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Gammon M. Earhart
Washington University School of Medicine in St. Louis

James T. Cavanaugh
University of New England

Terry D. Ellis
Boston University

Matthew P. Ford
University of Alabama - Birmingham

Kenneth B. Foreman
University of Utah

See next page for additional authors

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Authors

Gammon M. Earhart, James T. Cavanaugh, Terry D. Ellis, Matthew P. Ford, Kenneth B. Foreman, and Leland E. Dibble

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

Earhart G.M.[1], Cavanaugh J.T.[2], Ellis T.[3], Ford M.P.[4], Foreman K.B.[5], Dibble L.E.[5]

[1] Program in Physical Therapy, Washington University in St. Louis-School of Medicine

[2] Department of Physical Therapy, University of New England

[3] Department of Physical Therapy and Athletic Training, Boston University

[4] Department of Physical Therapy, School of Health Professions, University of Alabama at Birmingham

[5] Department of Physical Therapy, University of Utah, 520 Wakara Way, Salt Lake City, UT 84108

Corresponding Author:
Gammon M. Earhart, PhD, PT
Assistant Professor of Physical Therapy, Anatomy & Neurobiology, and Neurology
Washington University School of Medicine
Program in Physical Therapy
Campus Box 8502
4444 Forest Park Blvd.
St. Louis, MO 63108
314-286-1425
earhartg@wusm.wustl.edu

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ABSTRACT

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:** 262 individuals with PD (67% male, H&Y = 2.3 +/- 0.7) completed the 9HPT along with a battery of other tests that included 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 +/- 15.7s with the dominant and 32.2 +/- 12.4s with the non-dominant hand. Test-retest reliability of two trials performed with the same hand was high (dominant r = 0.88, non-dominant r = 0.91). Women performed the test significantly faster than men, and non-freezers significantly faster than freezers. For either hand, age, bradykinesia, and freezing of gait scores individually predicted significant portions of the variance in 9HPT time. Gender also was a significant predictor, but for the non-dominant hand only. Tremor and rigidity did not predict performance. **Discussion and Conclusions:** The 9HPT appears to be a clinically useful measure for assessing upper extremity function in individuals with PD and has advantages over previously used methods including standardization, known normative values for healthy controls, commercial availability, transportability, and ease of administration.

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

BACKGROUND AND PURPOSE

The motor symptoms of Parkinson disease (PD) commonly affect the upper extremities [1-3]. Impaired upper extremity function in PD has been associated with limitations in activities of daily living and reductions in quality of life [4]. 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 [5]. In addition, items used to assess upper extremity function within the UPDRS may not reflect clinically relevant dexterity tasks and as such are not ecologically valid. Other measures that might detect subtle impairment or are more responsive to change have undergone only limited scrutiny [6-8].

Several studies have used some version of peg insertion to assess motor function. For example, a series of studies conducted by Müller et al. examined upper extremity function using a peg insertion task that involved placement of 25 pegs into a computerized contact board [9-11]. 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 where pegs were transferred from one row to another [5,12]. The authors of these studies noted that the peg insertion task correlated well with disease severity and duration, was quite 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 have potential utility as an outcome measure in clinical trials.

A limitation of these prior 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 [13-15]. The 9HPT requires participants to quickly place 9 small pegs from a holding tray into holes on a board and then remove them. As such, 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 [17,18].

To our knowledge, only a few studies have specifically evaluated the 9HPT in people with PD [6,19,20]. In one study, a small sample of people with PD performed the 9HPT as part of a battery of assessments administered via the internet [19]. This study showed that the 9HPT could be successfully administered remotely with high intra- and inter-rater 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 [20]. 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 (i.e., motor blocks), remain unclear [21,22].

The broad objective of the present study was to continue to evaluate the potential clinical utility of the 9HPT. Specifically, we examined 9HPT results collected from a large sample of individuals with PD 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.

