated. Thus, the relative influences on 9HPT performance of bradykinesia, tremor, and rigidity, as well as sudden arrests in ongoing movement (ie, motor blocks), remain unclear.<sup>20,21</sup>

The broad objective of this study was to evaluate the potential clinical utility of the 9HPT in a large sample of individuals with PD. Specifically, we examined 9HPT results to determine population-specific average values (and compare these to published norms for healthy controls), test-retest reliability, minimal detectable change values, and to identify factors predictive of test performance. We also sought to compare 9HPT values among individuals with PD with published normative values for healthy adults.

## METHODS

### Participants

Two hundred sixty-four individuals with idiopathic PD were recruited and tested at 4 different clinical sites as part of the CHOP-PD study, a prospective longitudinal cohort study designed to track the natural history of mobility and quality of life changes in individuals with PD.<sup>22</sup> Inclusion criteria were as follows: (1) at least 40 years of age, (2) neurologist diagnosed idiopathic PD (using UK Brain Bank criteria)<sup>23</sup>, (3) Hoehn & Yahr (H&Y)<sup>24</sup> Stages 1 to 4, (4) Mini-Mental State Examination<sup>25</sup>  $\geq 24/30$ , and (5) living in the community. Exclusion criteria included diagnosis of atypical Parkinsonism, H&Y Stage 5, and previous surgical management of PD. Participants were tested on medication, generally 1 to 1.5 hours after taking their antiparkinson medication.

### Data Collection

Complete data collection procedures for the longitudinal study have been described elsewhere.<sup>22</sup> The study protocol was

approved by the local institutional review boards of each of the data collection sites and written informed consent was obtained from all participants prior to participation. Motor impairments were rated by an examiner using the Movement Disorders Society Unified Parkinson's Disease Rating Scale motor subscale (MDS-UPDRS-III).<sup>26</sup> The occurrence of motor blocks during functional activities was captured using the Freezing of Gait Questionnaire (FOG-Q).<sup>27</sup> Participants performed 2 trials of the 9HPT with the dominant hand and 2 with the nondominant hand. Dominance was based on handedness regardless of which side had more severe PD motor symptoms. Side of worst motor symptoms was plotted and the distribution examined, revealing that the worst side was well distributed in the sample and as such was not taken into account in the analyses. Trials were performed first with the dominant hand and then with the nondominant hand, per the standardized administration instructions for the test. Table and chair heights and distance from the pegboard were adjusted individually for each subject based on comfort. Trials were completed one after the other with a brief rest in between trials. This short test-retest interval was chosen for practical purposes, as we needed to complete the protocol in a single visit. This also allowed us to be sure that medication status was similar across all trials. Instructions were as follows, "On this test, I want you to pick up the pegs one at a time, using one hand only, and put them into the holes as quickly as you can in any order until all the holes are filled. Then, without pausing, remove the pegs one at a time and return them to the container as quickly as you can. We'll have you do this two times with each hand. We'll start with your [dominant] hand. You can hold the peg board steady with your [nondominant] hand. If a peg falls onto the table, please retrieve it and continue with the task. If a peg falls on the floor, keep working on the task and I will retrieve it for you. See how fast you can put all of the pegs in and take them out again. Are you ready? Begin."

### Data Analysis

Only baseline data were used for analysis. Based on our understanding of upper extremity function in PD, variables of interest were (1) age, (2) sex, (3) medication (expressed as daily levodopa equivalents), (4) years with diagnosed PD, (5) H&Y stage, (6) total score on the FOG-Q, (7) rigidity (operationally defined as the MDS-UPDRS rigidity item score for the upper extremity), (8) bradykinesia (operationally defined as the sum of MDS-UPDRS finger tapping, hand movements, and pronation-supination items for the upper extremity), (9) tremor (operationally defined as the sum of MDS-UPDRS postural, kinetic, and resting tremor items for the upper extremity), and (10) 9HPT scores. Rigidity, bradykinesia, and tremor scores were determined separately for the dominant and nondominant hand, as were 9HPT scores.

