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The Unified Parkinson's Disease Rating Scale as a predictor of peak aerobic capacity and ambulatory function

Frederick M. Ivey, PhD;[1–2*] Leslie I. Katzel, MD, PhD;[2–3] John D. Sorkin, MD, PhD;[2–3] Richard F. Macko, MD;[1–2] Lisa M. Shulman, MD[1]

[1]University of Maryland School of Medicine, Department of Neurology, Baltimore, MD; [2]Division of Gerontology and Geriatric Medicine, Department of Veterans Affairs (VA) and VA Medical Center, Geriatric Research, Education and Clinical Center, Baltimore, MD; [3]University of Maryland School of Medicine, Department of Medicine, Baltimore, MD

Abstract—The Unified Parkinson's Disease Rating Scale (UPDRS) is a widely applied index of disease severity. Our objective was to assess the utility of UPDRS for predicting peak aerobic capacity (VO_2 peak) and ambulatory function. Participants (n = 70) underwent evaluation for UPDRS (Total and Motor ratings), VO_2 peak, 6-minute walk distance (6MW), and 30-foot self-selected walking speed (SSWS). Using regression, we determined the extent to which the Total and Motor UPDRS scores predicted each functional capacity measure after adjusting for age and sex. We also tested whether adding the Hoehn and Yahr scale (H-Y) to the model changed predictive power of the UPDRS. Adjusted for age and sex, both the Total UPDRS and Motor UPDRS subscale failed to predict VO_2 peak. The Total UPDRS did weakly predict 6MW and SSWS (both $p < 0.05$), but the Motor UPDRS subscale did not predict these ambulatory function tests. After adding H-Y to the model, Total UPDRS was no longer an independent predictor of 6MW but remained a predictor of SSWS. We conclude that Total and Motor UPDRS rating scales do not predict VO_2 peak, but that a weak relationship exists between Total UPDRS and measures of ambulatory function.

Key words: 6-minute walk distance, ambulatory function, disease severity, endurance, motor function, Parkinson disease, self-selected walking speed, UPDRS, VO_2 peak, walking.

INTRODUCTION

The Unified Parkinson's Disease Rating Scale (UPDRS) is the most widely applied rating instrument for Parkinson disease (PD) [1–2]. The Total UPDRS score includes 31 items contributing to three subscales: (I) Mentation, Behavior, and Mood; (II) Activities of Daily Living; and (III) Motor Examination [2]. The UPDRS does not assess general cardiovascular fitness and provides only limited information on functional performance relevant to daily activities, although this information would facilitate clinical decision-making. Therefore, there is value in determining the predictive power of the UPDRS for more time-consuming and resource-intensive measures such as peak aerobic capacity (VO_2 peak) and ambulatory function.

The UPDRS includes an examination of extrapyramidal motor function and has been shown to predict physical performance measures with a strong balance component, such as Berg Balance and the functional

Abbreviations: 6MW = 6-minute walk distance, H-Y = Hoehn and Yahr scale, PD = Parkinson disease, SE = standard error, SSWS = self-selected walking speed, UPDRS = Unified Parkinson's Disease Rating Scale, VA = Department of Veterans Affairs, VO_2 peak = peak aerobic capacity.

***Address all correspondence to Frederick M. Ivey, PhD; Department of Neurology, University of Maryland School of Medicine, Baltimore VA Medical Center Geriatrics Service/GRECC, BT(18) GR, 10 North Greene St, Baltimore, MD 21201-1524; 410-637-3218; fax: 410-605-7913.**
Email: fivey@grecc.umaryland.edu

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reach tests [3–4]. Further, previous studies have shown that the UPDRS associates with daily function [3–5] and is sensitive to change over time [1] and across rehabilitation interventions [5–6]. However, uncertainty remains regarding the extent to which UPDRS predicts important aspects of function associated with ambulatory function, considering that prior investigations have failed to observe associations between UPDRS and 6-minute walk distance (6MW) [7] or between UPRDS and submaximal oxygen consumption during treadmill walking [8]. Importantly, no studies have evaluated whether the UPDRS predicts VO_2 peak, a gold standard objective physical performance measure of cardiovascular fitness. Hence, the current study sought to enhance understanding about whether UPDRS predicts VO_2 peak and ambulatory function by examining the relationship of Total and Motor UPDRS with VO_2 peak, 6MW, and floor walking speed. Based on limited prior work, we hypothesized that UPDRS would fall short of predicting VO_2 peak and ambulatory function, both of which have an endurance requirement.

