

Faculty of Pharmacy and Medicine
Department of Human Neurosciences
Specialization School in Neurology

Axial Impairment in Parkinson's Disease: Multimodal Assessment of Gait and Balance



SAPIENZA
UNIVERSITÀ DI ROMA

Supervisor

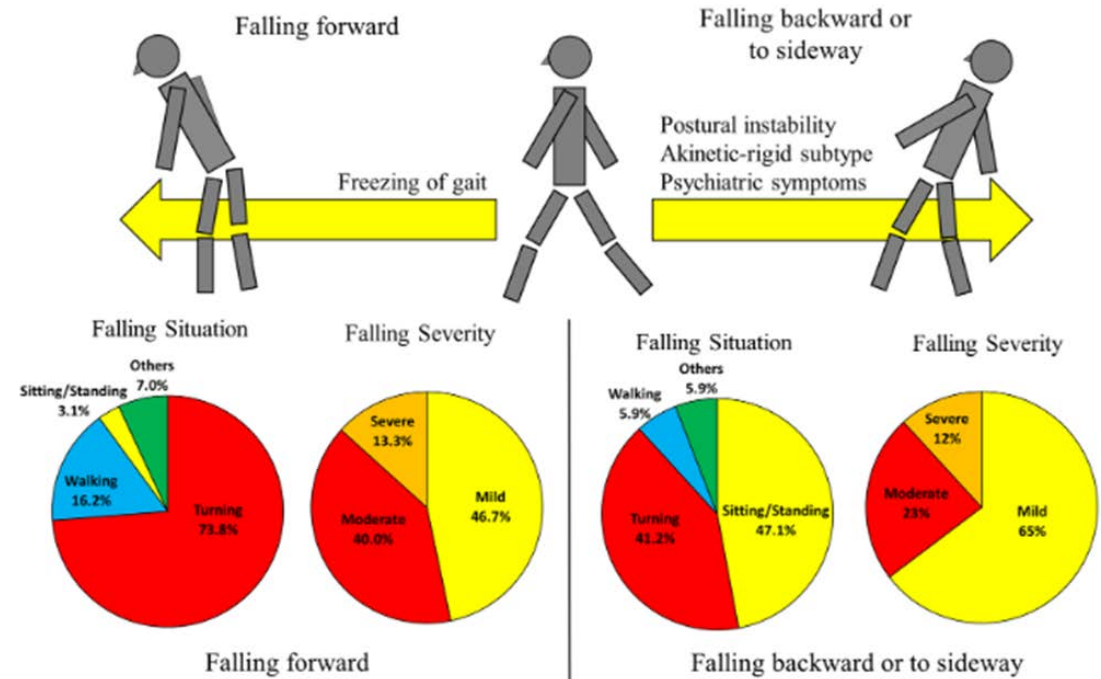
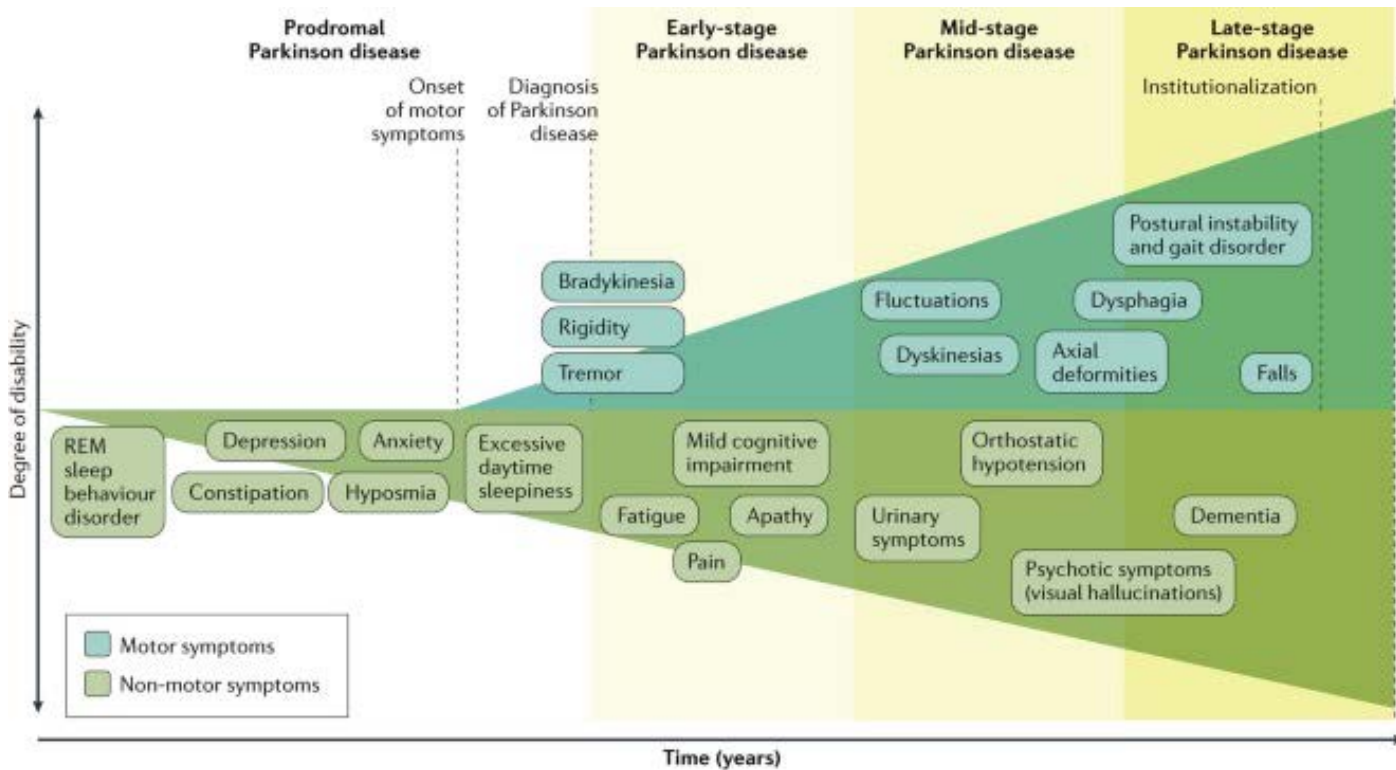
Prof. Alfredo Berardelli

Candidate

Dr. Alessandro Zampogna

Academic Year 2019/2020

Axial Impairment in Parkinson's Disease

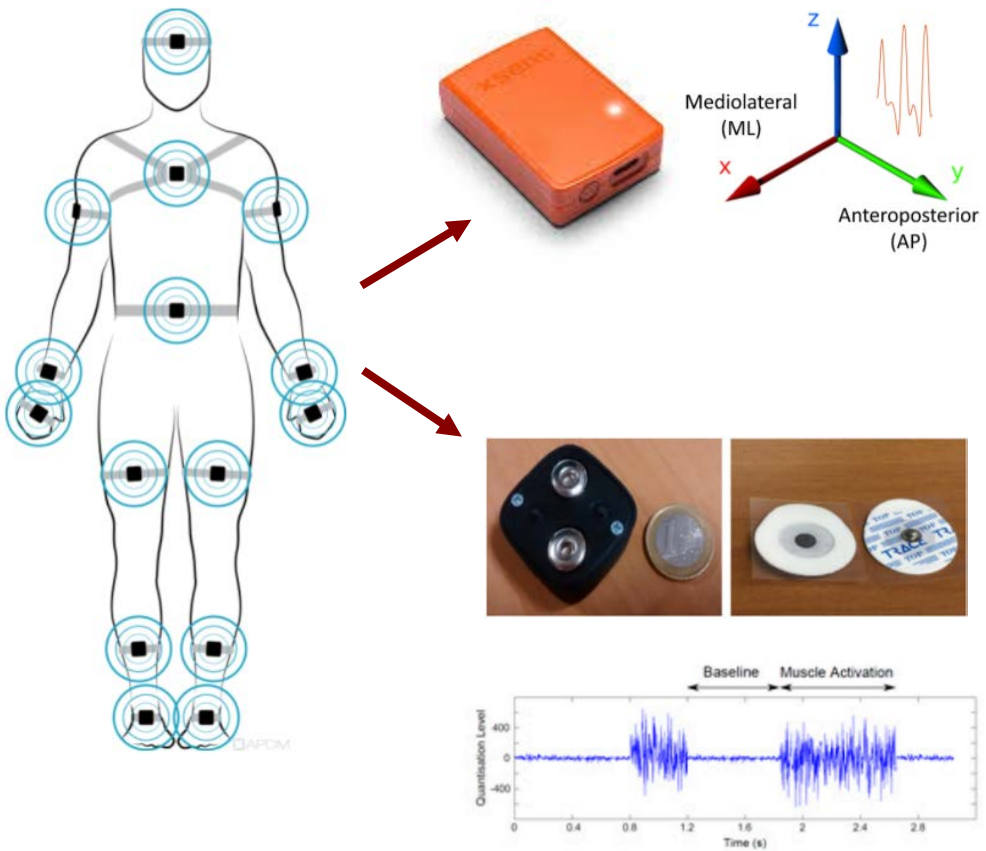


Nature Reviews | Disease Primers

Freezing of Gait (FOG)