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METHODS

Participants

Two hundred sixty-four individuals with idiopathic PD were recruited and tested at four 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 PD [23]. Inclusion criteria were as follows: 1) at least 40 years of age, 2) neurologist diagnosed idiopathic PD (using UK Brain Bank criteria), 3) Hoehn & Yahr stages 1-4, 4) MMSE $\geq$ 24/30, and 5) living in the community. Exclusion criteria included diagnosis of atypical Parkinsonism, Hoehn & Yahr stage 5, and previous surgical management of PD. Participants were tested on medication, generally 1-1.5 hours after taking their anti-parkinson medication.

Data Collection

Complete data collection procedures for the longitudinal study have been described elsewhere [23]. 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 MDS-UPDRS-III motor subscale [24]. The occurrence of motor blocks during functional activities was captured using a Freezing of Gait questionnaire (FOG-Q) [25]. Participants performed two trials of the 9HPT with the dominant hand and two with the non-dominant hand. Dominance was based on handedness regardless of which side had more severe PD motor symptoms. Side of worst motor symptoms 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 non-dominant hand, per the standardized administration instructions for the test. 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 [NON-DOMINANT] 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) gender; 3) medication, expressed as daily levodopa equivalents (LEDD); 4) years with diagnosed PD; 5) Hoehn & Yahr (H&Y) stage; 6) total score on the FOG_Q; 7) rigidity, operationalized as the MDS-UPDRS score for the upper extremity; 8) bradykinesia, operationalized as the sum of MDS-UPDRS finger tapping, hand movements, and pronation-supination items for the upper extremity; 9) tremor, operationalized 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 non-dominant hand, as were 9HPT scores.

Descriptive statistics were used to characterize average 9HPT values. Test-retest reliability of two trials performed with the same hand was determined using intraclass correlations coefficient (ICC 2,1). Minimum detectable change values were calculated using the following equation:

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

where SD is the standard deviation of baseline scores and r_{xx} was the Pearson correlation between the two trials performed with the same hand [26].

Values for the two trials performed with the same hand were averaged for all other analyses. Performance between men and women, between "freezers" and "non-freezers," and between the study sample and published norms for age-matched healthy controls (n=14 males, 31 females) [16] 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 [27]. 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 9-HPT 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 non-dominant 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 appear in Table 1 for the sample as a whole, for men vs. women, and for freezers vs. non-freezers. For the entire sample, time (mean +/- SD) to complete the 9HPT was 31.4 +/- 15.7s with the dominant hand and 32.2 +/- 12.4s with the non-dominant hand. 9HPT times were generally lower (i.e., faster speed) among participants at H&Y Stage I (n = 12, dominant = 23.5 ± 5.6s, non-dominant = 23.5 ± 5.2s) relative to participants at H&Y Stage IV (n = 15, dominant = 43.3 ± 15.9s, non-dominant = 47.9 ± 15.9s) (Table 2). Figure 1 shows 9HPT times for the dominant and non-dominant hand in groups of healthy, age-matched men and women control,[16] men and women with PD, and for freezers and non-freezers with PD. Freezers took longer to complete the 9HPT than non-freezers [t(260)= -5.54, p<0.001, 2-tailed]. For people with PD,

there were no differences in performance with the dominant versus the non-dominant 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 in 33.2 ± 14.7s (dominant hand) and 34.4 ± 12.8s (non-dominant hand), compared to women with PD, who completed the test in 29.1 ± 16.7s (dominant hand) and 29.5 ± 11.2s (non-dominant 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 non-dominant hand [Men: t(161)=-3.51, p<0.001; Women: t(142)=-3.95, p<0.001]. Age-matched healthy men completed the test in 21.1 ± 3.3s (dominant hand) and 22.3 +/- 3.7s (non-dominant hand). Age-matched healthy women completed the test in 19.9 ± 3.2s with the dominant hand and 21.4 ± 3.9s with the non-dominant hand.[16] 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 non-dominant) for two consecutive trials using either hand. The SEM was 1.02s for the dominant hand and 0.82s for the non-dominant hand, with a minimum detectable change of 2.6 s for the dominant hand and 1.3s for the non-dominant hand.