Descriptive statistics were used to characterize average 9HPT values. Test-retest reliability of 2 trials performed with the same hand was determined using intraclass correlation coefficients (ICC<sub>2,1</sub>). Minimum detectable change (MDC) values were calculated using the following equation:

$$MDC_{SEM} = SD\sqrt{2(1-r_{xx})}$$

**Table 1.** Participant Characteristics

	Total Sample (n = 262), Means ± SD	Men (n = 149), Means ± SD	Women (n = 113), Means ± SD	Freezers (n = 93), Means ± SD	Nonfreezers (n = 169), Means ± SD
Age	67.7 ± 9.2	68.3 ± 9.3	66.9 ± 9.1	68.7 ± 8.7	67.1 ± 9.5
LEDD	664.1 ± 1210.8	676.5 ± 962.1	647.8 ± 1480.9	750.6 ± 482.8	616.6 ± 1464.1
Years with PD	6.2 ± 4.8	6.4 ± 4.8	5.9 ± 4.7	8.3 ± 5.2	5.0 ± 4.0
H&Y	2.3 ± 0.7	2.4 ± 0.7	2.3 ± 0.7	2.7 ± 0.8 <sup>a</sup>	2.2 ± 0.5
FOG-Q	6.0 ± 5.3	6.5 ± 5.5	5.4 ± 5.0	12.0 ± 3.6 <sup>a</sup>	2.7 ± 2.5
UPDRS-III	33.7 ± 15.0	35.3 ± 15.4	31.6 ± 14.3	42.0 ± 16.0 <sup>a</sup>	29.3 ± 12.5
Rig DOM	1.4 ± 0.8	1.5 ± 0.8	1.2 ± 0.9	1.6 ± 0.8 <sup>a</sup>	1.3 ± 0.8
Rig NON	1.4 ± 0.9	1.6 ± 0.8	1.3 ± 0.9	1.6 ± 0.8 <sup>a</sup>	1.4 ± 0.9
Brady DOM	4.1 ± 2.5	4.2 ± 2.5	4.0 ± 2.4	4.9 ± 2.6 <sup>a</sup>	3.7 ± 2.3
Brady NON	4.5 ± 2.6	4.6 ± 2.6	4.5 ± 2.6	5.4 ± 2.7 <sup>a</sup>	4.1 ± 2.4
Tremor DOM	1.6 ± 1.9	1.9 ± 2.1	1.2 ± 1.7	2.1 ± 2.4 <sup>a</sup>	1.4 ± 1.6
Tremor NON	1.6 ± 1.8	1.8 ± 1.8	1.5 ± 2.0	1.9 ± 2.2 <sup>a</sup>	1.5 ± 1.6

Abbreviations: Brady, Bradykinesia; DOM, dominant upper extremity; FOG-Q, Freezing of Gait Questionnaire; H&Y, Hoehn and Yahr; LEDD, Levodopa equivalent dose; NON, Nondominant Upper Extremity; Rig, Rigidity; UPDRS-III = Unified Parkinson's Disease Rating Scale Motor Subsection III.

<sup>a</sup>Significantly different from nonfreezers.

where SD is the standard deviation of baseline scores and  $r_{xx}$  is the Pearson correlation between the 2 trials performed with the same hand.<sup>28</sup>

Values for the 2 trials performed with the same hand were averaged for all other analyses. Differences in performance between men and women, between "freezers" and "nonfreezers," and between the study sample and published norms for age-matched healthy controls (n = 14 men, 31 women)<sup>29</sup> were compared using independent samples *t* tests on means and standard deviations. *Freezers* were defined as individuals with a score of 2 or greater on Item 3 of the FOG-Q, indicating a history of freezing at least once per week.<sup>30</sup> Pearson correlations were used to examine relationships between all measures of interest. Correlations were then used to determine which items to enter into multiple regression analyses to determine what factors made a significant contribution to explaining 9HPT performance. All items that were significantly correlated ( $P \leq 0.05$ ) were entered into the regression analysis. Separate multiple regression analyses were conducted for each dependent variable for the dominant and nondominant hand. Variance inflation factors were evaluated to ensure that multicollinearity was not a concern. The level of significance for all analyses was set at  $P < 0.05$ .