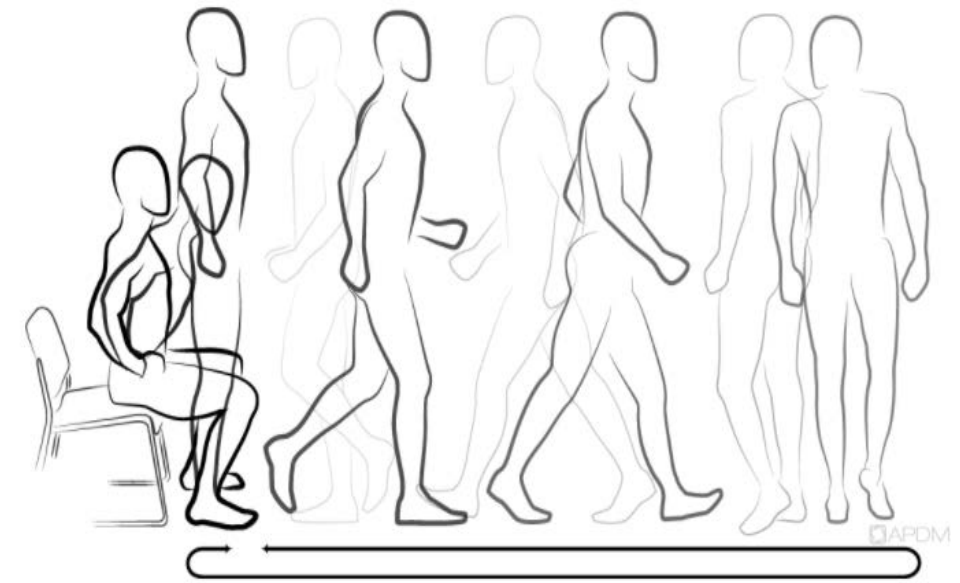
Sensor-based Assessment



1) DETECTION

2) CHARACTERIZATION

3) PREDICTION



FOG Detection

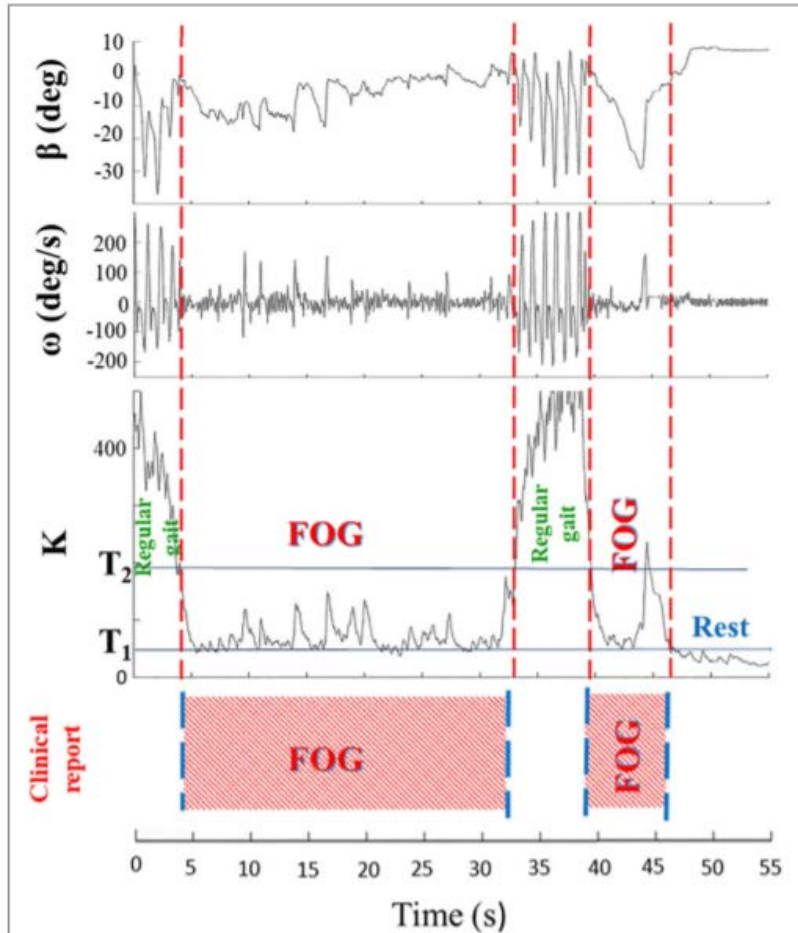


FIGURE 3 | Angle β , angular velocity ω , K index, and clinical report during a sample test are shown. Clinical report allows to define two threshold values (T_1 and T_2) of K index, which automatically classify three stationary states: regular gait ($K > T_2$), rest state ($K < T_1$), and freezing of gait (FOG) episodes ($T_2 > K > T_1$). The wide dynamic range of the K index easily identifies distinct regions with different gait behaviors. Detection latency: 400 ms