METHODS

Subjects

Recruits for this cross-sectional study came from the University of Maryland Parkinson's Disease Center and the Baltimore Department of Veterans Affairs (VA) Medical Center. All had volunteered to participate in a randomized exercise intervention trial designed specifically for PD patients. Entry criteria for this study have been described previously in Katzel et al. [9] and are included in the **Appendix** (available online only).

All tests of VO_2 peak and ambulatory function were conducted on separate days to avoid the confounding effects of fatigue. The tests were done in the same order for all subjects. The treadmill VO_2 peak test was done 1 wk after assessment of ambulatory function (self-selected walking speed [SSWS] and 6MW). Further, all study evaluations (rating scales, VO_2 peak, and ambulatory function testing) were conducted soon after medication intake (<3 h) while the subjects were "on." When required, subjects took an additional dose to maintain the "on" state during evaluation.

Unified Parkinson's Disease Rating Scale Evaluation

The UPDRS scale was scored by a single neurologist to avoid the confounding effects of interrater variability. The evaluator is a board-certified neurologist and specialist in PD who is certified in the administration of the UPDRS. The UPDRS Total score was computed as the sum of UPDRS subscales I, II, and III.

Peak Aerobic Capacity

Treadmill testing was always conducted during the early afternoon hours when subjects were "on" soon after taking medication. Exercise tests were terminated according to American College of Sports Medicine guidelines [10]. Gait belts and other safety precautions protected against falls resulting from loss of balance. There were no falls during the treadmill VO_2 peak tests or assessments of ambulatory function. Subjects were instructed to use as little handrail support as possible during the treadmill tests.

Both the treadmill testing (VO_2 peak) and overground ambulatory function testing (SSWS and 6MW) protocols have been previously described for this study population in articles by Katzel et al. [9,11], and those descriptions are provided in the **Appendix** (available online only).

Statistical Methods

Separate multiple regressions were used to evaluate UPDRS as a predictor of each of the three performance measures (VO_2 peak, SSWS, and 6MW). For each outcome, a separate analysis for both Total UPDRS and Motor UPDRS was run. All analyses were originally adjusted for age and sex. The models were then rerun after adding a simpler measure of disease progression (Hoehn and Yahr scale [H-Y]) to determine whether the predictive strength of the UPDRS remained. H-Y is a clinical staging instrument that is even more widely utilized than UPDRS. Therefore, addition of H-Y to the model answers an important question related to whether UPDRS adds anything to the functional information obtained from the more routine H-Y scale. Probability values ≤ 0.05 were considered significant.

RESULTS

Subjects

A total of 70 participants were studied. Fewer observations (n = 64) were available for the 6MW analysis because of missed tests. Participants were predominantly Caucasian (90%) and male (71%) and had a mean age of 65 yr (**Table 1**). The mean H-Y score of 2.2 was indicative

of a mild to moderately impaired population of PD participants. The means for SSWS, 6MW, and VO_2 peak were also consistent with mild to moderate disability. The diversity of disability is captured by the range of scores for the total UPDRS (15–89) and H-Y (1.5–3.0) (**Table 1**).

Unified Parkinson's Disease Rating Scale as Predictor of Peak Aerobic Capacity

Neither Total UPDRS (–0.024 ± 0.034, β ± standard error [SE], p = 0.492) nor Motor UPDRS (–0.038 ± 0.048, β ± SE, p = 0.429) were significant predictors of VO_2 peak after correcting for age and sex (**Table 2**). Both age (–0.190 ± 0.042, $p < 0.001$) and sex (–3.821 ± 0.986, $p < 0.001$) were independent predictors of VO_2 peak. For each year of age, VO_2 dropped by about 0.2 mL/kg/min, and female participants with PD had VO_2 peak measurements that were on average 3.8 mL/kg/min lower than males. Neither H-Y alone nor H-Y combined with the UPDRS measures was a significant predictor of VO_2 peak.

