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Measurement and correction of stooped posture using wearable sensors in patients with Parkinsonism

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Background
The stooped or bent posture is one of the typical postural deformities in patients with Parkinsonism. This deformity usually aggravated during walking. Sometimes, verbal or sensory cues are helpful to correct their posture during walking. However, the severity of the stooped posture is difficult to measure quantitatively during walking, and continuous feedback on their posture is also difficult to be provided during their activities.

Objectives
The study objectives were to measure the degree of stooped posture using wearable sensors during walking in patients with Parkinsonism and to investigate whether sensory feedback using vibration of the sensors improve their posture.

Materials and Methods
Patients with Parkinsonism and stooped posture due to forward flexion of the thoracolumbar region were recruited in this study. Patients who showed fixed kyphosis or severe dyskinesia/tremor were excluded. Two wearable sensors containing 3-axis accelerometers were attached at the upper neck (neck sensor), and just below the C7 spinous process (back sensor), respectively (Fig. 1). After calibration of the sensors in most upright posture (defined as 0 degree), the sensors continuously recording the sagittal angles at 1 kHz and averaged the data at every seconds during 6-min walking test. This measurement was validated in healthy subjects by comparing with 3D camera system with markers (Optitrack) with mean absolute errors of 0.9 to 1.5 degree. In the control session, the patients walked with the sensors as usual. In the vibration session, sensory feedback was provided by vibration of the neck sensor when the sagittal angle was lower than the threshold angle (10 or 20 degree). The sequence of the sessions was quasi-randomized according to the order of participation. The absolute sagittal angles in most upright posture before walking and mean changes of the sagittal angles during walking were measured in each patient.

Results
Ten patients with Parkinsonism participated in the study. Because 2 patients were excluded due to measurement errors, data of 8 patients (7 females and 70.25 ± 6.11 years old) were analyzed (Table 1). The neck and back flexion somewhat aggravated during gait, but the changes were less than average 10 degree in most patients in both measurement sessions. Therefore, it was difficult to evaluate the effect of sensory feedback by vibration. However, some patients showed immediate response to the feedback and corrected their posture during gait (Fig. 2).

Conclusion
This pilot study suggests that stooped posture could be measured quantitatively during gait using the wearable sensors in patients with Parkinsonism. Sensory feedback by vibration of the sensors may be helpful to correct the posture during gait in selected patients. A further study is warranted to validate the effect of sensory feedback using the wearable sensors in patients with Parkinsonism.

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Fig. 1. Two wearable sensors to measure neck and back flexion angles.

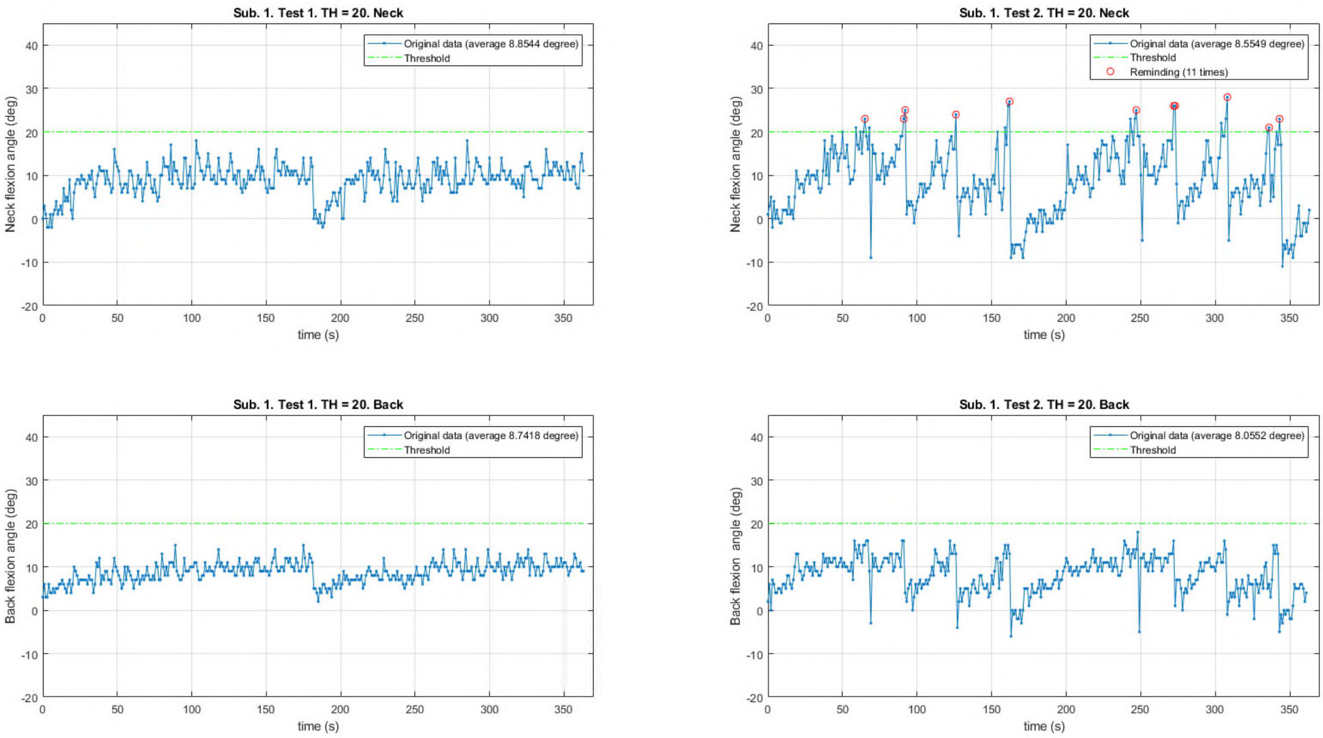

Fig. 2. The changes of neck and back flexion angles continuously measured during 6-min walking test in an example case (R001). In the vibration session (Test 2) with 20 degree of the threshold angle, the patients responded immediately to the neck sensor vibration (red circles), and corrected both neck and back flexion postures.

Subject	Sex	Age	H&Y	Threshold	Control				Vibration				
					Base_N	Base_B	Mean_N	Mean_B	Base_N	Base_B	Mean_N	Mean_B	Vib #
R001	F	74	2.5	20	87	72	8.85	8.74	101	75	8.56	8.05	11
R004	F	72	3	20	100	63	3.2	2.52	105	62	13.15	5.57	17
R005	F	74	2.5	20	102	52	-0.33	5.87	104	55	6.75	5.66	0
R006	F	79	3	20	92	55	9.57	6.53	88	53	3.53	8.69	0
R007	F	65	2	10	97	60	2.85	2.55	97	62	-2.6	-1.68	0
R008	F	72	3	10	99	52	0.78	5.29	99	55	-1.18	3.54	11
R009	M	66	3	10	91	89	20.21	16.46	88	83	12.99	23.11	240
R010	F	60	2.5	10	96	91	9.72	-2.75	77	89	5.39	1.03	27
Average					95.5	66.75	6.86	5.65	94.88	66.75	5.82	6.75	38.25

Table 1. Characteristics and individual data of the study participants