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A New Rating Instrument to Assess Festination and Freezing Gait in Parkinsonian Patients

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Abstract: Festination and freezing of gait (FOG) are sudden episodic inabilities to initiate or sustain locomotion mostly experienced during the later stages of Parkinson's disease (PD) or other higher-level gait disorders. The aim of this study was to develop a clinical rating instrument for short-interval rating of festination and FOG. Foot movements of 33 patients were video taped and rated during 12 episodes in a standardized course on a four-level interval scale according to severity. Motor blocks were provoked in four situations and by three levels of dual-tasking (tasks). Addition of the item scores produced a FOG score. The assessment requires less than 15 min. The inter-rater and re-test reliability of the FOG score is high (Kendall $\kappa = 0.85$–0.92, $P < 0.0001$). Variability of the item scale due to situations and tasks can be attributed to unidimensional group factors (Cronbach's α 0.84 and 0.94). Group comparisons and a logistic regression model show significant effects for both situations and tasks on the item scale (Friedman test: "situation": $P < 0.0001$, "task": $P < 0.0001$). Six patients with PD have significantly different scores during mobile (practical ON; 6.2 ± 3.9) and immobile (practical OFF; 15.8 ± 4.6) medication states ($P < 0.05$). The FOG score correlates with the 10 m number of steps ($\rho = 0.58$; $P = 0.001$) and with the self-evaluation of FOG ($\rho = 0.51$; $P < 0.01$). Our results encourage the further use of the FOG score to evaluate festination and FOG. © 2010 Movement Disorder Society

Key words: Parkinson's disease; rating instrument; freezing; gait disorder

Freezing of gait (FOG) is defined as an episodic gait disorder in the presence of Parkinson's disease (PD) or other higher-level gait disorders. It is characterized as a general inability to produce effective steps and includes the complete arrest of gait as well as festination.[1] FOG can be distinguished from bradykinesia,[2] and is not correlated to rigidity or postural instability.[3] FOG most often is observed in PD, but also occurs in vascular or atypical Parkinson syndromes.[4] Provoking factors are starting locomotion, turning, approaching narrow spaces or a destination, and stressful situations.[5] However, FOG can also occur without provocation.[6] The levodopa (L-dopa) blood level effects the occurrence of FOG in PD. FOG can be observed more often during off-phases, but FOG during mobile and even dyskinetic phases exists, and is a challenge to treat.[7] As FOG is a multi-dimensional and complex disorder varying in severity, duration, phenomenology, and time of occurrence, a standardized clinical assessment for FOG by a rater has not been suggested yet. Nevertheless, evaluation of FOG is of high importance. FOG not only hinders efficient locomotion but also affects quality of life beyond gait and mobility.[8] Moreover, FOG correlates with falls and associated morbidity.[9,10]

Among the approaches to achieve a standardized measurement of FOG is the question 14 of the "old" United Parkinson's Disease Rating Scale. However, this question does not differentiate the symptom from the cause, and records frequency and consequential falls on one scale. The Freezing of Gait Questionnaire

Additional Supporting Information may be found in the online version of this article.

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(FOG-Q) has been established for the self-evaluation of patients.[11] As it asks to estimate the frequency and duration of FOG during an unspecific time period it can not be used for short-interval measures, necessary to determine acute therapeutic effects. Question 14 of the UPDRS and the FOG-Q do not evaluate FOG in dual-task situations. Cognitively challenging situations may set the stage for, and increase the likelihood that FOG occurs.[12]

The 14-item Parkinson-Activity-Scale (PAS) assesses general mobility, and includes six questions that are related to FOG during starts or turns.[13] Pressure sensitive insoles or accelerometers worn on the calf detect FOG episodes more exactly and objectively than the clinician's eye.[14] However, their use has been the domain of scientific queries and the widespread clinical implementation and standardization has not been achieved yet. To ensure valid and reliable measurement of FOG, a combined methodology with tests of complex gait together with a FOG-Q has been recommended.[15] For the clinical examination it has been suggested to provoke FOG using a trajectory including turns, narrow passages, starts, and dual-task situations.[16]

Our goal was to develop a clinical instrument that is fast, cheap, and allows short-interval assessment. We chose to rate freezing severity according to the phenomenology of the leg movements, since the measurement of precise duration data, especially in festinating patients, would have required the use of technical devices to establish start and end of the FOG episode that are not commonly available precluding a broader application of the score.