Unified Parkinson's Disease Scale as Predictor of Ambulatory Function

When UPDRS ratings were evaluated for prediction of ambulatory function (6MW and SSWS), only Total

Table 1.
Participant characteristics.

Variable	Mean ± SD	Range
Age (yr) (n = 70)	65 ± 11	42–86
Race (White: Black: Hispanic)	63:5:2	—
Hoehn and Yahr Score	2.2 ± 0.4	1.5–3.0
UPDRS Total Score	47.1 ± 12.8	15–89
UPDRS Motor Score	32.3 ± 9.6	11–59
Body Mass Index (kg/m^2)	28.4 ± 5.0	18.0–41.6
Self-Selected Walking Speed (m/s)	1.1 ± 0.2	0.5–1.7
6-Minute Walk Distance (m) (n = 64)	414 ± 102	122–654
VO_2 Peak (mL/kg/min)	21.4 ± 4.2	12.8–32.0

SD = standard deviation, UPDRS = Unified Parkinson's Disease Rating Scale, VO_2 peak = peak aerobic capacity.

Table 2.
Relationship between Unified Parkinson's Disease Rating Scale (UPDRS) (Total and Motor scales) and peak aerobic capacity (VO_2 peak) with and without (bold) Hoehn-Yahr scale entered in model.

Outcome	N	R^2	Effect	Intercept	Age (yr)	Sex (F vs M)	Hoehn-Yahr (Low vs High)	UPDRS	
								Total	Motor
VO_2 peak (mL/kg/min)	70	0.311	β	35.995	–0.190	–3.821	—	**–0.024**	—
			SE	3.187	0.042	0.986	—	**0.034**	—
			p	0.000	0.000	0.000	—	**0.492**	—
	70	0.313	β	36.619	–0.189	–3.955	–0.461	–0.028	—
			SE	3.583	0.042	1.050	1.179	0.036	—
			p	0.000	0.000	0.000	0.697	0.439	—
	70	0.313	β	36.015	–0.187	–3.966	—	—	**–0.038**
			SE	3.113	0.042	1.014	—	—	**0.048**
			p	0.000	0.000	0.000	—	—	**0.429**
	70	0.314	β	36.400	–0.187	–4.071	–0.338	—	–0.041
			SE	3.389	0.042	1.080	1.131	—	0.049
			p	0.000	0.000	0.000	0.766	—	0.408
	70	0.307	β	35.119	–0.191	–3.802	–0.148	—	—
			SE	3.013	0.042	1.028	1.105	—	—
			p	0.000	0.000	0.000	0.894	—	—

F = female, M = male, SE = standard error of mean.

UPDRS was an independent predictor for 6MW (–2.122 ± 0.884, $\beta \pm$ SE, $p = 0.020$) and SSWS (–0.005 ± 0.002, $p = 0.008$) after adjusting for age and sex (**Table 3**). Total UPDRS, age, and sex explained 16 percent of the variance in 6MW and 24 percent of the variance in SSWS, indicating a weak but statistically significant relationship (**Figure**). Conversely, Motor UPDRS was not a significant predictor of either SSWS or 6MW, adjusting for age and sex. For both ambulatory function tests, age but not sex was a significant independent predictor. When H-Y score was added to the model, the Total UPDRS was no longer a significant independent predictor of 6MW, but the independent relationship between Total UPDRS and SSWS was retained ($p = 0.046$) (**Table 3**). Thus, the independent predictive strength of Total UPDRS for longer distance ambulatory function was compromised when a simpler global measure of disease severity was added. H-Y evaluated alone without UPDRS in the model did predict a significant portion of the variance for both ambulatory function measures (**Table 3**).

Table 3.
Relationship between Unified Parkinson's Disease Rating Scale (UPDRS) and function accessed by 6-Minute Walk Distance and Self-Selected Walking Speed with and without (bold) Hoehn-Yahr entered in model.