## RESULTS

The final analysis included complete data sets from 262 participants. Study variables for the sample as a whole, for men versus women, and for freezers versus nonfreezers are given in Table 1. For the entire sample, time (mean ± SD) to complete the 9HPT was 31.4 ± 15.7 s with the dominant hand and 32.2 ± 12.4 s with the nondominant hand. The 9HPT times were generally lower (ie, faster speed) among participants at H&Y Stage 1 (n = 12, dominant = 23.5 ± 5.6 s, nondominant = 23.5 ± 5.2 s) relative to participants at H&Y Stage 4 (n = 15, dominant = 43.3 ± 15.9 s, nondominant = 47.9 ± 15.9 s; Table 2). Figure 1 shows 9HPT times for the dominant and nondominant hand in groups of healthy, age-matched men and women,<sup>29</sup> men and women with PD, and for freezers and nonfreezers with PD. Freezers took longer to complete the 9HPT than nonfreezers ( $t_{260} = -5.54$ ,  $P < 0.001$ , 2-tailed). For people with PD, there were no differences in performance

**Table 2.** 9-Hole Peg Test Scores by Hoehn & Yahr Stage

Modified Hoehn & Yahr Stage	Dominant Hand, Means ± SD	Nondominant Hand, Means ± SD
1 (n = 12)	23.5 ± 5.6	23.5 ± 5.2
1.5 (n = 4)	23.4 ± 3.2	31.2 ± 10.1
2 (n = 112)	26.6 ± 6.6	27.5 ± 6.4
2.5 (n = 62)	34.3 ± 22.5	34.4 ± 12.9
3 (n = 52)	36.7 ± 16.4	36.8 ± 13.4
4 (n = 15)	43.3 ± 15.9	47.9 ± 15.9

with the dominant versus the nondominant hand for the sample as a whole or for any subgroup. There were no order effects evident in the data.

Men with PD completed the test using the dominant and nondominant hand, respectively, in 33.2 ± 14.7 s and 34.4 ± 12.8 s, compared to women with PD who completed the test in 29.1 ± 16.7 s with the dominant hand and 29.5 ± 11.2 s with the nondominant hand. Men with PD took longer to complete the 9HPT than women with PD ( $t_{260} = 2.12$ ,  $P = 0.04$ , 2-tailed). Compared to age-matched controls, men and women with PD took longer to perform the 9HPT with the dominant hand (Men:  $t_{161} = -3.04$ ,  $P = 0.003$ ; Women:  $t_{142} = -3.05$ ,  $P = 0.003$ ) and with the nondominant hand (Men:  $t_{161} = -3.51$ ,  $P < 0.001$ ; Women:  $t_{142} = -3.95$ ,  $P < 0.001$ ). Age-matched healthy men completed the test with the dominant and nondominant hands, respectively, in 21.1 ± 3.3 s and 22.3 ± 3.7 s. Age-matched healthy women completed the test in 19.9 ± 3.2 s with the dominant hand and 21.4 ± 3.9 s with the nondominant hand.<sup>29</sup> On average, people with PD took approximately 50% longer than healthy adults to complete the test, or on the order of 3 standard deviations above the mean of the age-matched healthy adult group.

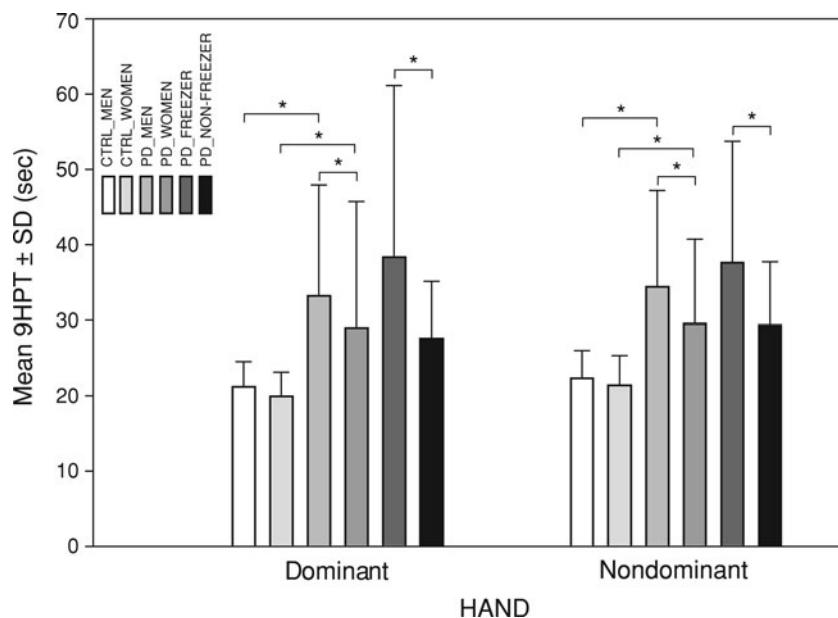
Test-retest reliability in the PD sample was high ( $ICC_{2,1} = 0.88$  for dominant and 0.91 for nondominant) for two consecutive trials using either hand. The SEM was 1.02 s for the dominant hand and 0.82 s for the nondominant hand, with a minimum detectable change of 2.6 s for the dominant hand and 1.3 s for the nondominant hand.

