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Clinimetrics of Freezing of Gait

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Abstract: The clinical assessment of freezing of gait (FOG) provides great challenges. Patients often do not realize what FOG really is. Assessing FOG is further complicated by the episodic, unpredictable, and variable presentation, as well as the complex relationship with medication. Here, we provide some practical recommendations for a standardized clinical approach. During history taking, presence of FOG is best ascertained by asking about the characteristic feeling of "being glued to the floor." Detection of FOG is greatly facilitated by demonstrating what FOG actually looks like, not only to the patient but also to the spouse or other carer. History taking further focuses on the specific circumstances that provoke FOG and on its severity, preferably using standardized questionnaires. Physical examination should be done both during the ON and OFF state, to judge the influence of treatment. Evaluation includes a dedicated "gait trajectory" that features specific triggers to elicit FOG (gait initiation; a narrow passage; dual tasking; and rapid 360° axial turns in both directions). Evaluating the response to external cues has diagnostic importance, and helps to determine possible therapeutic interventions. Because of the tight interplay between FOG and mental functions, the evaluation must include cognitive testing (mainly frontal executive functions) and judgment of mood. Neuroimaging is required for most patients in order to detect underlying pathology, in particular lesions of the frontal lobe or their connections to the basal ganglia. Various quantitative gait assessments have been proposed, but these methods have not proven value for clinical practice. © 2008 Movement Disorder Society

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Freezing of gait (FOG) is a curious type of gait disorder. It is unusual because of its "episodic" character: the gait problem is sometimes there, but often it is not. Patients with FOG can experience debilitating episodes during which they are unable to start walking or, while walking, suddenly fail to continue moving forward. Because of this sudden and unpredictable nature, FOG is an important cause of falls and injuries.[1]

FOG is a challenge for clinicians. Many patients inadvertently deny having FOG because they do not properly know what actual freezing looks like. Even when patients report having FOG at home, the phenomenon is notoriously difficult to elicit in the clinical setting. Apparently, excitement associated with the doctor's visit or the patient's extra attention to gait during physical examination can temporarily suppress FOG (a form of "kinesia paradoxa"). Another explanation is that FOG, which is typically provoked while walking in tight quarters,[2] is less likely to occur in a widely spaced hospital corridor than at home in a crammed living room. This failure to demonstrate the problem that hinders them so much at home is very frustrating for patients and carers. It is also inconvenient for doctors who need to base their clinical management decisions based on observations in the examination room.

FOG provides equally great challenges for researchers. In a formal testing environment (e.g. a gait laboratory), it is even more difficult to elicit FOG.[3] This makes it hard to evaluate the underlying pathophysiol-

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ogy. Also, because of the aforementioned problems, it is not easy to reliably classify a patient as being either a "freezer" or a "non-freezer," yet many research studies are typically focused on a between-group comparison of freezers versus no-freezers (e.g. in neuroimaging studies). Just as in linkage analyses in the field of genetics, misclassifications can have a great impact on the statistical reliability of such studies.

In this review, we will present the available methods to assess FOG, including history taking, physical examination, quantitative gait analysis and neuroimaging (Table 1).

TABLE 1. *Several useful "tips and tricks" for the assessment of FOG*

History	Ask about being 'glued to the floor'
	Provide demonstration of FOG, including different subtypes:
	Shuffling forward with small steps
	Trembling in place
	Total akinesia
	Interview spouse/other carer
	Ask patient/carer to maintain a FOG diary
	Ask about triggering circumstances: turning, starting, tight quarters, dual tasking, reaching destination.
	Ask about attenuating circumstances (e.g. external or internal cues)
	Differentiate between ON vs. OFF period FOG: ask about FOG immediately after waking up ask about recent changes in medication
	Falls that point to FOG:
	Forward falls
	Falls during turning
	'Spontaneous' falls
	Use the standardised FOG Questionnaire[4]
Physical examination	On and OFF (before first morning dose of medication or at 'end-of-dose')
	Gait trajectory, including (Fig. 2):
	Gait ignition
	Crossing narrow passage (Doorway/Two chairs)
	(>) 360° axial turns in both directions
	Voluntary stop
	The trajectory should be repeated as quickly as possible and while performing a dual task (mental arithmic task)
	Videotape for objective assessment and future comparison
	Physiotherapist to make home visit and assess effect of cues
	Focus attention by cues:
	Auditory: metronome
	Visual: stripes on the floor
	Mental: counting
	Guideline available via http://www.rescueproject.org/http://www.kngf.nl/index.html?dossier_id=81&dossiers=1
	Divert attention using dual tasks
	Differentiate FOG episode from normal stop
	Preceded by decreased step length and increased cadence
	Trembling/shuffling forward
	Increased flexed posture with fixed flexion hip, knee, ankle
	Ask about concurrent feeling of being 'glued to the floor'
	Simple quantification
	Timed up and Go test[5]
	Parkinson Activity Scale[5,6]
Ancillary investigations	Structural neuroimaging to detect underlying pathology
	No place yet for functional neuroimaging or elaborate quantitative measures