[INSERT TABLE 1 ABOUT HERE]

[INSERT TABLE 2 ABOUT HERE]

[INSERT FIGURE 1 ABOUT HERE]

Pearson correlations between study variables are shown in Table 3. For each hand, the variables that were significant (p ≤ 0.05) were entered into multiple regression analyses. The variables entered were: age, gender, years with PD, H&Y, 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 non-dominant hand, age, bradykinesia, FOG_Q, and gender combined to explain 41.0% of the variance in 9HPT performance, with gender contributing only 2% to the overall R^2; 22% of the variance was explained by bradykinesia alone (Table 4). Multicollinearity was not a concern in either regression analysis; variance inflation factors were all ≤ 1.2.

[INSERT TABLE 3 ABOUT HERE]

[INSERT TABLE 4 ABOUT HERE]

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, supported its intra- and inter-rater reliability and potential utility as a responsive measure of change [19,20]. To our knowledge, the present 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.

Test-retest reliability

Test-retest reliability for two test trials conducted with either hand was high (ICC (2,1) =0.88, 0.91), producing relatively small SEM values. Consequently, the MDC in 9HPT

performance in people with PD, H&Y Stages I – IV, was determined to be 2.6s for the dominant hand and 1.3s for the non-dominant 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 the present study we determined test-retest reliability between trials administered consecutively during the same session. In contrast, prior studies reporting relatively poor test-retest reliability (r=0.45) compared trials administered one week apart.[15] Future work should determine the test-retest reliability of the 9HPT administered to people with PD in separate sessions a week or more apart.

Influence of Non-modifiable Factors

Several non-modifiable factors appeared to contribute to 9HPT performance. Most notably, the presence of PD appeared to produce higher test times. In fact, people with PD, even while on their anti-parkinson medications, generally took approximately 50% longer on average than age-matched healthy adults to complete the test. Given that mean 9HPT time in the PD sample was approximately 3 SD 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 [19,20]. Moreover, given that the mean 9HPT time among H&Y I participants also was one SD 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 non-modifiable 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 – 0.41) than in healthy adults (r = 0.89 – 0.91) [16]. Based on our results, the difference in the strength of the relationship is likely a result of the influence of additional factors (i.e., 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 gender on 9HPT times in the PD population was relatively small in comparison to other factors (i.e., 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 second (roughly 1/3 of a standard deviation). Moreover, gender explained only a small percentage of the variance of 9HPT times and only for the non-dominant hand. Thus, in our view, gender would not be a critical non-modifiable factor to consider when comparing the 9HPT time of a person with PD to other people with PD. In contrast, gender would be an important consideration when comparing the 9HPT time of a person with PD to a similarly aged healthy adult.

Disease duration and stage of progression also were evaluated as non-modifiable 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 [6]. To our knowledge, however, no previous analysis had simultaneously examined the relative contributions of bradykinesia, freezing, tremor, and rigidity to physical performance on an upper extremity functional task. The findings suggests that compared to the other motor impairments, bradykinesia might make 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 that suggested upper extremity motor blocks and freezing of gait may share a common underlying mechanism [22]. In this context, our data provided further, albeit preliminary, support for the idea that interventions targeting motor blocks in PD potentially might 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 prior work demonstrating that tremor does not appear to be related to bradykinesia[3] and that other instrumented measures of bradykinesia such as spiral drawing on a digitizing tablet were not influenced by tremor [6]. The finding 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 clinical relevant fine motor dexterity task that is not examined in the MDS-UPDRS. Unlike some other commercially available tests [6], the 9HPT is relatively inexpensive and requires no specialized training to administer.