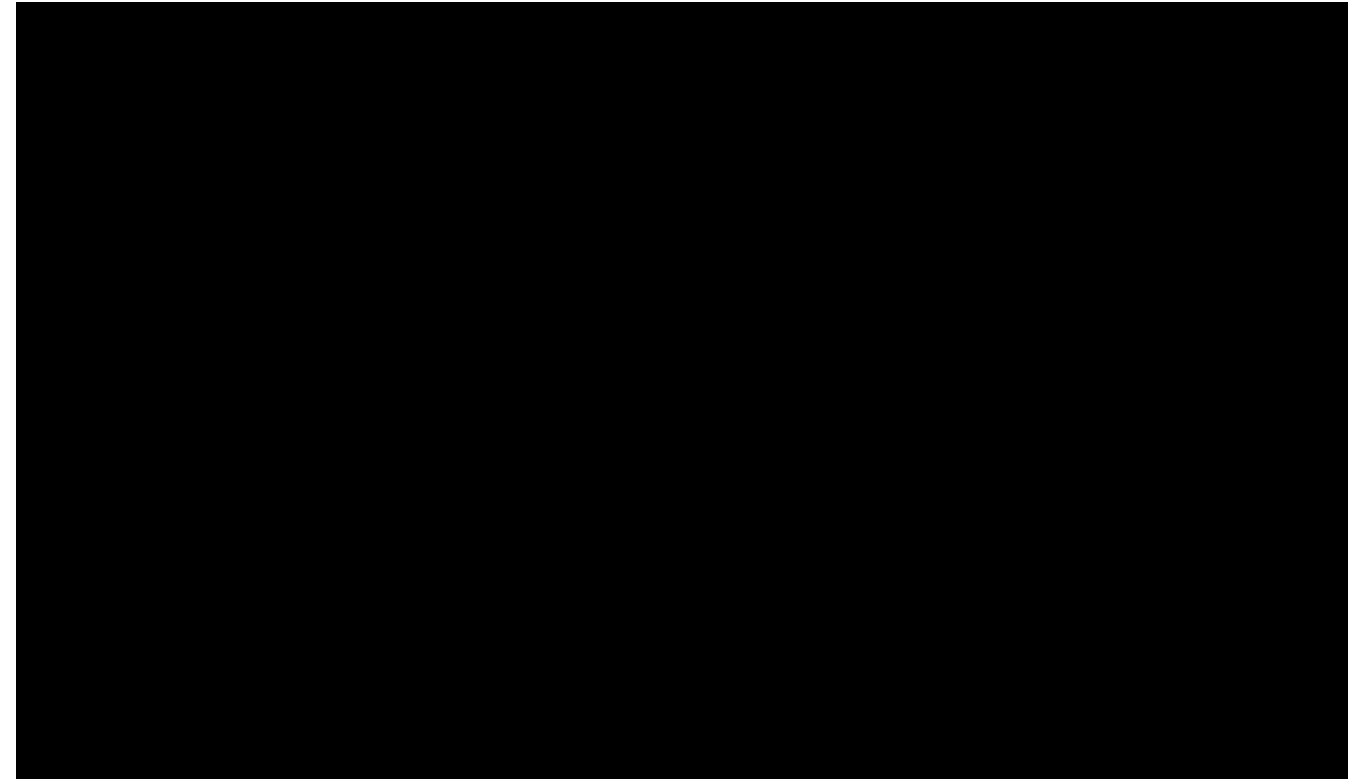
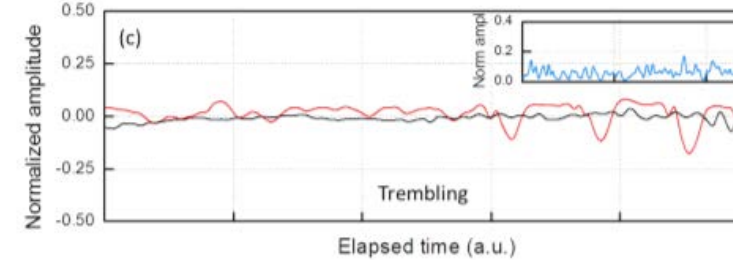
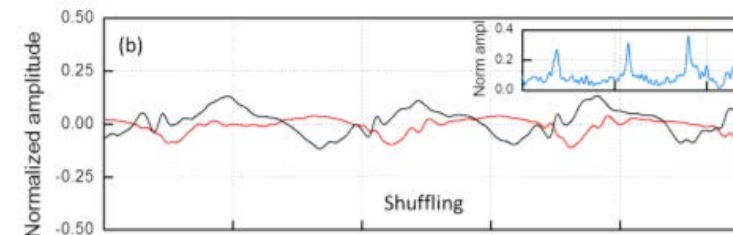
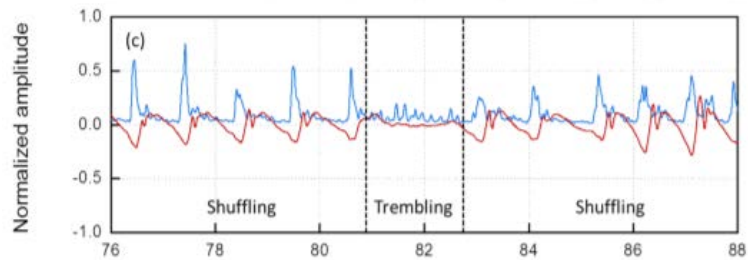
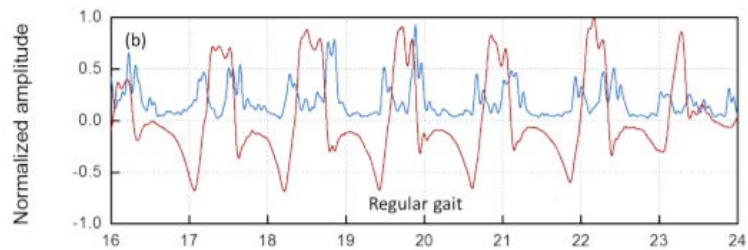
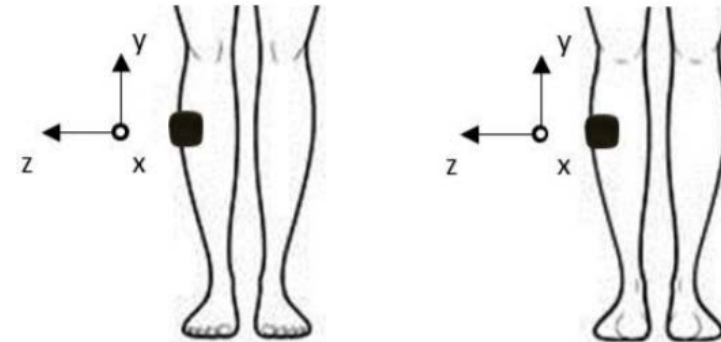
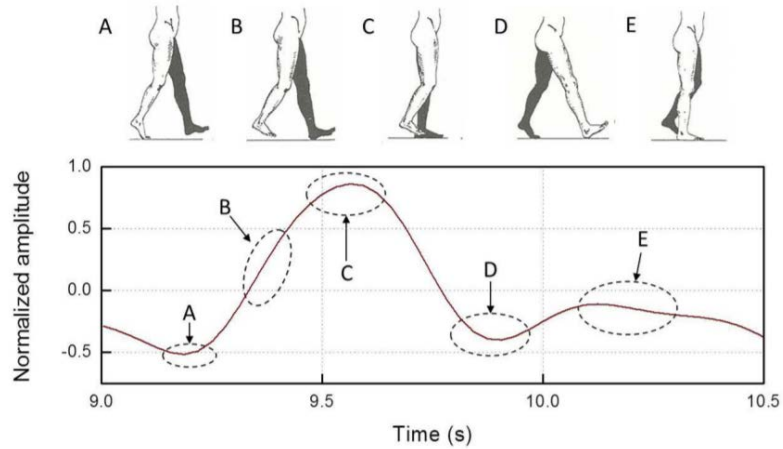


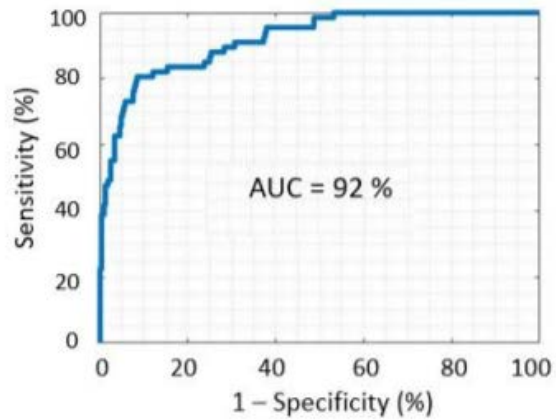
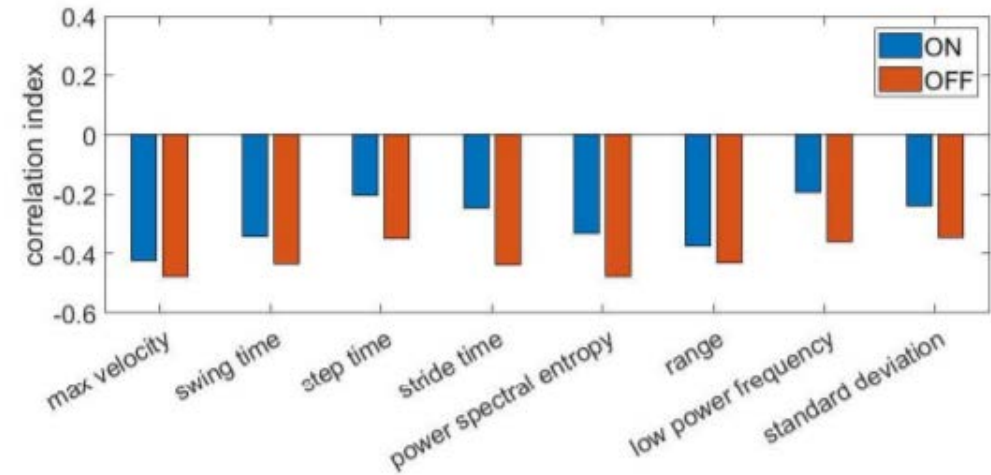
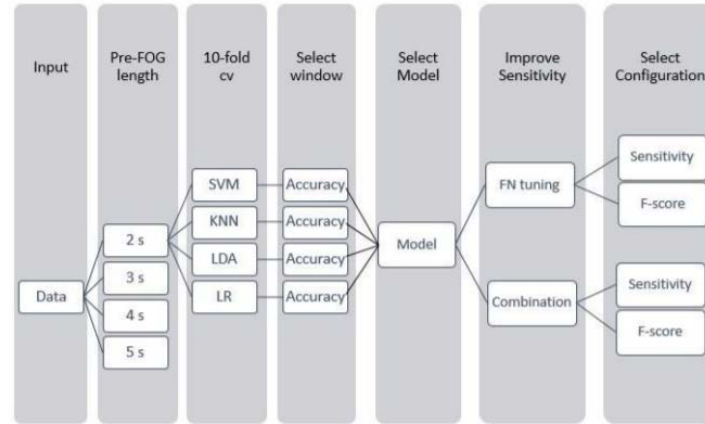
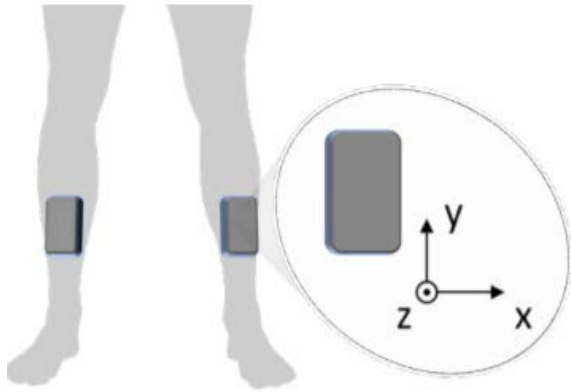
TABLE 2 | Average (\pm SD) Timed Up and Go (TUG) duration, total freezing of gait (FOG) duration, step velocity, stride length, stride time, and cadence in healthy subjects and Parkinson's disease (PD) patients with and without FOG, OFF and ON therapy.