HISTORY TAKING

Presence of FOG

It is usually insufficient to simply ask about "freezing," because not all patients interpret this correctly. Instead, ask if patients experience the characteristic feeling of "being glued to the floor." Another helpful suggestion is to ascertain whether patients understand what you mean, by demonstrating a typical FOG episode. The examiner may imitate FOG, or show videos of typical FOG episodes. This should be presented not just to the patient, but also to the spouse or other immediate carer who provide a valuable resource of information because they regularly observe FOG in the domestic situation.[7]

Sometimes, the presence of falls may point to the presence of FOG.[1] Three types of falls are particularly associated with FOG: forward falls (which are the inevitable result when the feet suddenly become stuck while walking); lateral falls during turning, sometimes resulting in hip fractures (which are typically caused by a fall sideways onto the trochanter of the hip); and "unexplained" and seemingly spontaneous falls. In our experience, when patients with unexplained falls (but subjectively no FOG) are carefully examined in both the ON and OFF state (and using specific tricks to provoke FOG – see Physical Examination), FOG can often be identified as the likely cause of the falls. Interestingly, even though FOG is an important source of falls in PD, there is no difference in frequency or duration of FOG episodes between falling and nonfalling freezers.[4] Apparently, even a brief FOG episode can be sufficient to make people fall, so clinicians should do their utmost to detect even these mild forms of FOG.

A phenomenon that is closely related to FOG is "festination," where patients take increasingly rapid and small sequential steps during walking. This festination phenomenon is common in severely affected patients. Like FOG, it is an episodic gait disturbance, and one may speculate that festination in fact reflects a form of FOG (the "shuffling forward" type). Indeed, patients who experience festination are also more

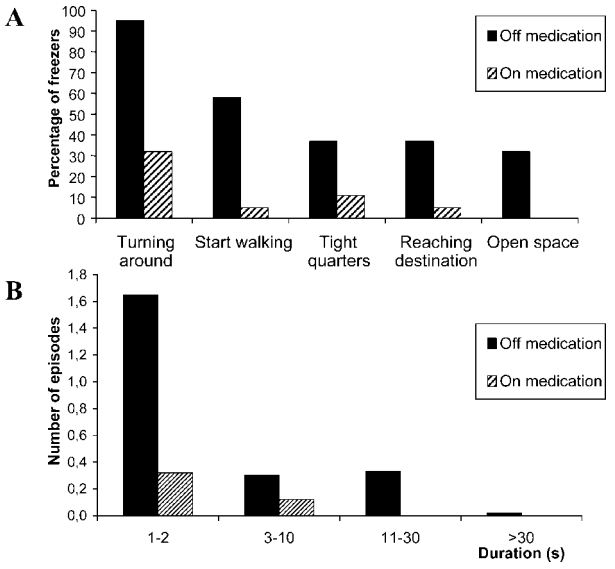

FIG. 1. Characteristics of FOG episodes. **A:** Circumstances under which freezing of gait (FOG) occurs. **B:** Duration of FOG episodes. Data for this figure have been distilled from a study of 19 patients with Parkinson's disease and OFF period FOG.[2]

likely to experience FOG.[8] However, an important difference between festination and the shuffling type of FOG is that the characteristic "magnetic feeling" under the feet is not present in festination. Moreover, festination occurs typically while walking, whereas FOG occurs most often while initiating gait or during turning. More research is needed to unambiguously differentiate these two types of episodic gait disturbances.

Freezing Circumstances

FOG typically occurs during a shift of attention or a circumstantial or directional change. Specific questions should be tailored to FOG while starting to walk, turning around, moving in tight quarters, when dual tasking (e.g. walking and talking at the same time) or when reaching a destination. Turning around appears to be the strongest provoking factor (see Fig. 1).[2,9] Stress associated with the need to move under time constraints, for example when the telephone or doorbell suddenly rings, may also provoke FOG.[10] Specific environments can either provoke FOG (e.g. a busy living room with thick carpets) or help to overcome FOG (e.g. crossing a street at a zebra).

