BALANCE AND FALLS IN INDIVIDUALS WITH PARKINSON'S DISEASE

Eveline Pasman, M.D.

PhD Candidate Neural Control of Posture and Movement Lab

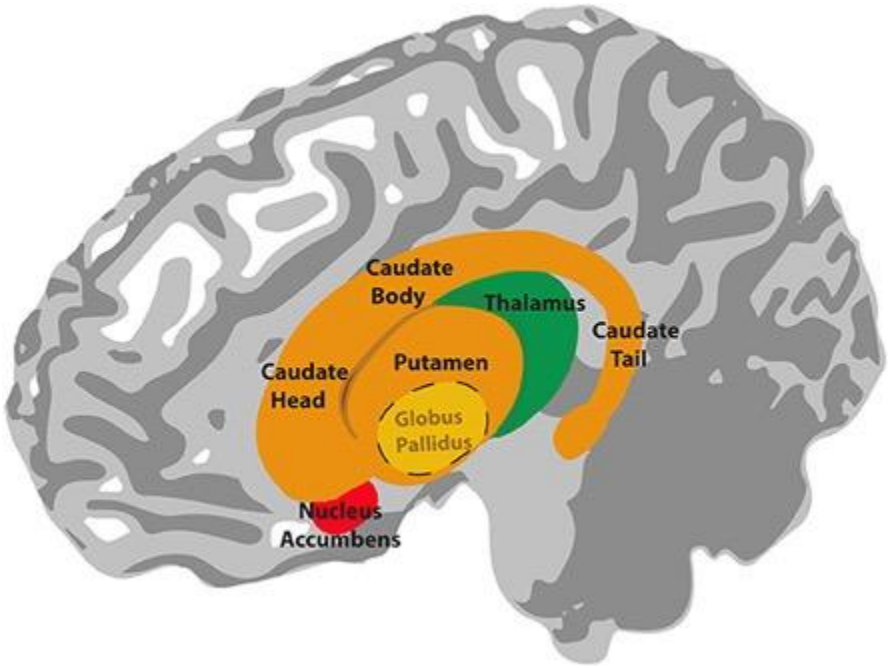
Origins of Balance Deficits and Falls Research Cluster

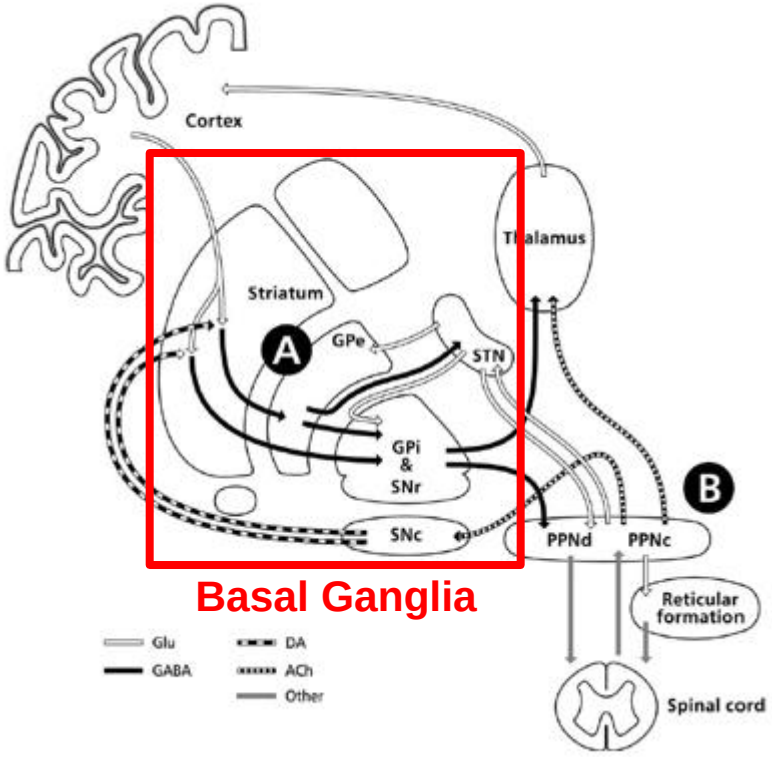
School of Kinesiology, University of British Columbia

PRESENTATION OUTLINE

- **Short overview of Parkinson's disease (PD)**
- **Falls in individuals with PD**
- **Measuring postural instability**
- **Effects of PD on postural control**
- **Fear and anxiety in individuals with PD**
- **Effects of fear and anxiety on postural control**
  - In healthy participants
  - In individuals with PD
- **New research on postural instability in PD**