Outcome	*N*	R^2	Effect	Intercept	Age (yr)	Sex (F vs M)	Hoehn-Yahr (Low vs High)	UPDRS	
								Total	Motor
6-Minute	64	0.163	β	676.069	–2.493	–21.565	—	**–2.122**	—
Walk (m)			SE	83.460	1.112	26.222	—	**0.884**	—
			p	0.000	0.029	0.414	—	**0.020**	—
	64	0.387	β	482.189	–2.510	27.150	130.982	–0.442	—
			SE	83.193	0.960	24.927	28.163	0.844	—
			p	0.000	0.011	0.280	0.000	0.603	—
	64	0.088	β	609.261	–2.601	–18.307	—	—	**–0.821**
			SE	85.995	1.167	28.533	—	—	**1.328**
			p	0.000	0.030	0.524	—	—	**0.539**
	64	0.391	β	426.279	–2.642	39.269	143.462	—	0.937
			SE	78.474	0.962	25.794	26.458	—	1.141
			p	0.000	0.008	0.133	0.000	—	0.415
	64	0.384	β	457.681	–2.545	30.990	137.289	—	—
			SE	68.340	0.952	23.678	25.299	—	—
			p	0.000	0.010	0.196	0.000	—	—
Self-Selected	70	0.237	β	1.890	–0.008	–0.104	—	**–0.005**	—
Walking Speed			SE	0.183	0.002	0.057	—	**0.002**	—
(m/s)			*p*	0.000	0.001	0.071	—	**0.008**	—
	70	0.270	β	1.738	–0.008	–0.071	0.113	–0.004	—
			SE	0.201	0.002	0.059	0.066	0.002	—
			p	0.000	0.001	0.232	0.092	0.046	—
	70	0.185	β	1.791	–0.008	–0.116	—		**–0.005**
			SE	0.185	0.002	0.060	—	—	**0.003**
			p	0.000	0.002	0.058	—	—	**0.095**
	70	0.242	β	1.629	–0.008	–0.072	0.143	—	–0.004
			SE	0.194	0.002	0.062	0.065	—	0.003
			p	0.000	0.002	0.249	0.031	—	0.212
	70	0.223	β	1.518	–0.008	–0.049	0.159	—	—
			SE	0.174	0.002	0.059	0.064	—	—
			p	0.000	0.001	0.415	0.015	—	—

F = female, M = male, SE = standard error of mean.

DISCUSSION

Our results show that neither the Total nor Motor UPDRS predicts VO_2 peak in mild to moderate PD. Total UPDRS but not Motor UPDRS was found to weakly predict ambulatory function. These findings extend the work of previous investigations on the clinical and functional significance of UPDRS ratings [3,12–13].

The UPDRS is the most common instrument used to track PD severity and is widely considered the gold standard for evaluation of PD in both clinical and research settings [1–2]. The UPDRS has attained this status based on both its reliability [14–16] and sensitivity to change over time [6,17]. Nonetheless, the relationship between UPDRS ratings and progression of disability is not fully understood [18–19]. The ability of the UPDRS to predict performance on quantitative tests of physical function has also not been fully established [3]. Our study shows that UPDRS is not associated with VO_2 peak, a performance measure relevant to cardiovascular and metabolic health as well as general functional capacity. Items in the UPDRS focus predominantly on the motor features of PD including bradykinesia, rigidity, and tremor [1–2]. Non-motor features of PD such as cognitive impairment, autonomic dysfunction, depression, and sleep disorders have received increasing attention in recent years [20–21] and may contribute to variations in functional status. Interestingly, none of the items on the UPDRS assess the level of physical activity or endurance.