Influence of Medication

Most patients—possibly up to 90% of freezers, but this is not precisely known—suffer from "OFF state FOG," with more frequent and severe freezing episodes when medication effects have worn off. A minority of patients has more severe FOG during the "ON state," apparently because dopaminergic drugs can sometimes cause freezing. In studies comparing dopamine receptor agonists to levodopa, agonists were more frequently associated with FOG,[10] but this may also be explained by their lower therapeutic efficacy on OFF state FOG. Differentiating between OFF versus ON state FOG has obvious therapeutic implications. When in doubt, a useful trick is to ask patients whether they experience any FOG immediately after waking up, before intake of the first morning dose of antiparkinson medication. When FOG is present at this time, the patient is likely to have OFF period FOG, and the first morning dose will then typically alleviate the complaints. Conversely, when FOG is absent or minimal upon awakening, but aggravated by taking antiparkinson medication, ON period FOG is most likely. It also helps to ask about recent changes in antiparkinson medication. For example, if FOG developed shortly after the start of a new or a higher dose of a dopaminergic drug, ON period FOG should be considered.

Differentiating between OFF and ON state FOG has consequences for drug therapy: OFF state FOG usually improves with higher doses of antiparkinson medication, while patients with predominantly ON period FOG may improve with tapering of antiparkinson medication. Interestingly, the effect of external cues (as a means to improve FOG) is also different between ON and OFF state FOG.[11–13] Several cueing modalities—visual, auditory, tactile, and mental—can improve FOG,[14–16] but these effects appear to be greatest for patients with OFF period FOG.[12] Note, however, that severe akinetic FOG (which is more common in the OFF state compared with the ON state) is not always alleviated by cueing.

The medication effects may provide information about the underlying etiology. Patients with ON period FOG that do not respond to cues may suffer from frontal pathology, rather than idiopathic Parkinson's disease, especially when they have a wide-based gait.[12]

Severity of FOG

The distress caused by FOG is related to the frequency, intensity, and duration of FOG episodes.[17] Most FOG episodes are actually brief, certainly during the ON state, typically lasting only several seconds and rarely more than 30 seconds.[2] There are three subtypes of FOG: shuffling forward with small steps (the least severe form); trembling in place; and total akinesia (the severest form). FOG during the ON state is

TABLE 2. *Scoring of FOG in the ADL section of the UPDRS*

0	No freezing when walking
1	Rare freezing when walking; may have start hesitation
2	Occasional freezing when walking
3	Frequent freezing. Occasionally falls from freezing
4	Frequent falls from freezing

less severe compared to OFF period FOG, with less frequent and briefer episodes, and presenting less often as total akinesia (Fig. 1B).[2]

Standardized Questionnaires

Several attempts have been made to develop rating scales for a standardized history taking of FOG. The current Unified Parkinson's Disease Rating Scale (UPDRS) merely features a single question concerning the presence of freezing (item 14 of Part II, ADL section).[18] The scoring system for this question (Table 2) places much emphasis on falling as a result of FOG while, as noted earlier, falling is not related to the frequency and duration of FOG.[4]

A specific set of questions has been bundled into the Freezing of Gait Questionnaire (FOGQ).[4] The FOGQ can help clinicians screen for the presence of FOG, and also to assess the subjective severity. A second version of the FOGQ (FOGQII), which is accompanied by a video to demonstrate FOG episodes to patients and their carers, has been developed to more specifically assess FOG.[7] The FOGQII also incorporates the impact of freezing on daily life, for example fear of falling. However, these questionnaires only assess FOG during turning and gait ignition, and no other circumstances that commonly cause FOG, such as negotiating narrow passages or performing a dual task. In addition, they do not document the effect of treatment interventions or the environment in which FOG occurs. Finally, the treatment effect (ON or OFF state) in which FOG predominantly occurs is not scored. As patients are asked to score the overall presence of FOG during the entire day (including well-controlled ON periods), the outcome of the FOGQ may not be strongly related to the presence of FOG during the OFF state.