Pearson correlations between study variables are shown in Table 3. For each hand, the variables that were significant

( $P \leq 0.05$ ) were entered into multiple regression analyses. The variables entered were: age, sex, years with PD, H&Y stage, FOG-Q, rigidity, bradykinesia, and tremor. For the dominant hand, age, bradykinesia, and FOG-Q together predicted 29.0% of the variance in 9HPT performance, with 21% of the variance explained by bradykinesia alone. For the nondominant hand, age, bradykinesia, FOG-Q, and sex combined to explain 41.0% of the variance in 9HPT performance; 22% of the variance was explained by bradykinesia alone, whereas sex contributed only 2% to the overall  $R^2$  (Table 4). Multicollinearity was not a concern in either regression analysis; variance inflation factors were all 1.2 or less.

## DISCUSSION

The 9HPT is an easily administered, commercially available, “low-tech” clinical assessment of upper extremity function, with established normative values for healthy controls across a wide range of ages. Previous studies of the 9HPT in people with PD, although conducted using small samples, support its intra- and interrater reliability and potential utility as a responsive measure of change.<sup>18,19</sup> To our knowledge, this study is the first to generate 9HPT average values, consider test-retest reliability, calculate preliminary MDC values, and identify factors that contribute to 9HPT performance specifically for people with PD.



**Figure 1.** 9-Hole Peg Test scores for age-matched men and women,<sup>29</sup> men and women with PD, and freezer and nonfreezers. Data are presented separately for the dominant and nondominant hands. Values are means  $\pm$  SD. Asterisks (\*) indicate significant differences between conditions at  $P \leq 0.003$ .

**Table 3. Correlations Among Variables<sup>a</sup>**

	Age	Sex	LEDD	Years With PD	H&Y	FOG-Q	Rig DOM	Rig NON	Brady DOM	Brady NON	Trem DOM	Trem NON	9HPT DOM	9HPT NON
Age	1.0	-0.08	-0.09	0.08	<b>0.28</b>	<b>0.16</b>	0.08	0.03	<b>0.28</b>	<b>0.22</b>	0.05	-0.06	<b>0.34</b>	<b>0.41</b>
Sex	...	1.0	-0.01	-0.05	-0.03	-0.11	-0.15 <sup>b</sup>	-0.13 <sup>b</sup>	-0.01	-0.00	<b>-0.16</b>	-0.07	-0.12 <sup>b</sup>	<b>-0.19</b>
LEDD	...	...	1.0	<b>0.21</b>	0.03	0.09	0.02	0.05	0.01	-0.05	0.08	0.01	0.06	0.08
Years with PD	...	...	...	1.0	<b>0.30</b>	<b>0.41</b>	<b>0.27</b>	<b>0.17</b>	<b>0.28</b>	<b>0.23</b>	<b>0.21</b>	<b>0.24</b>	<b>0.20</b>	<b>0.32</b>
H&Y	...	...	...	...	1.0	<b>0.47</b>	<b>0.28</b>	<b>0.22</b>	<b>0.53</b>	<b>0.48</b>	<b>0.22</b>	<b>0.19</b>	<b>0.28</b>	<b>0.37</b>
FOG-Q	...	...	...	...	...	1.0	<b>0.19</b>	0.14 <sup>b</sup>	<b>0.32</b>	<b>0.29</b>	0.12	0.16 <sup>b</sup>	<b>0.35</b>	<b>0.42</b>
Rig DOM	...	...	...	...	...	...	1.0	<b>0.53</b>	<b>0.45</b>	<b>0.29</b>	<b>0.26</b>	<b>0.27</b>	<b>0.20</b>	<b>0.20</b>
Rig NON	...	...	...	...	...	...	...	1.0	<b>0.31</b>	<b>0.36</b>	<b>0.18</b>	<b>0.19</b>	0.09	<b>0.21</b>
Brady DOM	...	...	...	...	...	...	...	...	1.0	<b>0.74</b>	<b>0.29</b>	<b>0.18</b>	<b>0.45</b>	<b>0.41</b>
Brady NON	...	...	...	...	...	...	...	...	...	1.0	<b>0.16</b>	<b>0.36</b>	<b>0.40</b>	<b>0.47</b>
Tremor DOM	...	...	...	...	...	...	...	...	...	...	1.0	<b>0.49</b>	<b>0.20</b>	0.11
Tremor NON	...	...	...	...	...	...	...	...	...	...	...	1.0	<b>0.17</b>	<b>0.18</b>
9HPT DOM	...	...	...	...	...	...	...	...	...	...	...	...	1.0	<b>0.67</b>
9HPT NON	...	...	...	...	...	...	...	...	...	...	...	...	...	1.0