The UPDRS has been shown to predict physical performance measures with a strong balance component. For example, Tanji et al. compared ratings on the Berg Balance Scale and Functional Reach tests with Total and Motor UPDRS in 79 participants with a range of PD severity [3]. The results showed relatively strong correlations between UPDRS ratings and these measures of physical performance. Similarly, Brusse et al. found associations between the UPDRS and tests of balance, but failed to observe associations with ambulatory function [4]. They concluded that the single item of gait assessment in the Motor UPDRS (item 29) is inadequate to reflect walking performance [4]. This point may also be relevant to the weak performance of the UPDRS in predicting the ambulatory function and VO_2 peak measures in this study. Hence, previous studies indicate that the UPDRS may be a decent predictor of short physical performance measures with a strong balance component, but our results and others cast doubt on its utility for predicting

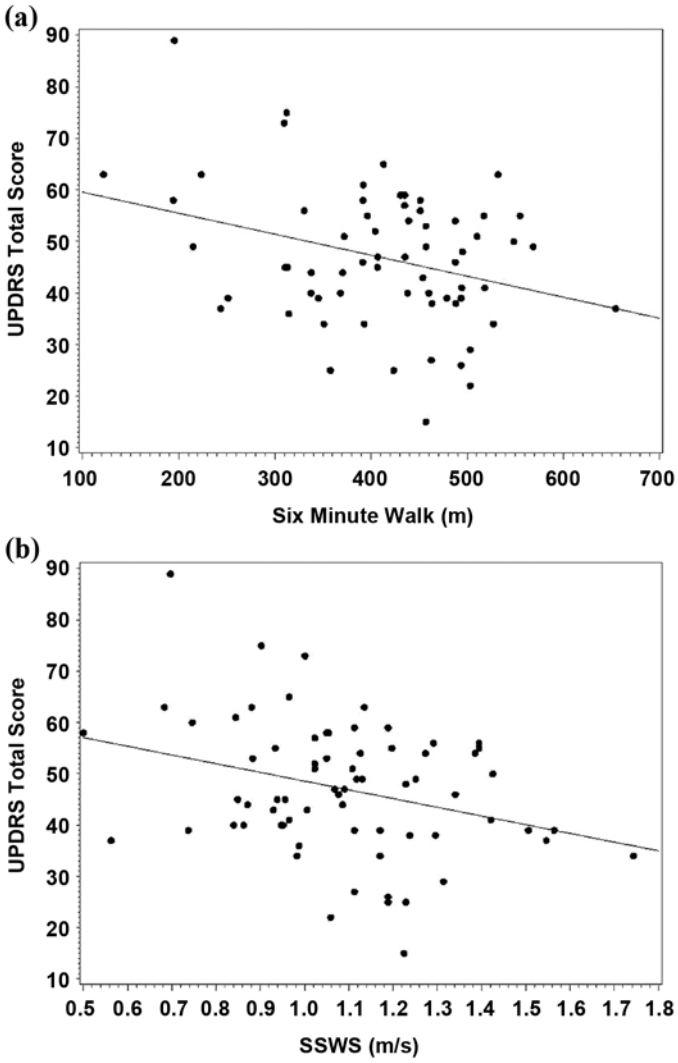

Figure.
Scatter plots depicting relationship between total Unified Parkinson's Disease Rating Scale (UPDRS) and **(a)** 6-minute walk or **(b)** self-selected walking speed (SSWS). Modest but significant relationship disappeared after adding Hoehn and Yahr to model for **(a)** but not **(b).**

ambulatory function and VO_2 peak performance, which requires sustained effort and a degree of endurance. Although studies have shown that the UPDRS is correlated with community ambulation patterns as measured by step activity monitoring [5], the distance walked over the course of a day in the community is a different aspect of function than measures of ambulatory function and VO_2 peak obtained during formal laboratory testing. This is based on the higher levels of effort required for the laboratory tests. Both our findings and those of Falvo and Earhart [7]

demonstrate that the UPDRS is not an independent predictor of 6MW when age and H-Y are added to the regression model.

The absence of an association between UPDRS and VO_2 peak observed in this study is partially supported by previous studies measuring VO_2 in PD. Canning et al. showed that VO_2 peak during cycle ergometry was not related to disease severity as assessed by H-Y staging [22]. Additionally, Christiansen et al. measured submaximal VO_2 during treadmill walking in PD (2.3 mph, 0 grade) and found that VO_2 was not correlated with Total UPDRS [8]. In combination with our results, it is reasonable to conclude that, in patients with mild to moderate PD, the UPDRS does not reflect either peak or submaximal aerobic performance.

