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ORIGINAL ARTICLE

Assessment of voice and speech symptoms in early Parkinson's disease by the Robertson dysarthria profile

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Abstract Changes in voice and speech are thought to involve 75–90 % of people with PD, but the impact of PD progression on voice/speech parameters is not well defined. In this study, we assessed voice/speech symptoms in 48 parkinsonian patients staging <3 on the modified Hoehn and Yahr scale and 37 healthy subjects using the Robertson dysarthria profile (a clinical–perceptual method exploring all components potentially involved in speech difficulties), the Voice handicap index (a validated measure of the impact of voice symptoms on quality of life) and the speech evaluation parameter contained in the Unified Parkinson's Disease Rating Scale part III (UPDRS-III). Accuracy and metric properties of the Robertson dysarthria profile were also measured. On Robertson dysarthria profile, all parkinsonian patients yielded lower scores than healthy control subjects. Differently, the Voice Handicap Index and the speech evaluation parameter contained in the UPDRS-III could detect speech/voice disturbances in 10 and 75 % of PD patients, respectively. Validation procedure in Parkinson's disease patients showed that the Robertson dysarthria profile has acceptable reliability, satisfactory internal consistency and scaling assumptions, lack of floor and ceiling effects, and partial correlations with UPDRS-III and Voice Handicap Index. We concluded that speech/voice disturbances are widely identified by the Robertson dysarthria profile in early parkinsonian patients, even when the disturbances do not carry a significant level of disability. Robertson dysarthria profile may be a valuable tool to detect speech/voice disturbances in Parkinson's disease.

Keywords Parkinson's disease · Dysarthria · Robertson dysarthria profile · Voice handicap index · UPDRS-III

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Introduction

Parkinson's disease (PD) is a multi-system disease associated with a variety of motor and nonmotor signs [1]. Cardinal motor signs, i.e., muscular rigidity, tremor, and bradykinesia, are thought to result, at least in part, from loss of dopaminergic neurons in the Substantia Nigra [1]. On the other hand, axial symptoms affecting postural stability, gait, ability to rise from a chair, and posture are probably associated with non-dopaminergic mechanisms [1, 2]. Parkinsonian motor symptoms may impair respiratory, phonatory and articulatory muscles and induce voice and speech disturbances [3–5]. Owing to respiratory limitations, PD patients may lack proper breathing support to produce normal phrases and loudness variation. At the phonatory level, vocal folds present reduced elongation and limited/unstable adduction, which impacts on voice quality and voice range profile. Finally, at the articulatory level, speech sound imprecision and resonance imbalance contribute to lower speech intelligibility. Therefore, parkinsonian speech is characterized by lower fundamental frequency (low pitch voice), monopitch and monoloudness (monotonous speech), phonoasthenia and lack of articulatory integrity [3–5]. Reduced message intelligibility with lack of sound precision and lower intonation patterns may limit communication and affect quality of life [6].

Although changes in voice and speech seem to occur in 75–90 % of PD patients [7, 8], the impact of PD

progression on voice/speech parameters is not well defined. A post-mortem confirmed study reported a late appearance of dysarthria in PD patients [9]. Nevertheless, voice/speech symptoms have been also described in early PD stages, but their frequency has not been accurately assessed. Most studies dealing with this issue were limited by the small size of the samples and the characteristics of the tools used to detect speech/voice disturbances, i.e., expert aided systems that can quantitatively measure acoustic parameters [10–15]. Such techniques, however, are not widely available in clinical neurological settings to screen a large number of patients. This goal can be achieved by perceptual voice analysis, a methodology based on listeners that make judgement about patient's voice parameters [7, 8, 13]. However, protocols of perceptual voice analysis are characterized by a variable and sometimes few number of voice parameters, which may negatively impact on the ability of such tools to detect voice/speech changes in PD.

Owing to the lack of validated clinical scales in patients with movement disorders and voice disturbances [18], we tested the ability of the Robertson dysarthria profile (RDP), a clinical–perceptual method exploring all components potentially involved in speech difficulties [16, 17], in detecting voice/speech change in PD patients staging <3 on the HY scale [19], i.e., patients with early PD that would theoretically express less severe voice/speech symptoms. As comparison, we referred to the Voice Handicap Index (VHI), a common validated patient-rated scale that has been developed to determine the level of disability experienced by patients with different voice disorders [20, 21], and to the perceptual evaluation parameter of voice (item 1) contained in the Unified Parkinson's Disease Rating Scale part III (UPDRS-III) [22]. Finally, the metric properties of RDP in early PD were also assessed.