Taken together, our study findings have three 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 gender. 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 one or more weeks apart.

Acknowledgements

REFERENCES

1. van den Berg C, Beek PJ, Wagenaar RC, van Wieringen PC. Coordination disorders in patients with Parkinson's disease: a study of paced rhythmic forearm movements. *Exp Brain Res* 2000;134(2):174-86.

2. Louis ED, Tang MX, Schupf N, Mayeux R. Functional correlates and prevalence of mild parkinsonian signs in a community population of older people. *Arch Neurol* 2005;62(2):297-302.

3. Louis ED, Levy G, Côte LJ, Mejia H, Fahn S, Marder K. Clinical correlates of action tremor in Parkinson disease. *Arch Neurol* 2001;58(10):1630-1634.

4. Broderick MP, Van Gemmert AW, Shill HA, Stelmach GA. Hypometria and bradykinesia during drawing movements in individuals with Parkinson's disease. *Exp Brain Res* 2009;197(3):223-233.

5. Stewart KC, Fernandez HH, Okun MS, Jacobson CE, Hass CJ. Distribution of motor impairments influences quality of life in Parkinson's disease. *Mov Disord* 2008;23(10):1466-1488.

6. Haaxma CA, Bloem BR, Borm GF, Horstink MWIM. Comparison of a timed motor test battery to the Unified Parkinson's Disease Rating Scale-III in Parkinson's disease. *Mov Disord* 2008;23(12): 1707-1717.

7. Banaszkiewicz K, Rudzinska M, Bukowczan S, Izworski A, Szczudlik A. Spiral drawing time as a measure of bradykinesia. *Neurol Neurochir Pol* 2009;43(1):16-21.

8. Yokoe M, Okuno R, Hamasaki T, Kurachi Y, Akazawa K, Sakoda S. Opening velocity, a novel parameter, for finger tapping test in patients with Parkinson's disease. *Parkinsonism Relat Disord* 2009;15(6):440-4.

9. Robichaud JA, Pfann KD, Leurgans S, Vaillancourt DE, Comella CL, Corcos DM. Variability of EMG patterns: a potential neurophysiological marker of Parkinson's disease? *Clin Neurophysiol* 2009;120(2):390-7.

10. Müller T, Benz S, Przuntek H. Tapping and peg insertion after levodopa intake in treated and de novo parkinsonian patients. *Can J Neurol Sci* 2002;29(1):73-77.

11. Müller T, Meisel M, Russ H, Przuntek H. Motor impairment influences Farnsworth-Munsell 100 Hue test error scores in Parkinson's disease patients. *J Neurol Sci* 2003;213:61-65.

12. Müller T, Erdmann C, Muhlack S, Breman D, Przuntek H, Woitalla D. Entacapone improves complex movement performance in patients with Parkinson's disease. *J Clin Neurosci* 2007;14:424-428.

13. Haaxma CA, Bloem BR, Overeem S, Borm GF, Horstink MWIM. Timed motor tests can detect subtle motor dysfunction in early Parkinson's disease. *Mov Disord* 2010;25(9):1150-1156.

14. Kellor M, Frost J, Silberberg N, Iversen I, Cummings R. Hand strength and dexterity. Amer *J Occup Ther* 1971;25(2):77-83.

15. Mathiowetz V, Weber K, Kashman N, Volland G. Adult norms for the nine hole peg test of finger dexterity. *Occ Ther J Res* 1985;5(1):24-38.

16. Oxford Grice K, Vogel KA, Le V, Mitchell A, Muniz S, Vollmer MA. Adult norms for a commercially available nine hold peg test for finger dexterity. *Am J Occup Ther* 2003;57(5):570-573.

17. Beebe JA, Lang CE. Relationships and responsiveness of six upper extremity function tests during the first six months of recovery after stroke. *J Neurol Phys Ther* 2009;Jun;33(2):96-103.