Limitations of this study include the failure to study the full range of PD severity. Because we studied subjects with mild to moderate impairment (H-Y 1.5–3 while "on," mean 2.2 ± 0.4), our results may not be generalizable to the full spectrum of disease severity. Floor effects may limit sensitivity of the UPDRS in milder stages of the disease [1]. In addition to studying a broader range of disease severity, future studies should compare UPDRS with a larger battery of objective functional outcome tests. In this study, the majority of patients (57%) did not experience motor fluctuations, while 43 percent had fluctuations. There is no way to completely eliminate potential effects from varying medication levels. However, we attempted to proactively address this by performing exercise and study evaluations while the subjects were within 3 h of antiparkinsonian medication administration. If participants perceived that their medications were wearing off, our protocol permitted administration of an additional dose of antiparkinsonian medication, but this was not necessary during the study.

CONCLUSIONS

To summarize, the results shed additional light on the functional and clinical relevance of the UPDRS. The data show that PD severity assessed by the UPDRS Motor Examination subscale does not predict VO_2 peak or ambulatory function (6MW, SSWS). Further, Total UPDRS does not predict VO_2 peak but does independently predict SSWS, albeit modestly. Although there was a weak association between 6MW and Total UPDRS, the relationship disappeared after adding H-Y to the model. Lack of association with VO_2 peak may partly be a function of the underemphasis of UPDRS items on ambulatory function and associated elements of endurance. The UPDRS will continue to be widely used in assessing disease progression and the effectiveness of neuroprotective agents and for therapeutic decision-making by clinicians [2,13]. Hence, increased understanding about the scale's limitations in predicting results on ambulatory function and VO_2 peak tests is important. Future attempts at revising the UPDRS scale should consider components related to sustained activity and endurance.

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Study concept and design: L. M. Shulman, R. F. Macko.
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Drafting of manuscript: F. M. Ivey.
Critical revision of manuscript for important intellectual content: F. M. Ivey, L. I. Katzel, J. D. Sorkin, R. F. Macko, L. M. Shulman.
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REFERENCES

1. Ebersbach G, Baas H, Csoti I, Müngersdorf M, Deuschl G. Scales in Parkinson's disease. J Neurol. 2006;253(Suppl 4): IV32–35. [PMID:16944355] http://dx.doi.org/10.1007/s00415-006-4008-0
2. Poewe W. Clinical measures of progression in Parkinson's disease. Mov Disord. 2009;24(S2):S671–76.
3. Tanji H, Gruber-Baldini AL, Anderson KE, Pretzer-Aboff I, Reich SG, Fishman PS, Weiner WJ, Shulman LM. A comparative study of physical performance measures in Parkinson's