PHYSICAL EXAMINATION

The next step in the diagnostic process involves the physical examination. Whenever possible, patients should be examined during both the OFF state (preferably following withdrawal of antiparkinson medication for at least 12 hours) and the subjective "best ON" state. Presence of FOG should ideally be examined using a standardized gait trajectory that features all possible circumstances that may provoke FOG: gait initiation; undisturbed walking in an open space; and walking under challenging situations (crossing a door or other narrow space), turning around and while performing a dual task (see Fig. 2). Performance can be videotaped in order to objectively evaluate the type of freezing, the duration of each episode and the frequency of FOG.[2] Interestingly, many patients only experience FOG during full turns (360° to 540°) and not during partial turns (180°), so a standardized gait trajectory should include such full turns.[2] We observed that wider turns seem to be easier for patients than turns "on the spot," and slow turns are easier than rapid turns. Also, the examination must include turning in both directions because FOG often shows a directional sensitivity, being much worse and sometimes even exclusively present for turns in either a rightward or leftward direction. Preliminary evidence in our laboratory shows that this directional sensitivity has no consistent relationship with the most affected side of the body. Others have included obstacles in their trajectory to provoke FOG.[3]

Performance on a gait trajectory can also be timed. An example is the Timed Up and Go test, where patients are observed and timed while rising from a chair, walking 3 m, turning around, walking back, and sitting down again.[5] Regular FOG will obviously increase the time needed to complete the test, but slowed performance can have many other causes as well. A test that also scores the *quality* of gait—in addition to timing—is the Parkinson Activity Scale (PAS). This scale also includes a Timed up and Go test, but is more specific for FOG because patients have to turn in a tight square.[6] Apart from the timing, the examiner scores the severity of FOG for both gait initiation and while turning (using an ordinal five-point scale). The PAS has recently been modified and now also includes a cognitive dual task

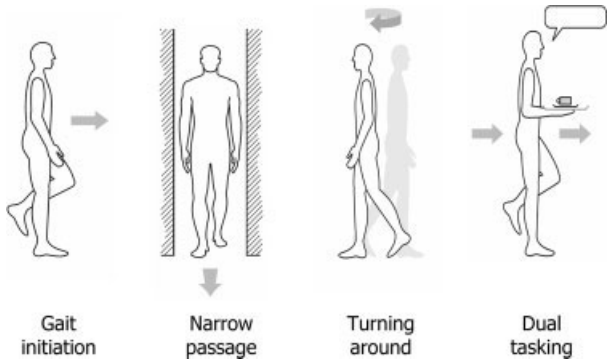

FIG. 2. Essential elements of a dedicated FOG trajectory.

(counting backwards) and a motor dual task (carrying a full glass of water) to provoke FOG.[19] In contrast to the original PAS, the modified PAS has not yet been investigated with respect to its psychometric properties. A disadvantage of the PAS is that it only includes a 180° turn.

We find it helpful to refer patients to a physiotherapist with expertise in movement disorders. Because the physiotherapist can spend more time with patients, they become familiarized with the environment, which makes FOG more likely to occur. Moreover, the physiotherapist can evaluate the effect of cueing strategies or cognitive movement strategies.[19] Furthermore, the physiotherapist can give tailored advice, such as making larger turns to avoid FOG, to increase attention to gait and to avoid dual tasking. Finally, the physiotherapist (or occupational therapist) can assess and train patients in their own home environment, where FOG occurs most commonly and where assessment in the OFF phase is more feasible.

Patients with FOG should receive a cognitive examination, especially testing the frontal executive functions and attention. Frontal executive dysfunction is related to gait impairment in Parkinson patients[20] and is associated with an increased risk of falls.[21] Moreover, frontal executive dysfunction and FOG frequently co-occur, but there is as yet no proof of a direct causal interrelationship.[22] Recklessness, decreased ability to learn cues, and an increased sensitivity to cognitive overload (for example when dual tasking) may explain why patients with frontal executive dysfunction are more prone to falls. Moreover, the presence of frontal executive dysfunction may give a clue to the underlying etiology, as it is more prominently present in atypical parkinsonism than in idiopathic Parkinson's disease.

Attention has a dual influence on FOG. On the one hand, attention to gait—with or without additional external cues—helps to relieve FOG, presumably by switching from automatic to more conscious walking. Judging the effect of different types of cues (visual, auditory, tactile, and mental) should be part of the examination, because not all patients improve with the same cueing modality. Moreover, an individual tailoring of cueing parameters is critical: when the cueing frequency is too high, patients will react with smaller steps that can in fact *induce* FOG.[11] Guidelines are available to implement the correct cueing therapy for individual freezers (http://www.kngf.nl/index.html?dossier_id=81&dossiers=1; http://www.rescueproject.org/).[19]