METHODS

Screening and Clinical Assessments

Patients with a diagnosis of Parkinsonism and gait disorder were screened for the occurrence of FOG episodes from January 1 until June 30, 2008. The diagnosis of FOG was established clinically by history taking, neurological examination, and interviewing the caregivers. In addition, disease severity was assessed with the motor part of the Unified Parkinson Disease Rating Scale. Gait speed (m/s), step length (m), and step frequency (steps/min) were calculated from counting steps and time needed for a 10 m walk at the patients' preferred speed. Patients were further evaluated using the FOG-questionnaire (FOG-Q), a six-item self-reportable questionnaire for the assessment of frequency and duration of FOG.[11] Impairments in balance function were examined using the Berg Balance Scale, a set of 14 standardized functional tasks.[17] The patients' fear of falling was assessed using the 16-item German version of the falls efficacy scale.[18]

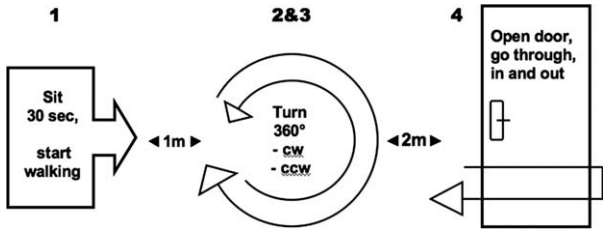

FIG. 1. The pictogram shows the course with four situations that are repeated three times with different levels of dual-tasking (tasks).

Freezing Assessment Course

Earlier studies had shown that a 60-foot course with starts, passing through a doorway and turns of 180°, provoked the occurrence of festination and FOG.[19] Other authors used more effectively turns of 360° or 540° in a 130 m trajectory and simulated tightness with chair rows standing 50 cm apart.[20] When motor blocks could not be elicited with obstacles, an additional cognitive task provoked FOG.[21] So, we started experimenting with a 100 m course but settled with at a one-room, one-door, one-chair setting, since we observed that festination and FOG could be reliably provoked with a set of simple maneuvers (see Fig. 1).

Patients were asked to sit down on a chair that was set up in front of a door. After 30 s, the patients were asked to stand up and walk to a floor mark (40 × 40 cm) as a small radius would provoke FOG more frequently.[22] Within the mark they performed two 360° turns, clockwise (cw) and counter-clockwise (ccw). Then, the patients were to open and walk through the door, turn outside, and come back to their chair. Because of the increased risk of falling in patients with FOG, we asked the patients to walk fast but safely.

Assessment of the FOG Score

Four situative maneuvers (situations) were chosen to be rated on a four-level interval scale: The start to walk, the turning within the floor mark (cw and ccw), and the passing through the door. The scaling follows a phenomenological derived concept that allows easy and clear distinctions: Zero points were given when no festination and no FOG was detected, one point was given for the observation of festination or any hastening steps ("shuffling"), two points were given for the observation of FOG (trembling-in-place or total akine-

sia), which the patient could overcome himself. Three points were given for any abortion of the task or any need of interference by the examiner, e.g., an acoustic or visual one-off cue to overcome the FOG episode. Festination was considered to be small, disturbed, and rapid steps, which left the patient with some degree of advancement.[1] Trembling-in-place was considered as a stop of locomotion with tremulous legs and no advancement. Total akinesia was considered as a stop of locomotion with no advancement and without any leg movements.