Subjects	State of therapy	TUG duration (s)	FOG duration (s)	Step velocity (cm/s)	Stride length (cm)	Stride time (s)	Cadence (steps/min)
16	Healthy subjects	18.6 \pm 5.7		118.7 \pm 37.17	77.7 \pm 32.11	0.8 \pm 0.10	111.2 \pm 14.25
28	PD patients with FOG	OFF	49.9 \pm 38.18	76.0 \pm 32.55	45.7 \pm 28.49	0.8 \pm 0.17	97.3 \pm 18.18
	ON	31.4 \pm 17.24	22.9 \pm 48.37	96.6 \pm 28.03	60.3 \pm 20.74	0.8 \pm 0.13	105.5 \pm 22.67
16	PD patients without FOG	OFF	24.4 \pm 7.79	71.4 \pm 22.50	52.6 \pm 21.25	0.9 \pm 0.13	107.0 \pm 18.83
	ON	21.5 \pm 6.56		74.7 \pm 19.61	48.0 \pm 21.17	0.8 \pm 0.17	106.2 \pm 17.62

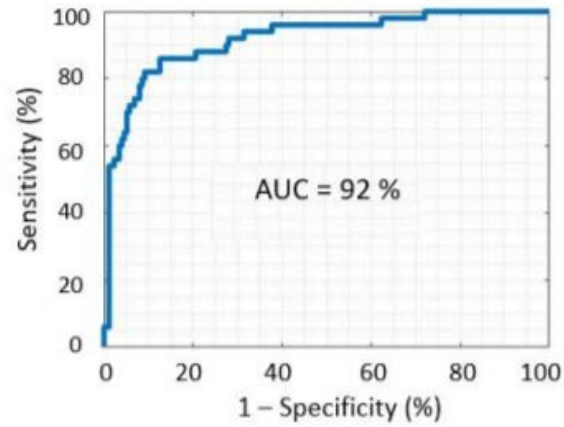
FOG Characterization



FOG Prediction



(a) ON therapy



(b) OFF therapy

Window Length (s)	SVM		kNN		LDA		LR	
	ON	OFF	ON	OFF	ON	OFF	ON	OFF
2	91.3	92.1	84.7	89.8	91.7	94.7	89.0	90.6
3	86.1	88.7	80.2	84.7	85.6	86.4	84.4	85.2
4	77.8	84.6	69.4	80.4	78.6	82.6	75.2	81.8
5	64.9	74.6	58.9	79.3	65.8	75.4	44.9	71.1

Magnetic Resonance Imaging

STRUCTURAL CHANGES

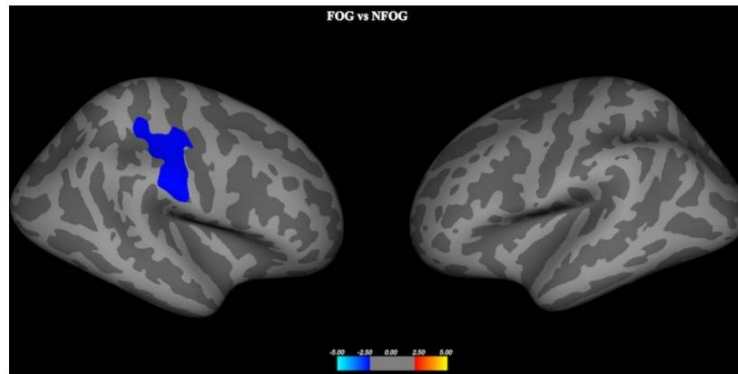
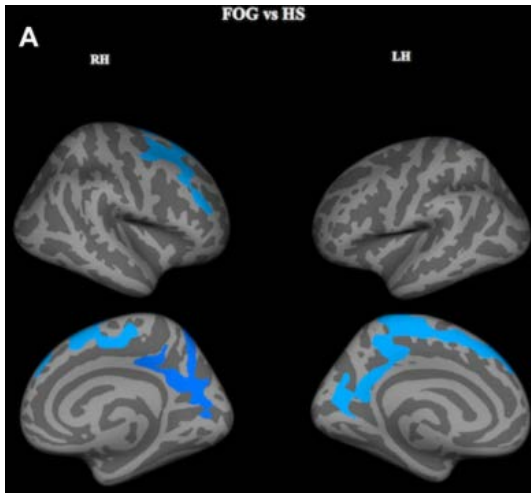
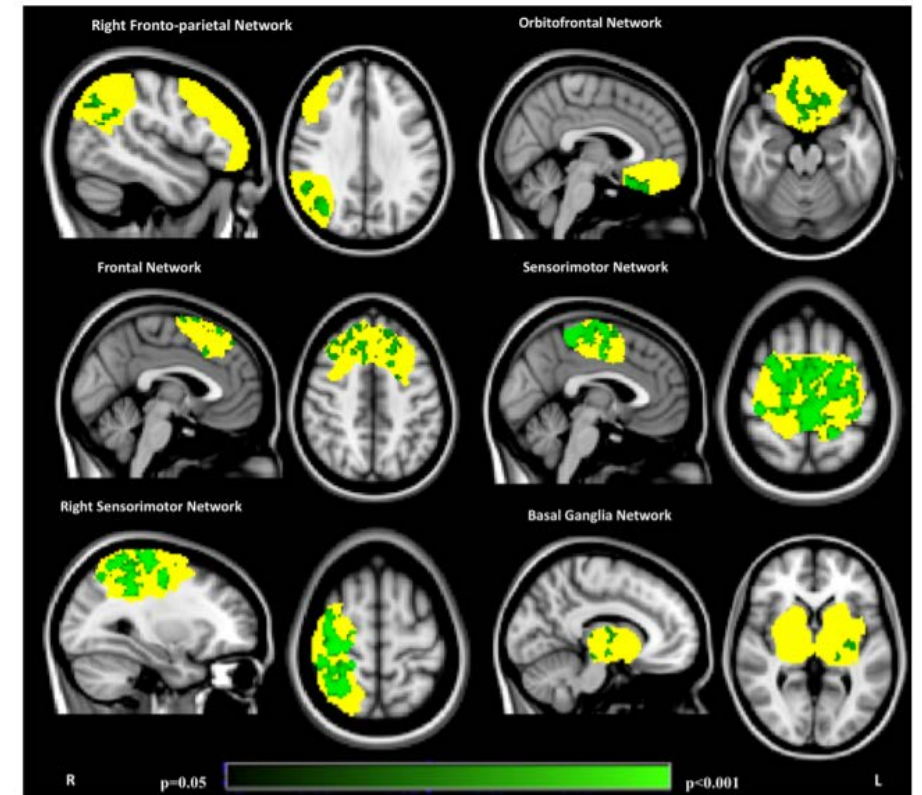


Fig. 2 Cortical areas (light blue) showing decreased SA in patients with FOG compared with patients without FOG. Maps are displayed on the semi-inflated average surface of FreeSurfer's QDEC (query, design, estimate and contrast) interface. Differences were obtained at $p < 0.05$ after multiple comparison correction. SA surface area

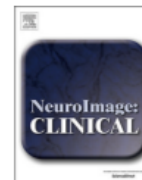
FUNCTIONAL CHANGES



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

NeuroImage: Clinical

journal homepage: www.elsevier.com/locate/ynicl



Neuroimaging advances in Parkinson's disease with freezing of gait: A systematic review