18. van Winsen LM, Kragt JJ, Hoogervorst EL, Polman CH, Uitdehaag BM. Outcome measurement in multiple sclerosis: detection of clinically relevant improvement. *Mult Scler* 2010;16(5):604-10.

19. Hoffman T, Russell T, Thompson L, Vincent A, Nelson M. Using the Internet to assess activities of daily living and hand function in people with Parkinson's disease. *NeuroRehabilitation* 2008;23(3):253-261.

20. Caglar AT, Gurses HN, Mutuluay FK, Kiziltan G. Effects of home exercises on motor performance in patients with Parkinson's disease. *Clin Rehabil* 2005; 9(8):8870-8877.

21. Popovic MB, Dzoljic E, Kostic V. A method to assess hand motor blocks in Parkinson's disease with digitizing tablet. *Tohoku J Exp Med* 2008;216(4):317-324.

22. Nieuwboer A, Vercruysse S, Feys P, Levin O, Spildooren J, Swinnen S. Upper limb movement interruptions are correlated to freezing of gait in Parkinson's disease. *Eur J Neurosci* 2009;29(7):1422-1430.

23. Dibble LE, Cavanaugh JT, Earhart GM, Ellis T, Ford M, Foreman KB. Charting the Progression of Disability in Parkinson Disease: Study Protocol for a Prospective Longitudinal Cohort Study. *BMC Neurology* 2010; 10:110. http://www.biomedcentral.com/1471-2377/10/110

24. Goetz CG, Tilley BC, Shaftman SR, Stebbins GT, Fahn S, Martinez-Martin P, et al.; Movement Disorder Society UPDRS Revision Task Force. Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): scale presentation and clinimetric testing results. *Mov Disord* 2008;23(15):2129-2170.

25. Giladi N, Tal J, Azulay T, Rascol O, Brooks DJ, Melamed E, Oertel W, et al. Validation of the freezing of gait questionnaire in patients with Parkinson's disease. *Mov Disord* 2009;24(5):655-661.

26. Lehman LA, Velozo CA. Ability to detect change in patient function: responsiveness Designs and methods of calculation. *J Hand Ther* 2010;23(4):361-371.

27. Nieuwboer A, Kwakkel G, Rochester L, Jones D, van Wegen E, Willems AM, et al. Cueing training in the home improves gait-related mobility in Parkinson's disease: the RESCUE trial. *J Neurol Neurosurg Psychiatry* 2007;78:134-140.
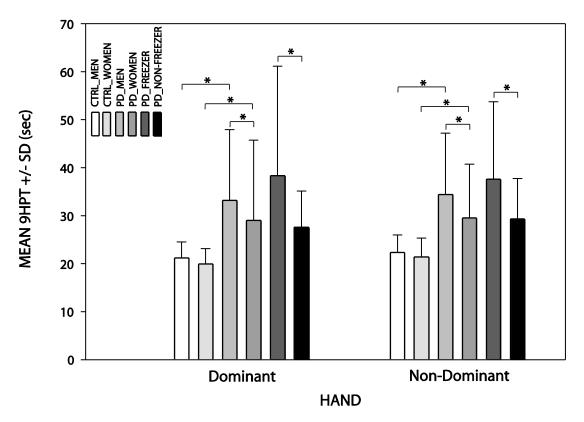
Figure Legend

Figure 1. This graph illustrates 9HPT scores for age-matched men and women[16], men and women with PD, and freezer and non-freezers. Data are presented separately for the dominant and non-dominant hands. Values are means ± SDs. Asterisks indicate significant differences between conditions at p ≤ 0.003.