On the other hand, diverting attention with a secondary task while walking makes patients more prone to develop FOG. Note that not all cessations of motor activity while performing a dual task should be seen as FOG, because very complex multiple tasks can also cause hesitations and motor "blocks" in a substantial proportion of healthy subject controls.[23] At least some of these blocks reflect a purposeful behavioral adaptation to prioritize certain specific actions in a complex situation, at the expense of others that are deemed less important. To differentiate such voluntary stops from FOG, the examiner should pay attention to the characteristics of the stop itself and the steps preceding the stop. First, a gait stop caused by FOG is accompanied by a flexed posture with fixed flexion in the hip, knee and ankle joints.[24] Second, the FOG stop is often not complete, with some residual trembling in place or forward shuffling.[2] Third, FOG episodes are often preceded by a progressive decrease in step length and increase in cadence.[3,25] Finally, it can be useful to ask patients whether they experienced the feeling of "being glued to the floor."

Other mental functions should also be examined. Depression is possibly associated with increased FOG severity.[26,27] FOG is also associated with anxiety: 62% of Parkinson patients with FOG were found to be moderately to markedly anxious, as compared with only 18% of patients without FOG.[26] Patients with FOG had more panic attacks (32% compared to 9%), with panic attacks often preceding, co-occurring or following an episode of FOG.

NEUROIMAGING

Structural neuroimaging can be important to detect pathology underlying FOG, such as frontal atrophy, frontal lesions, hydrocephalus, cerebrovascular lesions or abnormalities suggestive of atypical parkinsonian syndromes. Novel MRI techniques such as magnetization transfer imaging, diffusion-weighted imaging and magnetic resonance volumetry may gain significance in the future, as these are more sensitive in detecting abnormal features of atypical parkinsonism.[28] Other studies have used functional neuroimaging to gain better insights into the underlying pathophysiology and neural substrate of FOG.[29–31] Such techniques are currently only relevant for research purposes and are therefore not discussed in more detail here.

QUANTITATIVE GAIT ANALYSIS

It would be helpful to have a reliable, objective, and quantitative outcome measure for FOG, for example to detect FOG episodes in the home setting, or in clinical

trials to evaluate the effect of new therapeutic interventions. Several approaches are available, mainly for research purposes (to clarify the pathophysiology of FOG), but some have a potential clinical utility. One example is a device using angular velocity sensors that can measure trunk motion in different planes while subjects move about freely.[32] This has, for example, been used to quantify the "stops walking while talking" test[33] and to record trunk motion while making axial turns.[34] A theoretically interesting application would be to detect FOG episodes, although trunk sway measures are only an indirect derivative of possible FOG episodes in the legs. A more direct method to detect FOG consists of a goniometer and angular velocity sensor attached to the shank of one of the legs.[35]

Another approach to study FOG more directly is an ambulatory gait analysis system with pressure sensitive insoles that continuously record walking in freely moving subjects. The results of a study in Parkinson patients showed markedly increased stride-to stride variability in freezers compared with nonfreezers.[36] Another study using this approach showed a marked asymmetry and variability of swing time during gait in patients with FOG.[37]

More elaborate approaches are also available in specific gait laboratories, their advantage being the more detailed and comprehensive set of outcome measures, but with several clear disadvantages as well (costs; burden to the patient; and reduced likelihood of observing real FOG under these experimental conditions). These techniques are discussed in more detail in other contributions in this supplement.

TOWARDS A NEW DEFINITION OF "FREEZERS"

As outlined in the Introduction, it is crucial to have a reliable definition of freezers versus nonfreezers, as misclassification can greatly affect the outcome of research studies. Currently, there is no such classification system that can unambiguously separate freezers from nonfreezers. The main reason is that neither history taking nor physical examination is infallible, and gold standard laboratory measures are missing. We envision two possible approaches. The first would be an ordinal "black or white" classification, where patients would be defined as being a freezer when FOG is present according to *at least one* of the following assessments: (a) subjectively (using a FOG questionnaire); (b) according to the carer (using video demonstrations of FOG episodes); (c) during physical examination (using a standardized gait trajectory as defined in Table 1); (d) "objectively" at home (using ambulatory gait assessment techniques); or (e) during formal experimental testing in a laboratory setting (e.g. kinematic gait analyses during treadmill walking). An alternative, and perhaps more reasonable approach, would acknowledge the inherent difficulties in making an absolute distinction between freezers and nonfreezers, and rather attempt to classify the severity of FOG, ranging from either absent to marked. Such a continuous rating scale should accommodate the frequency, severity and specific provoking circumstances of FOG, and could be used as a covariate in statistical analyses. Future studies are needed to develop and validate such classification systems, as these are an essential requirement to gain more insights into this curious gait abnormality.

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