Three levels of multiple tasking were applied to this course. Patients were asked to perform the course with no pause in between the passages except for giving verbal instructions. The first passage of the course had to be performed with no additional task ("walking"). During the second passage, the patient had to perform a second motor task, i.e., carrying a tray with a plastic cup full of water ("carrying"). The third passage included the motor task and a mental task, i.e., performing a serial mathematical calculation ("carrying and calculation"). We asked the patients to talk out loud serial deductions of sevens starting at 100 (100, 93, 86...), or had them count backwards from 100 (100, 99, 98,...), or ultimately from 10 (10, 9, 8, ...), when they could not perform the more difficult calculations. If patients could not adhere to the complete set of instructions, they were reminded and restarted on the situation. While performing in the situations, no further instructions were given.

The FOG score was the sum of the 12 items rated during the performance of the four situations at three levels of dual-tasking. It ranges from 0 (gait without signs of festination or FOG) to 36 points (patient was not able to perform passages without help) (see Supporting Information, available online).

Video Off-Line Analysis

The passages were recorded on digital video (DV). Three raters (authors 1, 2, and 4) evaluated the video segments off-line which allowed for testing of inter-rater reliability, the ratings of author 4 (U.F.) who was blinded towards the other assessments was used for statistical calculations. The FOG score is designed to be assessed without video documentation. Scoring zero points for "normal gait" and three points for "abortion of the task/external help" is possible in real-time. The differentiation between one and two points is possible by looking at the patient's advancement during the episodes.

Statistical Methods

Descriptive data analyses and statistical tests were calculated with XL-STAT version 2009.5.01 (Addinsoft, New York) in Microsoft Excel. Normality of data was examined with the Shapiro-Wilk test. Inter-rater and intra-rater reliability was determined by calculating Kendall's correlation coefficient κ. Internal consistency of the FOG score was determined by calculation of two factorial analyses and determining Cronbach's α (1) for situations and (2) for tasks. To assess the dependency of the item score on situations and tasks, the non-parametric Friedman test and subsequent pairwise comparisons were calculated. Furthermore, effects of situation and tasks on the four-level scale were estimated by calculation of a multinomial logistic regression model. Criterion-validity was estimated by calculating Spearman correlation coefficient ρ. Comparative analysis within a dopa-responsive subgroup ($N = 6$) to detect effects of L-dopa on the FOG score was performed with the Wilcoxon signed-rank test. P values of <0.05 were considered to be statistically significant.

RESULTS

Study Population

Thirty-three patients who consented to have their gait assessed were included in the study. We excluded patients with severe dementia and those who were unable to walk without external help. The group consisted of 29 patients with Parkinson's disease (PD), one patient with multi-system atrophy of Parkinson type, and three patients with subcortical vascular encephalopathy. The group consisted of 25 male (75.7%) and 8 female (24.3%) patients. Median age was 72.1 (33.7–84.5). Patients with PD were evaluated during their mobile medication phases (practical ON). Six dopa-responsive patients were additionally evaluated during an immobile period (practical OFF) to assess the FOG score's sensitivity to medication induced changes. For cohort characteristics also see Table 1.

Description of the FOG Score Data

The freezing-provoking course can be set up within minutes. Depending on the severity of FOG it will take up to 15 min to assess the patient. The material required consists of a chair with armrests and floor marks (40 × 40 cm). It can be performed by patients who do not need permanent personal assistance during locomotion.

Our etiologically and clinically inhomogeneous cohort achieved a median of 9 (range: 0–36) on the FOG score. The mean value was 10.8 ± SD 9.3. Six patients scored the minimum of 0 points, although they previously had reported experiencing motor blocks.

TABLE 1. *Cohort characteristics*

Measures	N	Mean ± SD	Median	Min	Max	Test on normality
Age	33	69.9 ± 9.7	72.1	33.7	84.5	$P = 0.003$
FOG score	33	10.8 ± 9.3	9	0	36	$P = 0.004$
10 m steps	29	20.4 ± 6.9	18	13	39	$P = 0.007$
FOG questionnaire	33	14.2 ± 4.7	16	3	22	$P = 0.013$
UPDRS part III	30	24.1 ± 13.4	23	1	56	$P = 0.223$
Berg balance score	27	43.4 ± 11.5	42	17	56	$P = 0.005$
Falls efficacy scale	33	36.3 ± 13.2	32	16	62	$P = 0.128$

Descriptive statistics and tests on normality of the FOG score and other clinical measures. Only UPDRS III and falls efficacy scale were normally distributed in this cohort.