Subjects and methods

Study participants

Forty-eight PD patients were consecutively recruited during a 1-year period among those attending the outpatient movement disorder clinic of our Department. Idiopathic PD was diagnosed according to United Kingdom PD Society Brain Bank criteria [23]. Only patients staging <3 on the modified H&Y scale and reaching 24 or more on Mini Mental State Examination were enrolled. None of the patients reported speech or language disorders unrelated to their PD symptoms prior to the study. All patients were under antiparkinsonian treatment. Thirty-seven healthy controls (HC) of similar age and sex were recruited among relatives of non-parkinsonian outpatients attending our center during the study period. HC had no history of neurological or communication disorders or speech therapy. Case and control subjects were not informed about the study hypothesis and all gave consent to the study that was approved by the local ethics committee. Evaluators were not blinded to the case–control status, but they were unaware of study aims.

Data collection and assessments

Demographic data and clinical information were collected from case and control subjects by one neurologist who was unaware of the study hypothesis. Levodopa equivalent daily dose (LEDD) was calculated as reported [24]. Non-motor symptoms were checked by the non-motor symptom scale [25]. In PD patients, clinical examination was performed after at least 12 h overnight withdrawal of dopaminergic medication before administration of the morning dose of antidopaminergic medication, and severity of PD motor impairment was evaluated by UPDRS-III. Severity of non-axial symptoms was the sum of tremor, rigidity and bradikinesia scores; severity of axial symptoms was the sum of facial expression, arising from chair, posture, gait and postural stability scores. In both case and control subjects, voice and speech were tested by a speech therapist (MG) using the Italian versions of RDP [17] and VHI [21]. RDP contains eight domains (respiration, phonation, facial musculature, diadochokinesis, oral reflexes, articulation, intelligibility, prosody) each including 5–20 items evaluating subject's ability. The rating is on a 4-point scale and the total score ranges from 0 to 280 (the greater the score, the better the speech performance) [16, 17]. Reliability of RDP administration was tested by a second speech therapist approximately 10 months after the original study. To assess interobserver reliability, the second rater administered RDP to 9 HC subjects who had been included in the original case–control study. To test intraobserver reliability, RDP was administered twice (with a period of approximately two weeks elapsing between the two administrations) to the 9 HC subjects participating to interobserver reliability testing and to 4 new PD patients who were not included in the original sample. VHI is a patient-rated scale that has been developed to determine the level of disability experienced by patients with different voice disorders. The complete VHI has 30 items organized in 3 domains: a 10-item functional subscale, a 10-item emotional subscale, and a 10-item physical subscale. The rating is on a 5-point scale and total score ranges from 0 to 120 (score values of 30 or less indicate no disability) [20]. VHI has been translated and clinimetrically tested in several languages including Italian [21]. In the development and validation study performed on a heterogeneous set of disorders, VHI proved to have good internal consistency and test–retest reliability [20].

Statistical analysis

Data were expressed as mean ± SD unless otherwise indicated. Intraclass correlation coefficients, *t* tests, χ^2 tests, Spearman correlation coefficients, and linear regression analysis were computed using Stata 11 package (Stata Corporation, College Station, TX, USA). *p* values <0.05 were considered to be significant. With regard to clinimetric properties of RDP, floor and ceiling effects were evaluated by inspecting total score distribution near to bottom/top of the scale and considered to be acceptable if present in <15 % of cases [26]; scaling assumptions (testing whether the RDP items are correctly grouped) were tested by the item-total correlation: to this aim, Spearman correlation coefficients were computed and considered to be acceptable when >0.30 [27, 28]; internal consistency, that typically measures correlations between different items on the same scale to assess whether the items proposed for measuring the same general construct produce similar scores, was measured by Cronbach's alpha (that ranges between 0 and 1), a statistic calculated from the pairwise correlations between items: Cronbach's alpha >0.7 indicates an acceptable level of internal consistency [29]; convergent validity, that is the ability of RDP to correlate with other measures of severity, was tested by calculating the correlation between RDP and UPDRS-III speech item. Discriminant validity (the ability of RDP to differentiate severity from other measures) was assessed by the correlation between RDP and the disability scale VHI. Finally, precision of the RDP, that is the ability to detect small differences, was assessed regarding 1 SEM of the average total score as minimal important difference representative of a real change [27].