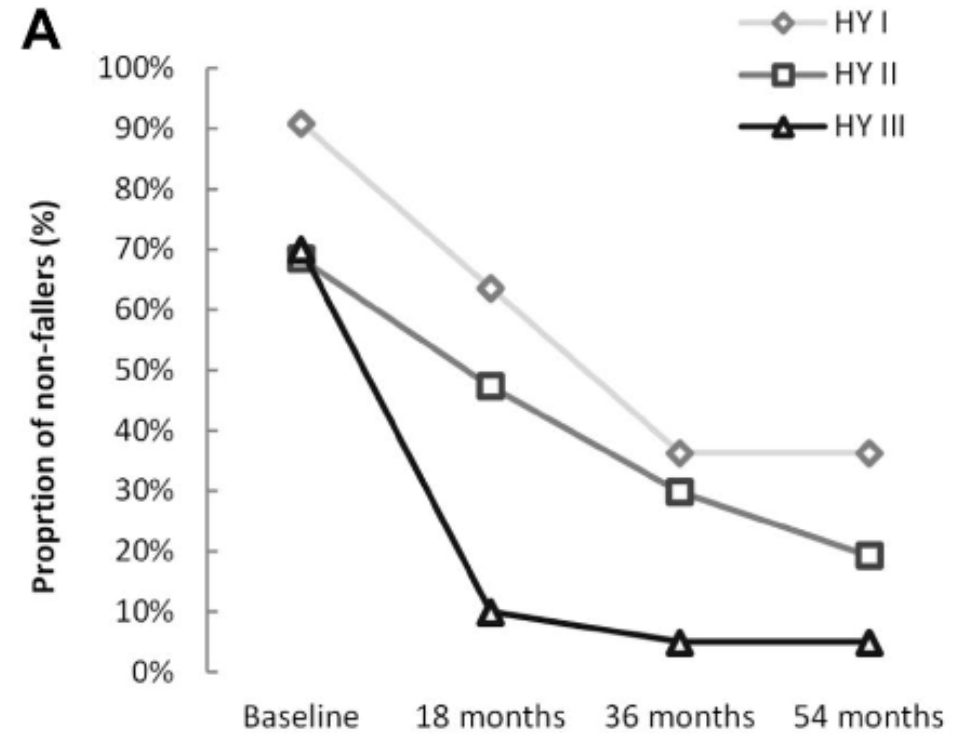
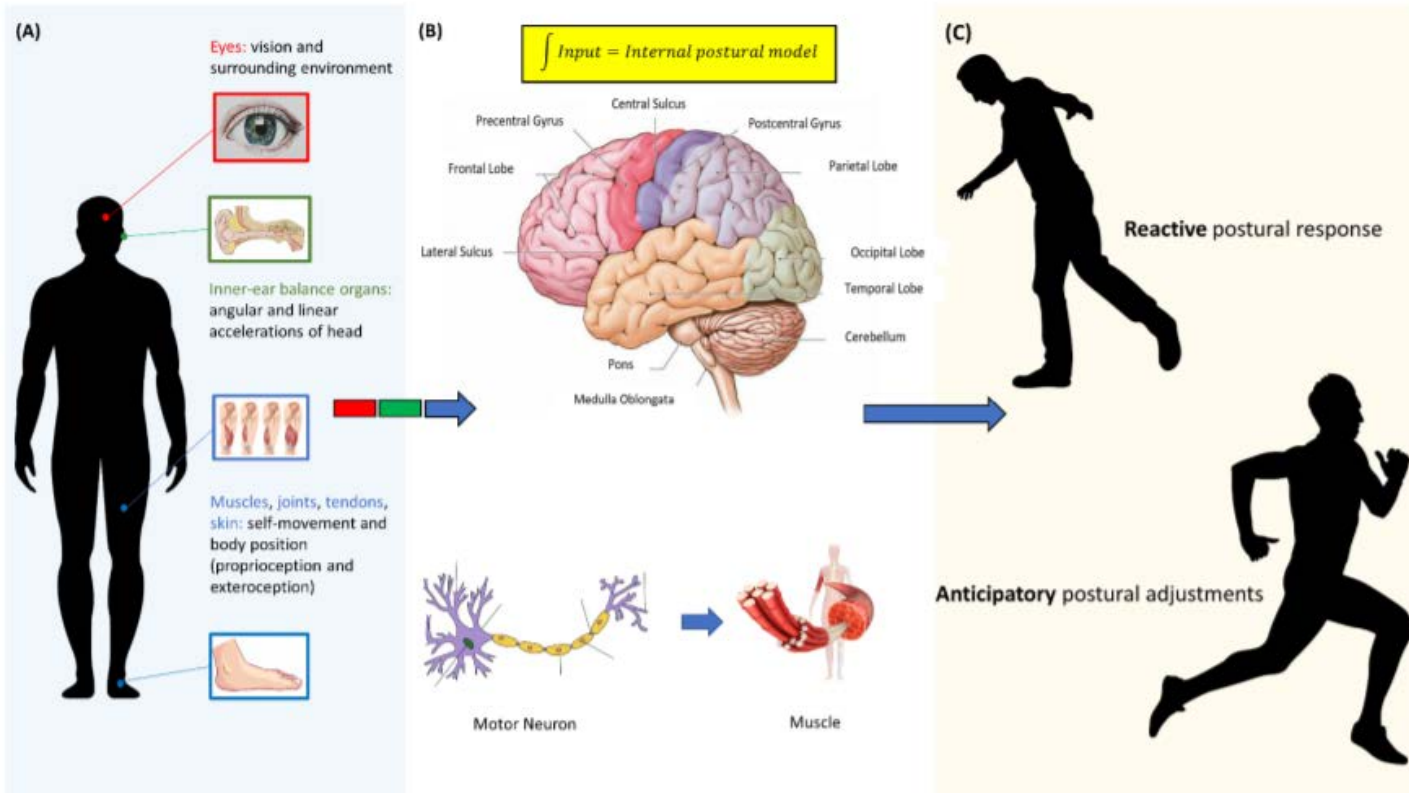
Komal Bharti^{a,1}, Antonio Suppa^{a,b,1}, Silvia Tommasin^a, Alessandro Zampogna^a, Sara Pietracupa^b, Alfredo Berardelli^{a,b}, Patrizia Pantano^{a,b,*}

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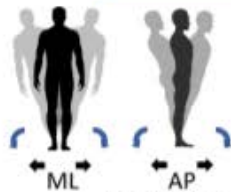
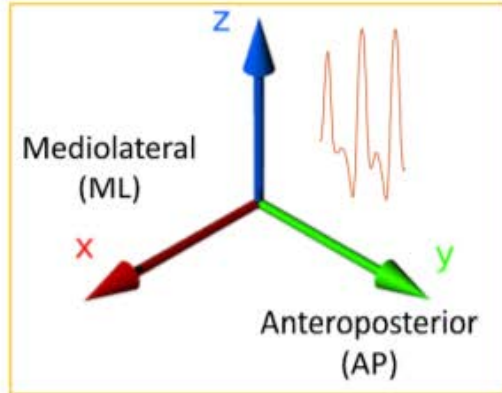
Balance