One patient scored the maximum score. FOG rendered him unable to start walking and turning without external help.

The floor effect of the score was high with six patients scoring a zero. This did not come surprisingly as we evaluated a number of patients during their mobile medication phase for which they reported not to experience FOG. Another reason could be the inherent episodic nature of motor blocks, and the high motivation of the patients.

Inter-Rater and Intra-Rater (Re-Test) Reliability

Three raters evaluated the patients' videos independently. Inter-rater reliability was calculated for the summed up FOG scores (N = 33) and for the ratings on item level (N = 396). Kendall's coefficients between the sum scores were 0.85–0.92 ($P < 0.0001$ for all correlations), on item-level Kendall's coefficients were 0.82–0.91 ($P < 0.0001$ for all correlations). One of the raters (U.F.) repeated the video-rating after 6 months. Kendall's coefficient between first FOG score and re-test was 0.97 ($P < 0.0001$).

Dimensionality and Internal Consistency

Two factorial analyses determined the dimensionality of the items using pooled datasets. The first looked at the situations (start, turn cw, turn ccw, doorway) by analyzing 297 items (33 patients × 3 raters × 3 tasks). It produced four factors with eigenvalues of 2.72, 0.74, 0.38, and 0.16, the largest explaining 67.9% of the variability, and a Cronbach's α of 0.84. The second analysis looked at tasks ("walking," "carrying," and "carrying and calculation") using 396 items (33 patients × 3 raters × 4 situations). It produced three factors with eigenvalues of 2.69, 0.23, and 0.08, respectively, factor one explaining 89.6% of the variability, and a Cronbach's α of 0.94. Taken together both calculations allow the conclusion that large portions of the items' variance due to the varied situations and tasks are attributable to unidimensional group factors.

Items Depend on Situations and Tasks

Using the same pooled data we determined the dependency of the items on situations (Friedman test, $P < 0.0001$), and on tasks ($P < 0.0001$). Post hoc group comparisons found significant differences for start, turns, and doorway situations, but not between cw and ccw turns (Bonferroni-corrected significance level $P < 0.01$), and between "walking" and "carrying and calculation" ($P < 0.05$), but not between "walking" and "carrying" or between "carrying" and "carrying and calculation." However, the task "carrying" had an in-

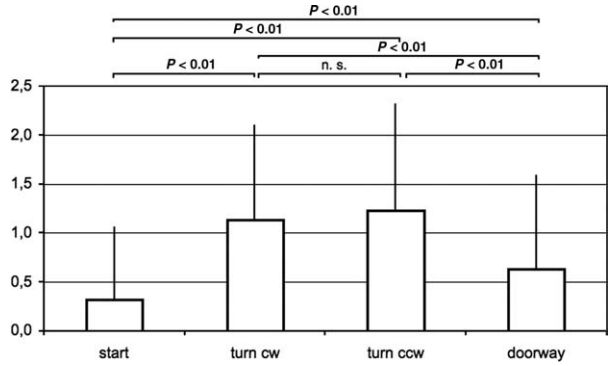

FIG. 2. Mean values of item scores of varied situations and tasks.

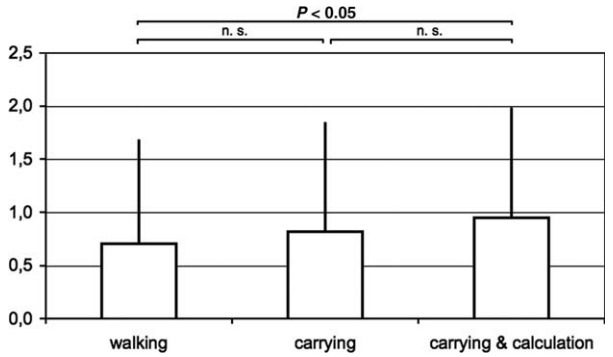

FIG. 3. Mean values of item scores of varied situations and tasks.