Results

Demographic and clinical features of study participants

Forty-eight PD patients and 37 HC subjects satisfied inclusion criteria during the study period and accepted to participate in the study. The two groups were similar for age (67 ± 9.7 vs. 66 ± 13, $p = 0.3$), sex (34 men and 14 women vs. 21 men and 16 women, $p = 0.2$) and years of schooling (8.1 ± 4.2 vs. 9.2 ± 4.7, $p = 0.1$). Mean age at PD onset was 61 ± 10 years and mean disease duration was 6 ± 4 years. On modified H&Y scale, 6 PD patients staged 1, 3 patients staged 1.5, 36 patients staged 2, and 3 patients staged 2.5. All PD patients received antiparkinsonian medication including dopamine agonists (*n* 36) and/or levodopa (*n* 21). Mean LEDD was 453 ± 263 mgs. The mean UPDRS-III score was 21.5 ± 7.8 (non-axial symptom score, 19 ± 18; axial symptom score, 4.2 ± 2.1). Non-motor symptoms reported by our PD patients included sleep disturbances (*n* 35), depression (*n* 18), autonomic disturbances (*n* 30), and sensory symptoms like hyposmia (*n* 42) and pain (*n* 27). Thirty-seven PD patients reported medication other than antiparkinsonian drugs, mainly including antidepressant drugs and antihypertensive drugs.

Speech/voice disturbances in parkinsonian patients

Figure 1 shows that PD patients yielded a significantly lower mean total RDP score than HC subjects (171 ± 39 vs. 270 ± 10, $p < 0.0001$). Total RDP scores from individual PD patients and HC subjects did not overlap (PD score range 41–239; HC score range 242–286). All the eight RDP domains scored significantly lower in PD patients (Table 1). However, the proportion of impaired PD patients was significantly lower ($p < 0.01$) in the articulation than in the prosody and phonation domains. Repeated RDP rating yielded acceptable (>0.80) [29] inter-rater reliability (total RDP score, ICC = 0.81, $p < 0.001$) and intra-rater reliability (total RDP score, ICC = 0.86, $p < 0.001$). Finally, 5/48 patients (10 %) scored >30 on VHI and 36/48 patients (75 %) scored >0 on UPDRS-III speech item.

Relationships between RDP and demographic/clinical features of parkinsonian patients

No significant correlation was found between total RDP score and sex ($r = -0.1, p = 0.7$), age ($r = -0.2, p = 0.2$),

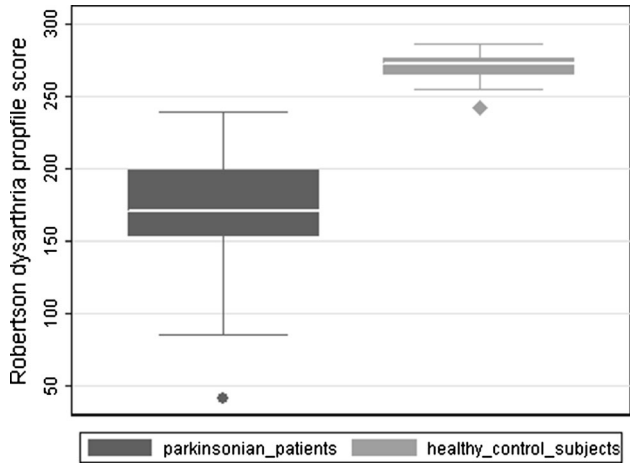

Fig. 1 Box plots in patients with Parkinson's disease and healthy control subjects. *Vertical solid lines* (whiskers) show lower and upper Robertson dysarthria profile scores. Box stretches from *lower* hinge (25th percentile) to *upper* hinge (75th percentile). Median is shown as *line* across each *box*. Outside score values are 41 in the parkinsonian group, 242 in the healthy control group. None of the score measurements in the parkinsonian group overlapped with values in the healthy control group