Abbreviations: Brady, Bradykinesia; DOM, dominant upper extremity; FOG-Q, Freezing of Gait Questionnaire; H&Y, Hoehn and Yahr; LEDD, Levodopa equivalent dose; NON, Nondominant Upper Extremity; Rig, Rigidity; 9HPT, 9-Hole Peg Test.

<sup>a</sup>Bolded items significant at  $P < 0.01$ .

<sup>b</sup>Significant at  $P < 0.05$ .

**Table 4.** Final Regression Models for 9HPT of Dominant (Top) and Nondominant (Bottom) Hand

	B	SE B	$\beta$	R <sup>2</sup> When Fit Alone	Partial R <sup>2</sup>	Total R <sup>2</sup> for This Variable and Variables Above
9HPT Dominant hand						
Age	0.36	0.09	0.21	0.11	0.06	0.11
Brady DOM	2.11	0.36	0.33	0.21	0.12	0.25
FOG-Q	0.60	0.16	0.21	0.12	0.05	0.29
9HPT Nondominant hand						
Age	0.38	0.07	0.29	0.17	0.12	0.17
Brady NON	1.59	0.24	0.33	0.22	0.14	0.32
FOG-Q	0.60	0.12	0.26	0.17	0.09	0.39
Sex	0.26	1.21	-0.14	0.04	0.03	0.41

Abbreviations: Brady, Bradykinesia; DOM, dominant upper extremity; FOG-Q, Freezing of Gait Questionnaire; NON, Nondominant Upper Extremity; 9HPT, 9-Hole Peg Test.

## Test-Retest Reliability

Test-retest reliability for 2 test trials conducted with either hand was high ( $ICC_{2,1} = 0.88, 0.91$ ), producing relatively small Standard Error of the Mean (SEM) values. Consequently, the MDC in 9HPT performance in people with PD, H&Y Stages 1 to 4, was determined to be 2.6 s for the dominant hand and 1.3 s for the nondominant hand. The finding suggests that the 9HPT may be a relatively sensitive measure of performance changes resulting from disease progression, pharmacological intervention, or rehabilitation. Importantly, test-retest reliability of the 9HPT in the PD sample was much higher than has been noted previously for healthy controls. Reasons for this discrepancy likely related to differences in the time interval between test administrations. In this study, we determined test-retest reliability between trials administered consecutively during the same session. In contrast, previous studies reporting relatively poor test-retest reliability ( $r = 0.45$ ) compared trials administered 1 week apart.<sup>15</sup> Future work should determine the test-retest reliability of the 9HPT administered to people with PD in separate sessions 1 week or more apart.

## Influence of Nonmodifiable Factors

Several nonmodifiable factors appeared to contribute to 9HPT performance. Most notably, the presence of PD appeared to produce higher test times. In fact, on average, even while on their antiparkinson medications, people with PD took approximately 50% longer than age-matched healthy adults to complete the test. Given that mean 9HPT time in the PD sample was approximately 3 standard deviations above the mean time of the healthy comparison group, we interpreted the difference to indicate that upper extremity function in the PD sample was clearly impaired. The finding further supports the use of the 9HPT as a means of identifying upper extremity performance deficits in people with PD.<sup>18,19</sup> Moreover, given that the mean 9HPT time among participants classified as H&Y 1 also was 1 standard deviation above the mean of the healthy comparison group and the difference exceeded our calculated MDC value, our data suggested that the 9HPT shows promise for detecting decrements in upper extremity function at early stages of the disease.