disease. Mov Disord. 2008;23(13):1897–1905. [PMID:18709681] http://dx.doi.org/10.1002/mds.22266
4. Brusse KJ, Zimdars S, Zalewski KR, Steffen TM. Testing functional performance in people with Parkinson disease. Phys Ther. 2005;85(2):134–41. [PMID:15679464]
5. Skidmore FM, Mackman CA, Pav B, Shulman LM, Garvan C, Macko RF, Heilman KM. Daily ambulatory activity levels in idiopathic Parkinson disease. J Rehabil Res Dev. 2008; 45(9):1343–48. [PMID:19319758] http://dx.doi.org/10.1682/JRRD.2008.01.0002
6. Schrag A, Spottke A, Quinn NP, Dodel R. Comparative responsiveness of Parkinson's disease scales to change over time. Mov Disord. 2009;24(6):813–18. [PMID:19199355] http://dx.doi.org/10.1002/mds.22438
7. Falvo MJ, Earhart GM. Six-minute walk distance in persons with Parkinson disease: a hierarchical regression model. Arch Phys Med Rehabil. 2009;90(6):1004–8. [PMID:19480877] http://dx.doi.org/10.1016/j.apmr.2008.12.018
8. Christiansen CL, Schenkman ML, McFann K, Wolfe P, Kohrt WM. Walking economy in people with Parkinson's disease. Mov Disord. 2009;24(10):1481–87. [PMID:19441128] http://dx.doi.org/10.1002/mds.22621
9. Katzel LI, Ivey FM, Sorkin JD, Macko RF, Smith B, Shulman LM. Impaired economy of gait and decreased six-minute walk distance in Parkinson's disease. Parkinsons Dis. 2012; 2012:1–6.
10. American College of Sports Medicine. Guidelines for exercise testing and prescription. Baltimore (MD): Lippincott, Williams & Wilkins; 2006.
11. Katzel LI, Sorkin JD, Macko RF, Smith B, Ivey FM, Shulman LM. Repeatability of aerobic capacity measurements in Parkinson disease. Med Sci Sports Exerc. 2011;43(12): 2381–87. [PMID:21606869] http://dx.doi.org/10.1249/MSS.0b013e31822432d4
12. Schrag A, Sampaio C, Counsell N, Poewe W. Minimal clinically important change on the unified Parkinson's disease rating scale. Mov Disord. 2006;21(8):1200–7. [PMID:16673410] http://dx.doi.org/10.1002/mds.20914
13. Shulman LM, Gruber-Baldini AL, Anderson KE, Fishman PS, Reich SG, Weiner WJ. The clinically important difference on the unified Parkinson's disease rating scale. Arch Neurol. 2010;67(1):64–70. [PMID:20065131] http://dx.doi.org/10.1001/archneurol.2009.295
14. Metman LV, Myre B, Verwey N, Hassin-Baer S, Arzbaecher J, Sierens D, Bakay R. Test-retest reliability of UPDRS-III, dyskinesia scales, and timed motor tests in patients with advanced Parkinson's disease: an argument against multiple baseline assessments. Mov Disord. 2004;19(9):1079–84. [PMID:15372601] http://dx.doi.org/10.1002/mds.20101
15. Martinez-Martin P, Forjaz MJ. Metric attributes of the unified Parkinson's disease rating scale 3.0 battery: Part I, feasibility, scaling assumptions, reliability, and precision. Mov Disord. 2006;21(8):1182–88. [PMID:16673397] http://dx.doi.org/10.1002/mds.20916
16. Martínez-Martín P, Gil-Nagel A, Gracia LM, Gómez JB, Martínez-Sarriés J, Bermejo F; The Cooperative Multicentric Group. Unified Parkinson's Disease Rating Scale characteristics and structure. Mov Disord. 1994;9(1):76–83. [PMID:8139608] http://dx.doi.org/10.1002/mds.870090112
17. Frazzitta G, Maestri R, Bertotti G, Uccellini D, Bazzini G, Abelli P, Aquilani R. Rehabilitation in Parkinson's disease: assessing the outcome using objective metabolic measurements. Mov Disord. 2010;25(5):609–14. [PMID:20201004] http://dx.doi.org/10.1002/mds.22871
18. Shulman LM, Gruber-Baldini AL, Anderson KE, Vaughan CG, Reich SG, Fishman PS, Weiner WJ. The evolution of disability in Parkinson disease. Mov Disord. 2008;23(6): 790–96. [PMID:18361474] http://dx.doi.org/10.1002/mds.21879
19. Espay AJ, Beaton DE, Morgante F, Gunraj CA, Lang AE, Chen R. Impairments of speed and amplitude of movement in Parkinson's disease: a pilot study. Mov Disord. 2009; 24(7):1001–8. [PMID:19230031] http://dx.doi.org/10.1002/mds.22480
20. Poewe W. The natural history of Parkinson's disease. J Neurol. 2006;253(Suppl 7):VII2–6. [PMID:17131223] http://dx.doi.org/10.1007/s00415-006-7002-7
21. Post B, Merkus MP, de Haan RJ, Speelman JD. Prognostic factors for the progression of Parkinson's disease: a systematic review. Mov Disord. 2007;22(13):1839–51.
22. Canning CG, Alison JA, Allen NE, Groeller H. Parkinson's disease: an investigation of exercise capacity, respiratory function, and gait. Arch Phys Med Rehabil. 1997;78(2): 199–207. [PMID:9041903] http://dx.doi.org/10.1016/S0003-9993(97)90264-1

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