Table 1 Score values from Robertson dysarthria profile domains in 48 patients with Parkinson's disease and 37 healthy control subjects

Domains contributing to the Robertson dysarthria profile	Parkinsonian patients (*n* 48)	Healthy control subjects (*n* 37)	Per cent of impaired/unimpaired parkinsonian patients (%)
Respiration	12.7 ± 4.6 (1–20)*	18 ± 2.5 (5–20)	67/33
Phonation	30.8 ± 7.9 (7–46)*	45 ± 3.1 (40–48)	74/26
Facial muscles	55.8 ± 13 (29–80)*	78.4 ± 2.4 (71–80)	86/14
Diadochokinesis	22.8 ± 5.4 (12–36)*	37 ± 4 (33–44)	73/27
Oral reflexes	7.4 ± 0.9 (4–8)*	27.8 ± 0.4 (26–28)	100/0
Articulation	17.7 ± 3.8 (6–22)*	20 ± 0.2 (19–20)	51/49
Intelligibility	12.3 ± 3.7 (6–21)*	23.8 ± 0.6 (22–24)	100/0
Prosody	14.5 ± 4.9 (5–23)*	19.8 ± 0.5 (18–20)	80/20

Values are mean ± SD; range of values is in parenthesis

* Student *t* test: significantly different from healthy control group, $p < 0.0001$

Table 2 Results of multivariable linear regression analysis performed in the parkinsonian patients

Robertson Dysarthria profile total score vs.	Beta coefficient	95 % confidence interval	*p*
UPDRS-III subscore for axial symptoms	−8.8	−17.5 to −0.2	0.046
UPDRS-III subscore for non-axial symptoms	−0.2	−0.9 to 0.6	0.6
Education (years of schooling)	3.1	−1.6 to 7.7	0.2

Estimates were adjusted for age, sex, disease duration, levodopa equivalent dose, depression and medication other than antiparkinsonian drugs

PD duration ($r = -0.2$, $p = 0.1$), LEDD ($r = -0.1$, $p = 0.6$), depression (-0.1, $p = 0.3$), or medication other dopaminergic drugs ($r = 0.1$, $p = 0.4$). Differently, RDP significantly correlated with years of schooling ($r = 0.3$, $p = 0.046$), UPDRS-III total score ($r = -0.3$, $p = 0.03$) and UPDRS-III subscores for both axial symptoms ($r = -0.4$, $p = 0.01$) and non-axial symptoms ($r = -0.3$, $p = 0.04$). To check the aforementioned correlations for possible confounding by other demographic/clinical variables, multivariable linear regression analysis was performed. On multivariable modeling (adjusted for age, sex, disease duration, LEDD, depression and medication other than dopaminergic drugs), the relationships between RDP and UPDRS-III subscore for non-axial symptoms and between RDP and years of schooling lacked significance, whereas the relationships between RDP total score and UPDRS-III subscore for axial symptoms remained the only significant predictor of total RDP score variance (Table 2). The beta coefficient indicated that each 1 point increase on UPDRS-III subscore for axial symptoms corresponded to 8.8 point decrease on RDP total score.

Clinimetrics of RDP in parkinsonian patients

The distribution of the total RDP score of the 48 PD patients shows that subjects with scores near the bottom/top of the scale did not exceed the 15 % standard (data not shown). With regard to scaling assumptions, item-total correlation coefficients ranged between 0.55 and 0.81 and were, therefore, greater than the criterion 0.30. Likewise, the level of internal consistency was acceptable (Cronbach's alpha = 0.78). With regard to the convergent validity, no significant correlation emerged between total RDP and UPDRS-III speech item scores ($r = -0.15$, p 0.33); however, UPDRS-III speech item significantly correlated with 4/8 RDP domains, including respiration ($r = -0.36$, p 0.02), articulation ($r = -0.31$, p 0.05), intelligibility ($r = -0.45$, p 0.004), and prosody ($r = -0.35$, p 0.03). Discriminant validity assessing the correlation between RDP and the quality of life scale VHI yielded a partial significant correlation between the scores from the two scales ($r = -0.38$, $p = 0.02$). Finally, precision of the RDP scale as indicated by SEM was 6.1.