Table 1. Participant Characteristics

	Total Sample (n=262)	Men (n=149)	Women (n=113)	Freezers (n=93)	Non-Freezers (n=169)
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*	2.2 ± 0.5
FOG_Q	6.0 ± 5.3	6.5 ± 5.5	5.4 ± 5.0	12.0 ± 3.6*	2.7 ± 2.5
UPDRS-III	33.7 ± 15.0	35.3 ± 15.4	31.6 ± 14.3	42.0 ± 16.0*	29.3 ± 12.5
Rig DOM	1.4 ± 0.8	1.5 ± 0.8	1.2 ± 0.9	1.6 ± 0.8*	1.3 ± 0.8
Rig NON	1.4 ± 0.9	1.6 ± 0.8	1.3 ± 0.9	1.6 ± 0.8*	1.4 ± 0.9
Brady DOM	4.1 ± 2.5	4.2 ± 2.5	4.0 ± 2.4	4.9 ± 2.6*	3.7 ± 2.3
Brady NON	4.5 ± 2.6	4.6 ± 2.6	4.5 ± 2.6	5.4 ± 2.7*	4.1 ± 2.4
Tremor DOM	1.6 ± 1.9	1.9 ± 2.1	1.2 ± 1.7	2.1 ± 2.4*	1.4 ± 1.6
Tremor NON	1.6 ± 1.8	1.8 ± 1.8	1.5 ± 2.0	1.9 ± 2.2*	1.5 ± 1.6

Values are means +/- SDs.

 * = significantly different from non-freezers

LEDD = Levodopa equivalent dose, H&Y = Hoehn and Yahr, FOG_Q= Freezing of Gait Questionnaire, UPDRS-III= Unified Parkinson Disease Rating Scale Motor Subsection III, Rig = Rigidity, Brady = Bradykinesia, DOM = Dominant Upper Extremity, NON = Non-dominant Upper Extremity

Table 2. 9HPT Scores by Hoehn &Yahr Stage

Modified Hoehn &Yahr Stage	Dominant Hand	Non-Dominant Hand
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

Values are means +/- SDs.

Table 3. Correlations Between Variables

	Age	Gender	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	0.28	0.16	0.08	0.03	0.28	0.22	0.05	-0.06	0.34	0.41
Gender	---	1.0	-0.01	-0.05	-0.03	-0.11	-0.15*	-0.13*	-0.01	-0.00	-0.16	-0.07	-0.12*	-0.19
LEDD	---	---	1.0	0.21	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	0.30	0.41	0.27	0.17	0.28	0.23	0.21	0.24	0.20	0.32
H&Y	---	---	---	---	1.0	0.47	0.28	0.22	0.53	0.48	0.22	0.19	0.28	0.37
FOG_Q	---	---	---	---	---	1.0	0.19	0.14*	0.32	0.29	0.12	0.16*	0.35	0.42
Rig DOM	---	---	---	---	---	---	1.0	0.53	0.45	0.29	0.26	0.27	0.20	0.20
Rig NON	---	---	---	---	---	---	---	1.0	0.31	0.36	0.18	0.19	0.09	0.21
Brady DOM	---	---	---	---	---	---	---	---	1.0	0.74	0.29	0.18	0.45	0.41
Brady NON	---	---	---	---	---	---	---	---	---	1.0	0.16	0.36	0.40	0.47
Trem DOM	---	---	---	---	---	---	---	---	---	---	1.0	0.49	0.20	0.11
Trem NON	---	---	---	---	---	---	---	---	---	---	---	1.0	0.17	0.18
9HPT DOM	---	---	---	---	---	---	---	---	---	---	---	---	1.0	0.67
9HPT NON	---	---	---	---	---	---	---	---	---	---	---	---	---	1.0

Bolded items significant at p < 0.01, * = significant at p < 0.05

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

9HPT DOMINANT HAND	B	SE B	β	R² When Fit Alone	Partial R²	Total R² for This Variable and Variables Above
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 NON-DOMINANT HAND	B	SE B	β	R² When Fit Alone	Partial R²	Total R² for This Variable and Variables Above
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
Gender	0.26	1.21	-.14	0.04	0.03	0.41