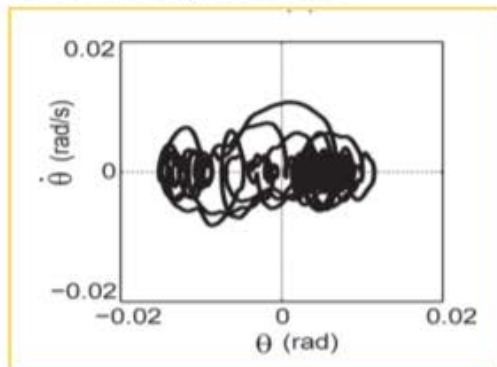
Sensor-based Assessment

(A) Inertial Sensors

Linear acceleration and angular velocity

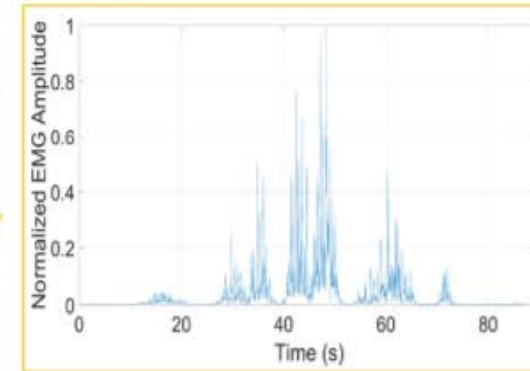


Postural Sway evaluation



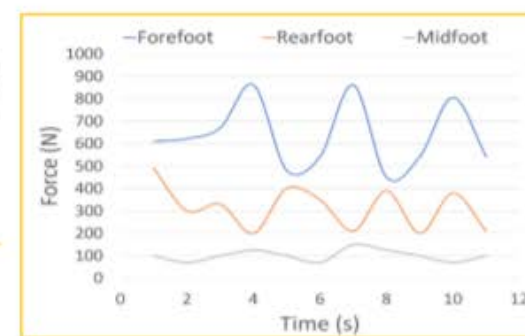
(B) Surface Electromyography

Sensors Muscle action potential



(C) Pressure Sensors

Surface Pressure



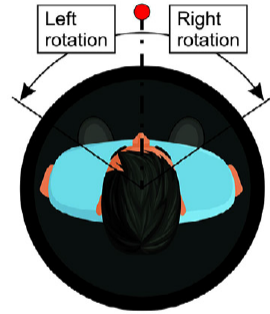
Pressure mapping



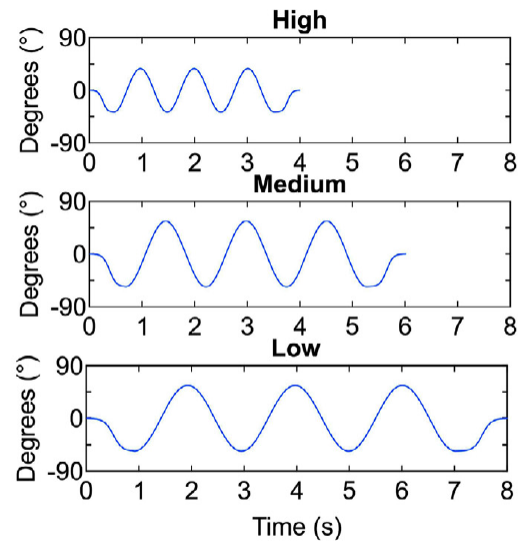
Sensor-based Dynamic Posturography



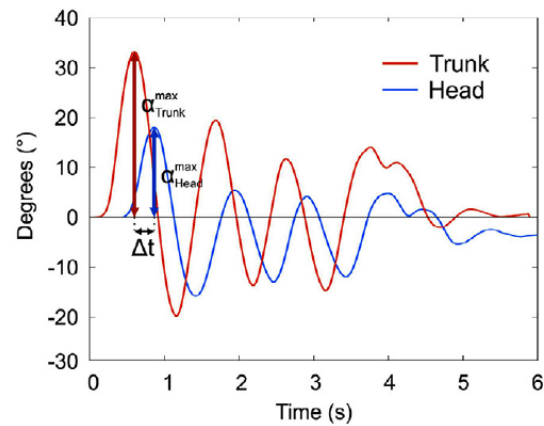
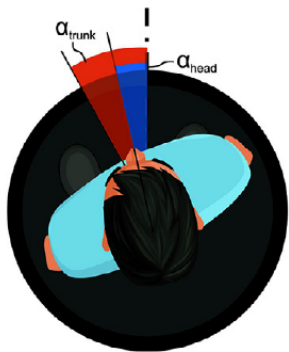
(a)



(b)



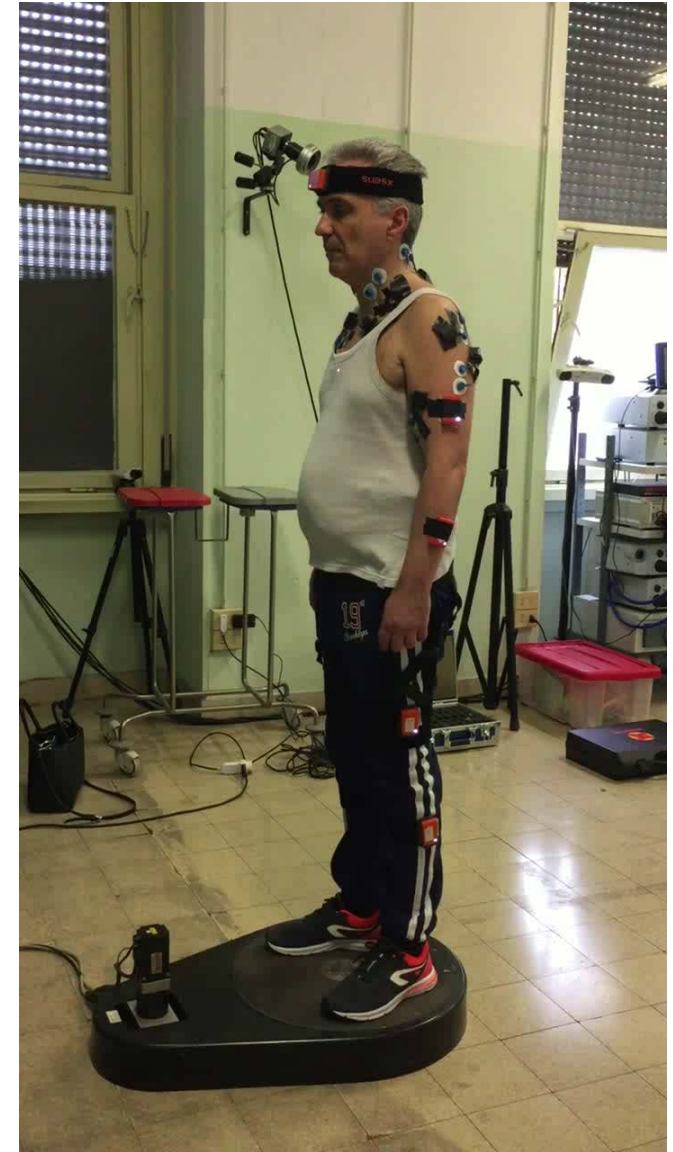
(c)



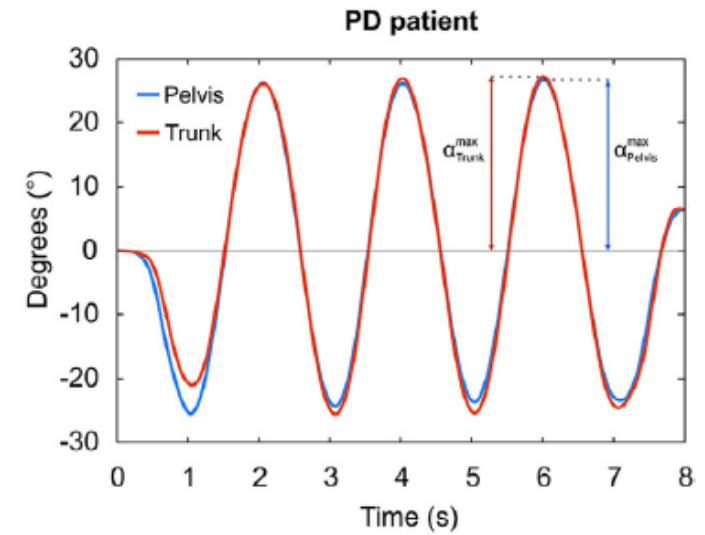
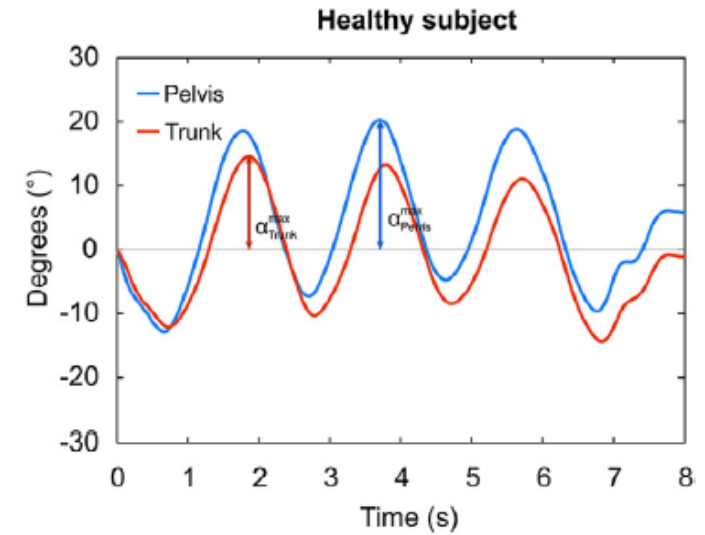
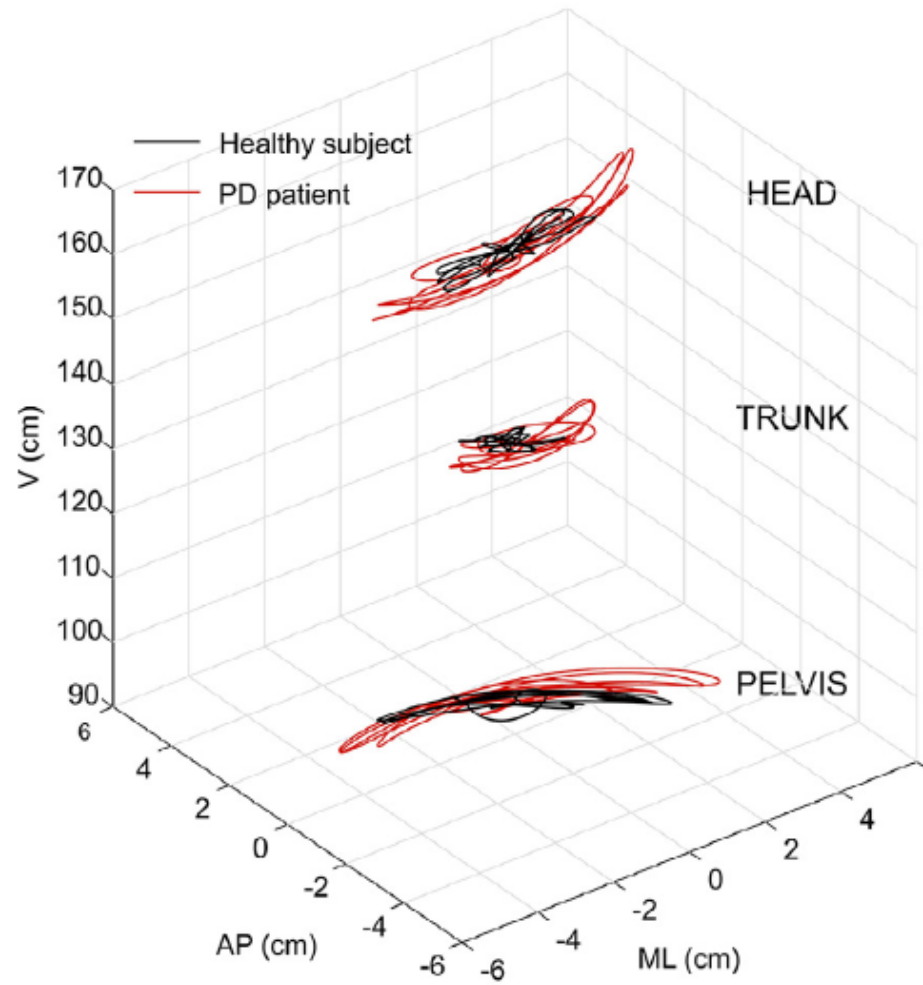
(e)