Discussion

In this sample of early PD, all patients yielded individual RDP scores lower than those reached by HC participants. Differently, VHI disability scale and UPDRS-III speech item could detect speech/voice disturbances in 10 and 75 % of PD patients, respectively. This suggests that speech/voice disturbance may be widely present in the early stages of PD even in the absence of a consistent level

of disability as measured by the VHI. All the eight RDP domains scored significantly lower in the PD group than in the HC group, thus indicating that all speech systems may be impaired in early PD. However, the different proportions of PD patients who were impaired in the various RDP domains indicated that articulatory disorders could occur less frequently than phonation disorders. Likewise, the articulatory domain was less frequently reported to be abnormal than the prosodic domain. Overall, the results of RDP administration in our sample of early PD patients correspond with findings from studies performing objective methodologies for exploring voice disorders in early PD [10, 11, 13]. On the basis of objective acoustic measurements, it was demonstrated that most subjects with early untreated PD have some form of vocal impairment [10], voice disorders were reported to occur more frequently than articulatory disorders [7, 8], and prosodic abnormalities were found to be dominant in early PD [10].

In the parkinsonian group, multivariable linear regression analysis yielded a significant correlation between total RDP score and severity of axial symptoms, whereas no significant correlation emerged between total RDP score and severity of non-axial symptoms. Although several studies did not find any correlation between vocal parameters and UPDRS-III scores [10, 30, 31], recent studies suggested a link between some voice aspects and axial motor symptoms. For instance, imprecise vowel articulation correlated to gait dysfunction [32], a marker of axial disease progression, and speech rate parameters correlated with axial symptoms, at least in men [33]. Since non-dopaminergic mechanisms are thought to contribute to axial PD symptoms [2], our findings add to the results of these studies in suggesting a contribution of non-dopaminergic systems to speech/voice disturbances.

The lack of correlation between total RDP score and LEDD observed in this sample is also consistent with previous studies showing that several PD speech problems do not predictably respond to chronic dopamine replacement therapy [34, 35]. However, the relationships between voice and speech performance and the dopaminergic system in PD are probably much more complex. This is suggested by recent observations indicating that vowel articulation and pitch variability may benefit from both short- and long-term dopaminergic treatment [34, 35], whereas long-term dopaminergic therapy may lead to increased occurrence of dysfluent words [36]. Likewise, deep brain stimulation, a technique thought to ameliorate parkinsonian symptoms at least in part through dopaminergic mechanisms, is known to cause a variety of speech-related side effects [37].

Validation procedure showed that the RDP has acceptable reliability and clinimetrics. As we observed that subjects with total score near the bottom or the top of the scale did not exceed 15 %, we could rule out the possibility of floor or ceiling effects [26]. Scaling assumptions were satisfactory since item-total correlation coefficients were greater than the criterion 0.30 [27, 28]. Internal consistency was acceptable for a scale with a relatively small number of items, particularly if one considers that Cronbach alpha reflects intercorrelations between items but it is also dependent on the number of items [29]. The partial correlation between RDP and the quality of life scale VHI [20], or the UPDRS-III speech item, a measure of speech severity that is widely used in clinical practice [22], indicates that RDP explores domains that are not considered by other scales. Estimation of voice-associated disability is present in the VHI but not in the RDP, while subject's abilities in the individual voice-associated features are not considered by UPDRS, but contribute to RDP. Our analysis did not detect any significant correlation between RDP and age, sex, or disease duration, which indicates that speech/voice disorders in early PD are probably independent of these variables. Finally, the lack of correlation between RDP score values and years of schooling on multivariable linear regression analysis indicates that the results of RDP administration to PD patients are probably unaffected by education level.

This study has limitations. First, assessors were not blinded to the case–control status, because it is difficult to blind a parkinsonian patient, even in the early stages of disease, from a normal subject. However, assessors were unaware of the study hypothesis. Second, interobserver reliability of RDP was assessed in a sample of HC subjects alone. Parkinsonian patients were not tested for interobserver reliability, because the assessment was performed several months after the first evaluation and, in the meanwhile, substantial changes in the voice condition of PD patients might have been occurred. However, PD patients were included in the intraobserver reliability testing that yielded satisfactory agreement. Finally, we did not compare patients in the on and off state of therapy. It must be stressed, however, that our patients were in the early stages of PD and were, therefore, unlikely to fluctuate in response to therapy.