In agreement with previous studies involving healthy adults, age was another important nonmodifiable contributor to 9HPT performance in people with PD. That is, older

individuals with PD generally took longer to complete the test than younger individuals with PD. Importantly, however, we found the relationship between 9HPT performance and age to be not as strong in people with PD ( $r = 0.34$  to 0.41) as in healthy adults ( $r = 0.89$ –0.91).<sup>29</sup> Based on our results, the difference in the strength of the relationship is likely a result of the influence of additional factors (ie, bradykinesia and freezing) that often have a substantial effect on people with PD.

Also consistent with previous studies of healthy adults, our data revealed that women with PD performed the 9HPT faster than men with PD of the same age. Importantly, however, the influence of sex on 9HPT times in the PD population was relatively small in comparison to other factors (ie, age, bradykinesia, and FOG-Q score). In fact, although statistically significant, the mean difference in 9HPT times between men and women with PD was about 4.5 seconds (roughly one-third of 1 standard deviation). Moreover, sex explained only a small percentage of the variance of 9HPT times and only for the nondominant hand. Thus, in our view, sex would not be a critical nonmodifiable factor to consider when comparing the 9HPT time of a person with PD to other people with PD.

Disease duration and stage of progression also were evaluated as nonmodifiable factors for their contribution to 9HPT time. Without controlling for other variables, both factors were significantly associated with performance; however, neither factor was found to be a unique contributor. We suspect that both factors, given their highly significant correlations with every other PD-related factor considered, were essentially redundant with the diagnosis of PD itself.

## Influence of Modifiable Factors

Of several potentially modifiable PD-specific factors, our data revealed that severity of bradykinesia contributed most significantly to 9HPT performance. That bradykinesia impairs hand dexterity in PD is not new.<sup>6</sup> To our knowledge, however, no previous analysis has simultaneously examined the relative contributions of bradykinesia, freezing, tremor, and rigidity to physical performance on an upper extremity functional task. The findings suggest that compared to the other motor impairments, bradykinesia may be the most suitable target of medical, surgical, or rehabilitation interventions designed to improve upper extremity function. Further study of this proposition is warranted.

Compared to the predictable influence of bradykinesia, the significant contribution of FOG-Q scores on 9HPT performance was perhaps more surprising. However, the finding was in keeping with recent work suggesting that upper extremity motor blocks and freezing of gait may share a common underlying mechanism.<sup>21</sup> In this context, our data provided further, albeit preliminary, support for the idea that interventions targeting motor blocks in PD may be useful for improving both lower and upper limb function.

Tremor and rigidity did not contribute significantly to 9HPT performance. The finding is consistent with previous work demonstrating that tremor does not appear to be related to bradykinesia<sup>3</sup> and that other instrumented measures of bradykinesia such as spiral drawing on a digitizing tablet were not influenced by tremor.<sup>6</sup> This suggests that interventions targeting tremor and rigidity potentially would have less of an impact on upper extremity function than those targeting bradykinesia or motor blocks. Further study of this proposition is warranted.

## CONCLUSIONS

The 9HPT appears to be a useful and appropriate measure for assessing upper extremity function in individuals with PD. It is a standardized, ratio scale tool with established norms that is commercially available and is portable for use in a variety of settings including the clinic, laboratory, and home. In addition, it assesses a clinically relevant fine motor dexterity task that is not examined in the MDS-UPDRS. Unlike some other commercially available tests,<sup>6</sup> the 9HPT is relatively inexpensive and requires no specialized training to administer.

Taken together, our study findings have 3 broad clinical implications. First, given substantial differences in 9HPT performance between people with PD and healthy adults, a PD-specific set of typical values appears necessary for performance comparisons among individuals with PD. Such comparisons should consider the influence of age but not necessarily sex. Second, given its potential for detecting upper extremity function deficits in early stages of PD in comparison to healthy adults, the 9HPT may be an especially important tool for making decisions about early intervention that might limit the impact of motor impairment and help maintain quality of life. Finally, as a potentially responsive measure of change, the 9HPT should be considered as one of a battery of tests for tracking changes in function over time if future studies show it has good test-retest reliability when tested 1 or more weeks apart.

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