

## 1           **Might it be possible to assess rigidity in PD patients remotely?**

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29 Rigidity is present in up to 89% of Parkinson's disease patients [1]. It refers to uniform and  
30 persistent resistance to passive movement at a joint, due to increased resting muscle tone [2]. The  
31 MDS-UPDRS part 3 is the gold-standard assessment of rigidity. This involves a clinician flexing and  
32 extending a patient's relaxed joint, assessing both upper (wrist, elbow, neck) and lower extremities  
33 (knee and ankle), as well as instructing the patient to perform voluntary movements in the  
34 contralateral limb, to accentuate rigidity. The need for hands-on assessment to detect and quantify  
35 rigidity makes implementation of remote video assessment difficult. Rigidity is therefore usually  
36 omitted from video ratings [3], thus a patient's symptomatology may not be completely represented  
37 via video assessment.

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39 We evaluated data collected as part of the standard clinical care of PD patients being assessed for  
40 Deep Brain Stimulation (DBS). Three experienced DBS specialist nurses performed a hands-on MDS-  
41 UPDRS rigidity assessment on 39 patients with Parkinson's disease, in the OFF and ON medication  
42 conditions. This assessment was video-recorded with patient's consent. The nurses re-rated the same  
43 videos of these patient's OFF and ON rigidity assessments between 6 months-2 years later. It was  
44 found that nurse's video scores of rigidity had excellent agreement with their own previous in-person  
45 scores ( $ICC=0.97$ ,  $CI=0.92-0.99$ ).

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47 To control for potential bias that may arise from nurses remembering patients that they had  
48 previously rated, 2 secondary experienced raters (Rater 1 and Rater 2) who had never seen the  
49 patients before, rated videos of a total of 51 patients who had had a rigidity assessment performed by  
50 a nurse, and their scores were compared to scores obtained from the hands on assessment. We found  
51 that each rater's video scores of rigidity also had excellent agreement with previous in-person rigidity  
52 scores ( $ICC=0.96$   $CI=0.95-0.97$ ). Assessors were asked to describe potential visual cues that guided  
53 their rigidity scores when watching videos of a previous clinician performing the assessment (see  
54 Table).

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Table. Potential visual cues used among raters when rating rigidity from videos of a previous clinician performing a rigidity assessment on a patient

MDS-UPDRS Score	MDS-UPDRS Description	Visual Cues
<b>0: Normal</b>	No rigidity.	<ul style="list-style-type: none"> <li>1. Can see clinician moving patient's limb with ease-floppy /limb appears loose/ fluidity of movement</li> <li>2. Full range of movement clearly observed</li> </ul>
<b>1: Slight</b>	Rigidity only detected with activation manoeuvre.	<ul style="list-style-type: none"> <li>1. Resistance/ stiffness/less fluidity/slowness observed when clinician moves limb, only when patient performs an activation manoeuvre</li> </ul>
<b>2: Mild</b>	Rigidity detected without the activation manoeuvre, but full range of motion is easily achieved.	<ul style="list-style-type: none"> <li>1. Slowness/ slight stiffness/less fluidity/ slight resistance/locking visible when clinician moves limb through movement trajectory</li> <li>2. No activation manoeuvre needed to observe above</li> <li>3. Full range of movement achieved with little observable effort from the clinician</li> </ul>
<b>3: Moderate</b>	Rigidity detected without the activation manoeuvre; full range of motion is achieved with effort.	<ul style="list-style-type: none"> <li>1. Clinician moves limb significantly slower/ marked resistance/ very stiff/significant locking</li> <li>2. No activation manoeuvre needed to observe above</li> <li>3. Full range of movement achieved with observable effort from the clinician</li> </ul>
<b>4: Severe</b>	Rigidity detected without the activation manoeuvre and full range of motion not achieved.	<ul style="list-style-type: none"> <li>1. Clinician is clearly unable to move limb to full range</li> <li>2. No activation manoeuvre needed to observe above</li> </ul>

56 MDS-UPDRS, Movement Disorder Society Revised Unified Parkinson's disease Rating Scale  
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60 These data suggest that it is possible to rate rigidity via videos, with excellent inter and intra rater  
61 agreement, if a clinician performed the original rigidity examination. The proposed visual cues guide  
62 above may be used to support rating rigidity via videos, but this needs further validation. This has  
63 implications for clinical trials, because it might allow the use of videos (performed previously by a  
64 nurse/clinician) for blinded rating of the rigidity section of the MDS-UPDRS part 3.

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66 Whether this may be useful for clinical care adds further complexity. Routine remote video  
67 assessments will not have the presence of a qualified clinician to perform the hands-on rigidity  
68 measure. In addition, the visual cues described here may not be present during examinations  
69 performed by clinicians from other centres with different backgrounds in training and, the visual cues  
70 described here were generated in an unblinded rigidity assessment and may not be applicable to  
71 blinded assessments by an additional rater. More data are needed with research methods addressing  
72 the above key points to further the findings presented in this primary investigation. Further  
73 exploration may also reveal whether the patient's spouse/carer could be instructed to perform the  
74 passive movements in the home environment, to allow a remote experienced observer to score  
75 rigidity through videos. This might explore further which visual cues most reliably indicate rigidity,  
76 which may be exploited in such assessments or even by machine learning approaches.  
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- 82 2. Statistical Analysis: A. Design, B. Execution, C. Review and Critique;
- 83 3. Manuscript Preparation: A. Writing of the first draft, B. Review and Critique.

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86 T.F.: 1A, 1B, 2C, 3B

37 C.M.: 1C

38 M.S.: 1C

39 J.C.: 1C

40

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43 All movement disorder clinic patients whose videos were analysed provided written consent for use of  
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