In conclusion, our findings suggest that RDP may be a useful tool to detect speech/voice disturbances in early PD patients, even when these disturbances do not carry a significant level of disability as measured by the VHI. RDP showed a greater efficiency in detecting speech/voice disturbances in early PD than UPDRS-III speech item, another perceptual measure of speech/voice disorder largely used in PD. RDP yielded acceptable reliability, lack of floor and ceiling effects, satisfactory scaling assumptions, and acceptable internal consistency, and partial correlations with the disability scale VHI and with

prior perceptual severity measure like UPDRS-III speech item. The latter observation indicates that RDP explores domains that are not considered by the other scales. RDP administration is relatively easy, only requiring a brief standardized clinical examination that lasts about 15 min and seems to be independent of education level. RDP may, therefore, be a valuable tool to assess voice/speech symptoms in natural history and pathophysiologic studies in PD.

Compliance with ethical standards

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Conflict of interest The authors declare that they have no conflict of interest.

References

1. Braak H, Del Tredici K, Rub U, de Vos RA, Jansen Steur EN, Braak E (2003) Staging of brain pathology related to sporadic Parkinson's disease. Neurobiol Aging 24:197–211
2. Bohnen NI, Cham R (2006) Postural control, gait, and dopamine functions in parkinsonian movement disorders. Clin Geriatr Med 22:797–812
3. Darley FL, Aronson AE, Brown JR (1969) Clusters of deviant speech dimensions in he dysarthrias. J Speech Lang Hear Res 12:462
4. Darley FL, Aronson AE, Brown JR (1969) Differential diagnostic patterns of dysarthria. J Speech Hear Res 12:246–269
5. Sapir S, Ramig L, Fox C (2008) Speech and swallowing disorders in Parkinson disease. Curr Opin Otolaryngol Head Neck Surg 16:205–210
6. Ramig LO, Fox C, Sapir S (2008) Speech treatment for Parkinson's disease. Expert Rev Neurother 8:297–309
7. Ho AK, Iansek HR, Marigliani C, Bradshawa JL, Gates S (1999) Speech impairment in a large sample of patients with Parkinson's disease. Behav Neurol 11:131–137
8. Logemann JA, Fisher HB, Boshes B, Blonsky ER (1978) Frequency and co-occurrence of vocal tract dysfunction in the speech of a large sample of parkinsonian patiens. J Speech Heart Disord 43:47–57
9. Muller J, Wenning GK, Verny M, McKee A, Chaudury KR, Jellinger K, Poewe W, Litvan I (2001) Progression of Dysarthria and dysphagia in post-mortem confirmed parkinsonian disorders. Arch Neurol 58:259–264
10. Rusz J, Cmejla R, Ruzickova H, Ruzicka E (2011) Quantitative acoustic measurements for characterization of speech and voice disorders in early untreated Parkinson's disease. J Acoust Soc Am 129:350–367
11. Stewart C, Winfield L, Hunt A, Bressman SB, Fahn S, Blitzer A, Brin MF (1995) Speech dysfunction in early Parkinson's disease. Mov Disord 10:562–565
12. Skodda S, Rinsche H, Schlegel U (2009) Progression of dysprosody in Parkinson's disease over time—a longitudinal study. Mov Disord 24:716–722
13. Midi I, Dogan M, Koseoglu M, Can G, Sehitoglu MA, Gunal DI (2008) Voice abnormalities and their relation with motor dysfunction in Parkinson's disease. Acta Neurol Scand 117:26–34
14. Rusz J, Cmejla R, Ruzickova H et al (2011) Acoustic assessment of voice and speech disorders in Parkinson's disease through quick vocal test. Mov Disord 26(10):1951–1952
15. Goberman AM, Coelho C (2002) Acoustic analysis of Parkinsonian speech I: speech characteristics and L-Dopa therapy. NeuroRehabilitation 17:237–246