$$G = \frac{\alpha_{\text{Head}}^{\text{max}}}{\alpha_{\text{Trunk}}^{\text{max}}}$$

$$\Phi \rightarrow \Delta t$$

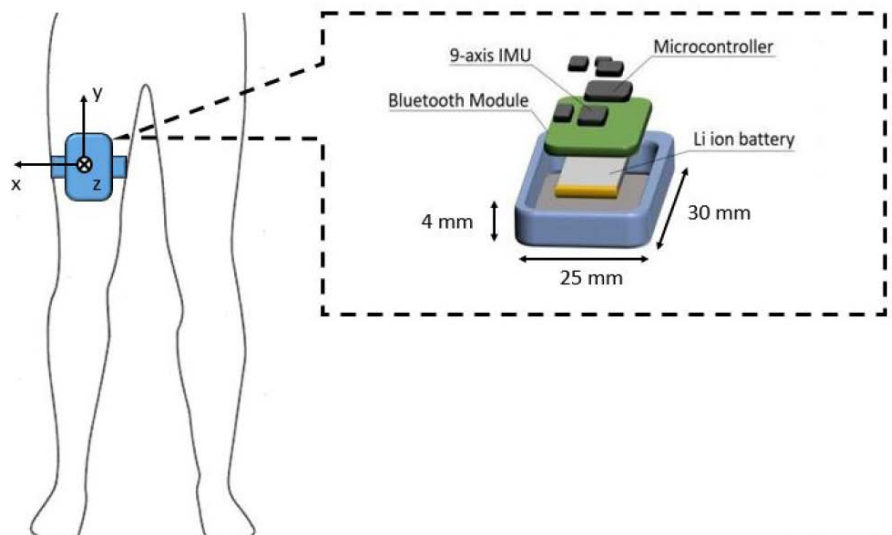


Early Balance Impairment in PD

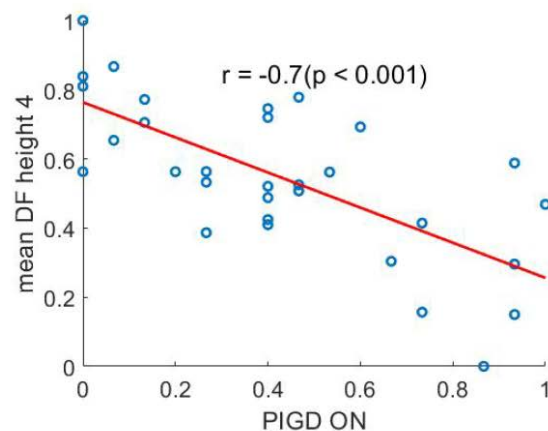
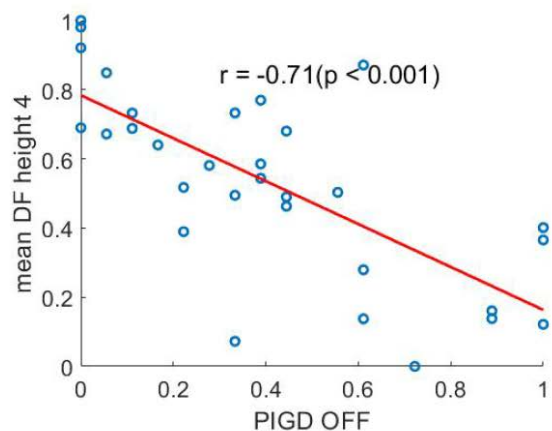


(b)

Postural Instability/Gait Difficulty Score Prediction

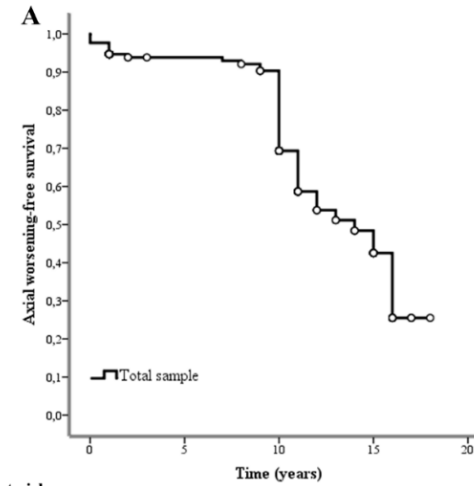
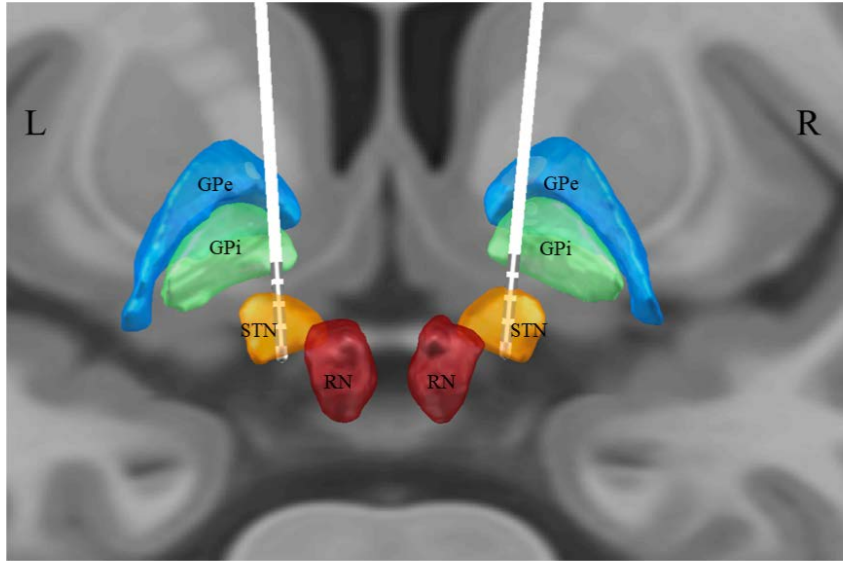


Pharmacological condition	ON	OFF			
Population	All	FOG+	FOG-		
# Features	5	10	15	20	25
Dimensionality reduction	Correlation-based	PCA			



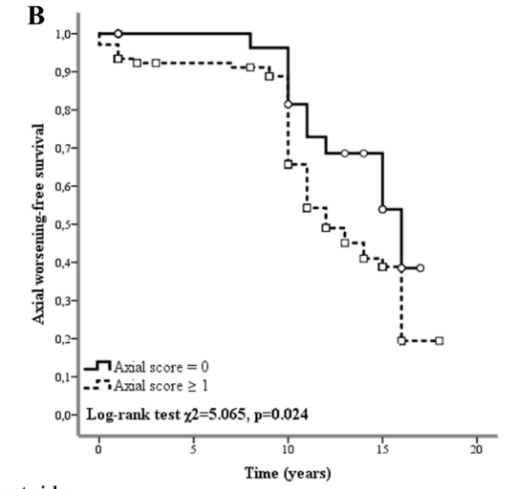
Therapy	FOG	Performance		
		r	RMSE	MAE
All	All	0.64	0.22	0.17
ON	All	0.75	0.20	0.16
	FOG+	0.71	0.27	0.21
OFF	FOG-	0.85	0.19	0.13
	All	0.79	0.19	0.15
	FOG+	0.83	0.22	0.19
	FOG-	0.79	0.21	0.15