TABLE 2. *Multinomial logistic regression model*

Item category	Source	Odds Ratios	Pr > χ^2
1	Walking	–	–
	Carrying	1.07	0.78
	Carrying and calculation	2.04	0.001
	Start	–	–
	Turn cw	9.05	<0.0001
	Turn ccw	8.57	<0.0001
	Doorway	1.45	0.25
2	Walking	–	–
	Carrying	1.33	0.131
	Carrying and calculation	1.83	0.001
	Start	–	–
	Turn cw	11.84	<0.0001
	Turn ccw	9.13	<0.0001
	Doorway	3.13	<0.000
3	Walking	–	–
	Carrying	1.37	0.30
	Carrying and calculation	2.18	0.01
	Start	–	–
	Turn cw	5.02	<0.0001
	Turn ccw	13.18	<0.0001
	Doorway	1.96	0.13

Odds ratios of the multinomial logistic regression model for the categories 1–3 of the four-item scale. "Walking" and "start" are "baseline conditions" ($a_1 = 0$) for the other explanatory variables' sources and the other sources' effects have to be interpreted accordingly. "Carrying" was the only condition that did not produce a significant effect, turns had the strongest effect on the item scale.

termediate and distinct position, and therefore, was added to the FOG score. Also, see Figures 2 and 3.

Logistic Regression Model

Using a pooled set of 1,188 items (33 patients × 3 raters × 4 situations × 3 tasks), we computed a multinomial logistic regression model (control category $a_1 = 0$) with the explanatory variables "situation" and "task" [Likelihood ratio (LR) = 2472.7; $P < 0.0001$]. Type III analyses revealed significant effects for both explanatory variables ("situation": DF = 9, χ^2(LR) = 256.4, $P < 0.0001$; "task": DF = 6, χ^2(LR) = 20.5, $P = 0.002$). Odds ratios for the item categories 1–3 are shown in Table 2. The situation and task that had the strongest effects on the rating scale were both the turns and the carrying and calculation condition, respectively.

Intercorrelations of the FOG Score with Other Measures

The FOG score demonstrated concurrence with self-reporting of FOG ($\rho = 0.51$, $P = 0.003$), the Berg balance score ($\rho = -0.55$, $P = 0.003$), and with the number of steps ($\rho = 0.58$, $P = 0.001$). The more we saw festination and FOG, the more the patients reported freezing in the FOG-Q, the more they had a disordered balance, and the more steps were needed for a 10 m walk. The FOG score did not correlate with the fear of falling assessed by the FES ($\rho = 0.31$, $P = 0.079$). The increased observation of festination or FOG was not associated with a more severe Parkinsonian disorder assessed by the motor part of the UPDRS ($\rho = 0.36$, $P = 0.052$). These results are summarized in Table 3.

Sensitivity to Medical State in Patients with PD

In six patients with PD, whose motor blocks clearly responded to dopaminergic therapy, the FOG score was assessed in practical ON and OFF conditions following clinical criteria and subjective consideration by the patient. These patients scored 6.2 ± 3.9 and 15.8 ± 4.6 during ON and OFF, respectively, demonstrating a sensitive response of the FOG score ($P < 0.05$) to L-dopa.

DISCUSSION

Our approach to rate festination and FOG in various conditions leads to a FOG score that specifically assesses the severity dimension according to the phenomenology of this gait disorder. This focused strategy distinguishes our score from other measures such as

TABLE 3. *Intercorrelations of clinical measures (Spearman)*

Variable	FOG score	10 m steps	BBS	FOG Q	UPDRS III	FES
FOG score	1	0.58***	−0.55**	0.51**	0.36	0.31*
10 m steps	0.58***	1	−0.82***	0.42*	0.37	0.28
BBS	−0.55**	−0.82***	1	−0.48	−0.67***	−0.50**
FOG Q	0.51**	0.42*	−0.48	1	0.30	0.30
UPDRS III	0.36	0.37	−0.67***	0.30	1	0.08
FES	0.31*	0.28	−0.50**	0.30	0.08	1