16. Robertson SJ, Thomson F (1987) Working with dysarthric clients: a practical guide to therapy for dysarthria. Communication Skill Builders, Tucson
17. Fussi FC (2010) Profilo di valutazione della disartria. Adattamento italiano del test di Robertson, raccolta di dati normativi e linee di intervento. Omega Edizioni, Torino
18. Albanese A, Sorbo FD, Comella C et al (2013) Dystonia rating scales: critique and recommendations. Mov Disord 28:874–883
19. Hoehn MM, Yahr MD (1967) Parkinsonism: onset, progression and mortality. Neurology 17:427–442
20. Jacobson B, Johnson A, Grywalski C et al (1997) The Voice Handicap Index (VHI): development and validation. Am J Speech-Lang Pathol 6:66–69
21. Schindler A, Ottaviani F, Mozzanica F et al (2010) Cross-cultural adaptation and validation of the Voice Handicap Index Into Italian. J Voice 24:708–714
22. Fahn S, Elton RL, Members of the UPDRS Development Committee (1987) Unified Parkinson's disease rating scale. In: Fahn S, Marsden CD, Calne DB, Goldstein M (eds) Recent developments in Parkinson's disease, vol 2. Macmillan Health Care Information, Florham Park, pp 153–164
23. Gelb DJ, Oliver E, Gilman S (1999) Diagnostic criteria for Parkinson's disease. Arch Neurol 56:33–39
24. Tomlinson CL, Stowe R, Patel S, Rick C, Gray R, Clarke CE (2010) Systematic review of levodopa dose equivalency reporting in Parkinson's disease. Mov Disord 25:2649–2653
25. Martinez-Martin P, Chaudhuri KR, Rojo-Abuin JM, Rodriguez-Blazquez C, Alvarez-Sanchez M, Arakaki T, Bergareche-Yarza A, Chade A, Garretto N, Gershanik O, Kurtis MM, Martinez-Castrillo JC, Mendoza-Rodriguez A, Moore HP, Rodriguez-Violante M, Singer C, Tilley BC, Huang J, Stebbins GT, Goetz CG (2015) Assessing the non-motor symptoms of Parkinson's disease: MDS-UPDRS and NMS Scale. Eur J Neurol 22(1):37–43
26. Hays RD, Anderson R, Revicki D (1993) Psychometric considerations in evaluating health-related quality of life measures. Qual Life Res 2:441–449
27. Nunnally JC, Bernstein IH (1994) Psychometric theory, 3rd edn. McGraw-Hill, New York
28. Fayers PM, Machin D (2000) Quality of life. Assessment, analysis and interpretation. Wiley, Chichester
29. Scientific Advisory Committee of the Medical Outcomes Trust (2002) Assessing health status and quality-of-life instruments: attributes and review criteria. Qual Life Res 11:193–205
30. Skodda S, Flasskamp A, Schlegel U (2011) Instability of syllable repetition as a marker of disease progression in Parkinson's disease: a longitudinal study. Mov Disord 26(1):59–64
31. Gamboa J, Jimenez-Jimenez J, Nieto A et al (1997) Acoustic voice analysis in patients with Parkinson's disease treated with dopaminergic drugs. J Voice 11:314–320
32. Skodda S, Grönheit W, Schlegel U (2012) Impairment of vowel articulation as a possible marker of disease progression in Parkinson's disease. PLoS ONE 7:e32132
33. Skodda S, Visser W, Schlegel U (2011) Gender related patterns of dysprosody in Parkinson's disease and correlation between speech variables and motor symptoms. J Voice 25:76–82
34. Skodda S, Visser W, Schlege U (2010) Short- and long-term dopaminergic effects on dysarthria in early Parkinson's disease. J Neural Transm 117:197–205

35. Rusz J, Mejla RC, Ruzickova H et al (2013) Evaluation of speech impairment in early stages of Parkinson's disease: a prospective study with the role of pharmacotherapy. J Neural Transm 120:319–329
36. Tykalová T, Rusz J, Čmejla R, Klempíř J, Růžičková H, Roth J, Růžička (2015) Effect of dopaminergic medication on speech dysfluency in Parkinson's disease: a longitudinal study. J Neural Transm 122:1135–1142
37. Johansson L, Möller S, Olofsson K et al (2014) Word-level intelligibility after caudal zona incerta stimulation for Parkinson's disease. Acta Neurol Scand 130:27–33