STN-DBS and Axial Impairment



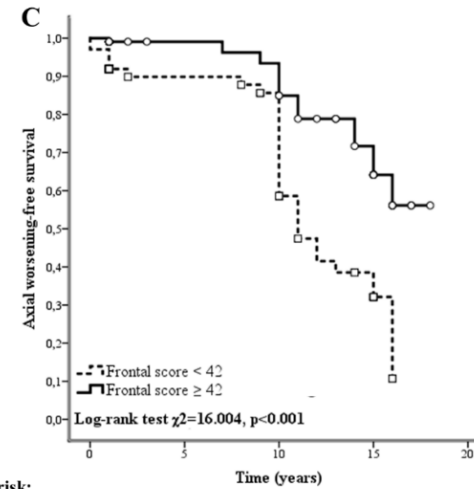
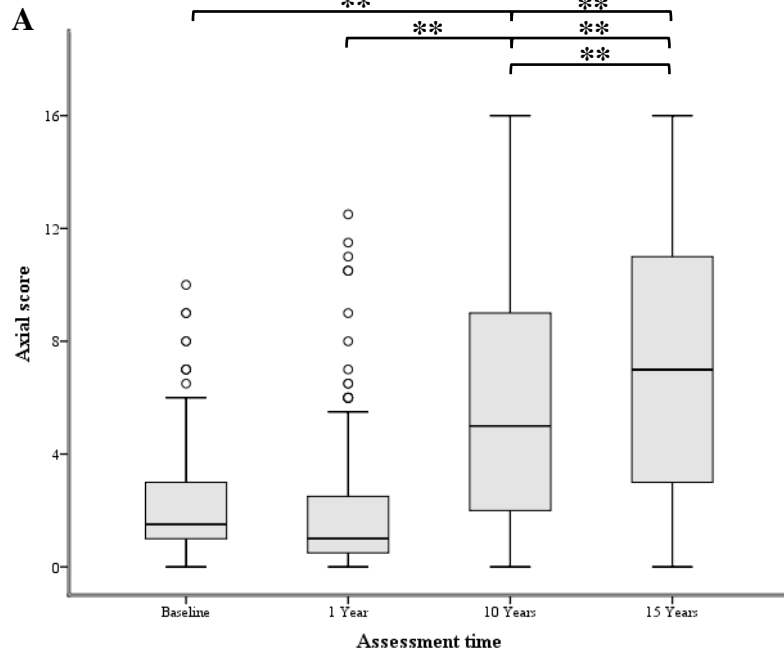
Number at risk:

	302	107	99	33	0
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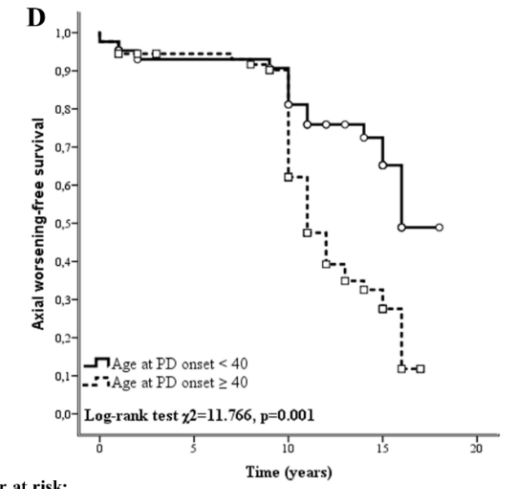
Number at risk:

	59	27	26	14	0
Axial score = 0					
Axial score ≥ 1	243	80	73	19	0



Number at risk:

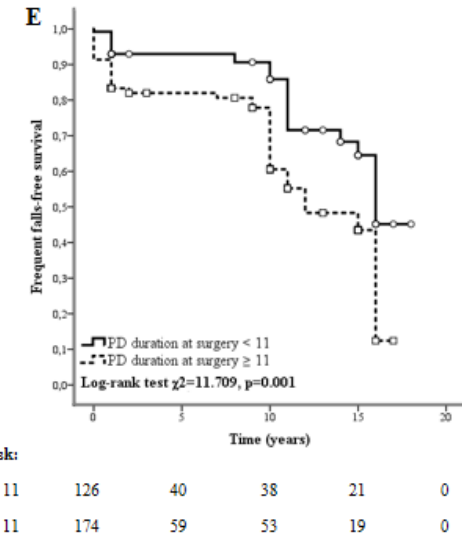
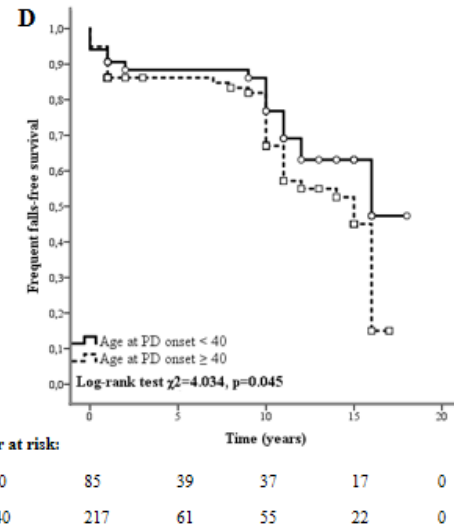
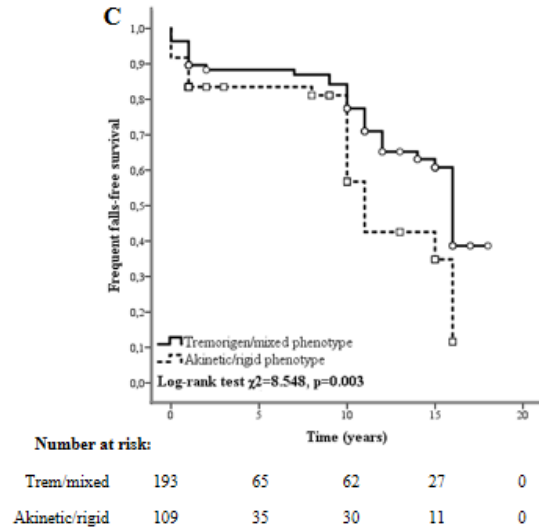
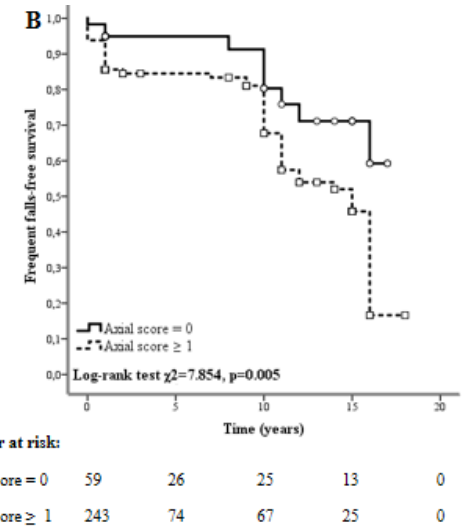
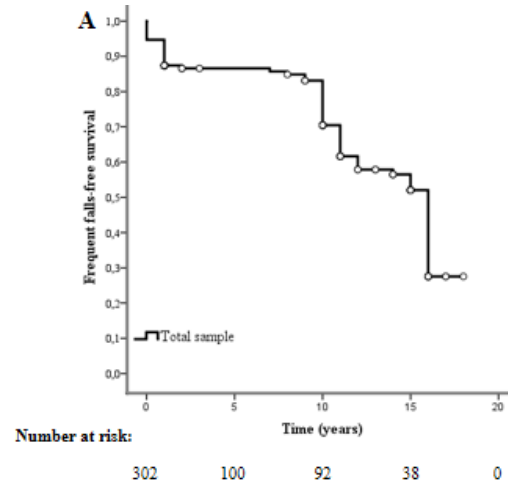
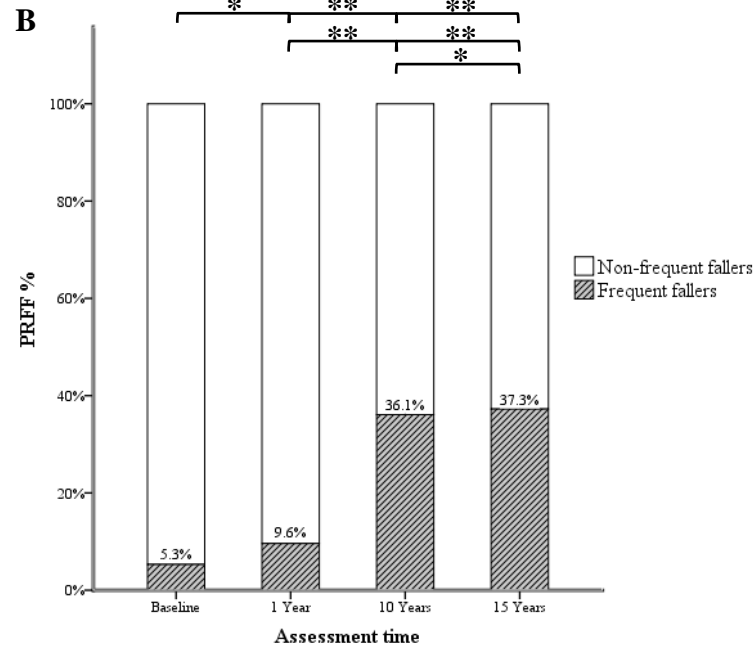
Frontal score < 42	136	43	38	12	0
Frontal score ≥ 42	108	35	33	19	0



Number at risk:

Age < 40	85	40	38	20	0
Age ≥ 40	217	67	61	13	0

STN-DBS and Falls



GRAZIE PER L'ATTENZIONE!