Spearman correlation coefficients ρ.
BBS, Berg balance scale; FES, falls efficacy scale; FOG-Q, freezing of gait questionnaire.
P values are indicated with superscript stars: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

the UPDRS or the PAS that evaluate freezing in the context of the Parkinsonian movement disorder. The four-level interval scale captures foot movements according to plain observable criteria. Clinimetric analyses show a high inter-rater reliability and high test-retest reliability. Four situations and three tasks form 12 different conditions to which the rating scale is applied. Varied situations and tasks have a measurable impact on the scale. These effects are summed up by the repeated design of the score, and thus, characterize the severity of freezing. The FOG score demonstrates a clear dependency to the medical state of patients with PD whose freezing disorder is dopa-responsive.

We have built the core item of the score on the assumption that festination (synonymous hastening steps, shuffling) is a less severe gait disorder than akinetic FOG (trembling-in-place or total akinesia), and that both forms are less severe compared to a disordered gait with a need for external help to continue walking. The critical point about this assumption's validity is whether the four-level scale catches subtle effects which are produced in circumstantial situations[5] or with dual tasks.[16] We have shown with two mathematical models that our item scale produces different results in varied situations and varied tasks using the Friedman test with pairwise comparisons, and a multinomial logistic regression model.

Among other results, the analyses show that among the varied tasks, "carrying" does not form a separate entity. Mean values of "carrying"-items were not distinguishable from either "walking" or "carrying and calculation" items although a trend to higher values compared to "walking" is observable. Moreover, the task "carrying" does not produce significant effects in the regression model. Now, these results question the usefulness to add the items of "carrying" to the FOG score. Since we have seen that a number of patients started to show festination or FOG with this dual motor task compared to "walking," and since other authors have made similar observations and have included this task in their models,[13] we decided to include the scores of the "carrying" task items despite those non-decisive results.

The more patients showed festination or FOG, the more their postural stability as measured by the Berg Balance scale was affected. This finding is in line with the clinical observation of others that Parkinsonian patients during the later stages of their disease display clinical signs of a freezing disorder and postural instability.[3] The self-evaluative FOG-Q correlated moderately with the FOG score. This finding was surprising, and challenges the isolated use of self-evaluation for the assessment of freezing.[23] Those six patients who scored zero points on our scale but considered themselves to be freezers in the questionnaire might have interpreted—their hypokinetic phases during the OFF state as freezing[16]—or were highly motivated. They also could be falsely negatively scored by missing their freezing during the assessment. Another reason for this discrepant finding could be that the FOG-Q asks for episodes of worst mobility[11] while the FOG score in this trial was assessed during "practical ON" conditions. Examination during OFF medication states likely would produce a higher sensitivity of the new score to detect freezing episodes. Future trials will have to examine this correlation with data that has been collected during OFF medication states.

Although we detected a similar correlation between the FOG-Q and the UPDRS part III as has been described recently by others,[11,24] we did not find such a correlation between our score and the UPDRS part III. Conceptionally, the motor part of the "old" UPDRS emphasizes the classic trias of Parkinsonian symptoms, i.e., tremor, rigidity, and bradykinesia, and has not been designed to include symptoms of movement initiation, such as freezing. Therefore, our results suggest that festination and FOG should be assessed by using a specific scale.

Limitations to our scale include varied degrees of standardization that could be achieved during the examinations of Parkinson patients of variable disease severity. We let the patients choose a velocity of gait that let them walk fast but feel safe. Moreover, we chose one of three varied calculation tasks to adapt for various degrees of intellectual capacity. These procedures introduced a variability that needs to be acknowledged in the interpretation of the results.

Our data encourages the further use of the FOG score for the evaluation of patients with freezing gait due to its clinimetric characteristics, its practicability, its cost-effectiveness, and its easy application. Future studies will have to determine its responsiveness to interventions, and its sensitivity to detect FOG in Parkinsonian patients.

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