OVERVIEW OF PARKINSON'S DISEASE

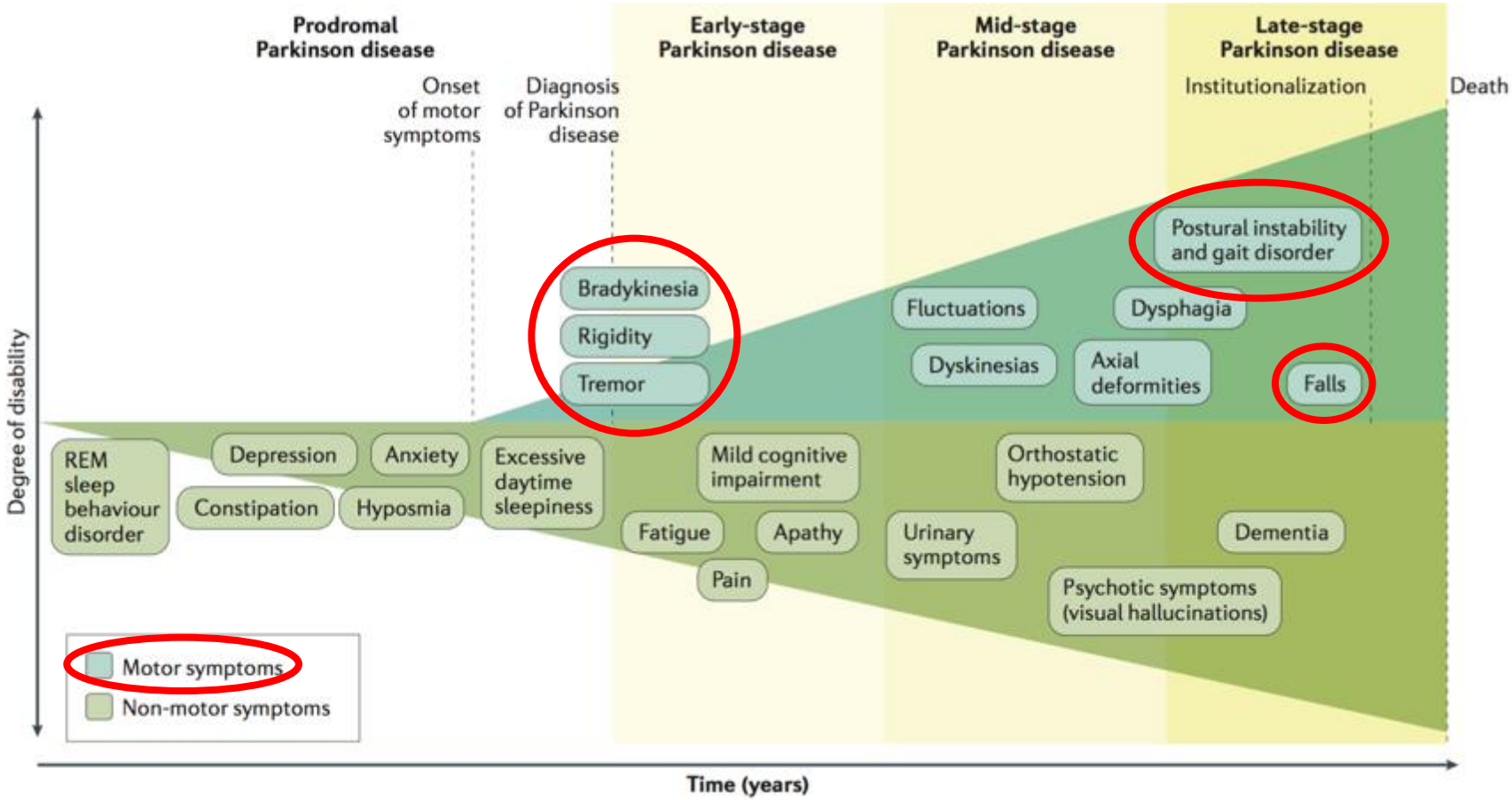




Source: https://commons.wikimedia.org/wiki/File:Anatomy_of_the_basal_ganglia.jpg

Visser et al., Neuroscience, 2008

HALLMARK SYMPTOMS OF PD



Poewe et al., Nature reviews. Disease primers., 2017

POSTURAL INSTABILITY IN PD

TABLE 1. *Comparison between the original and modified Hoehn and Yahr scale*

Hoehn and Yahr scale	Modified Hoehn and Yahr scale
1: Unilateral involvement only usually with minimal or no functional disability	1.0: Unilateral involvement only
	1.5: Unilateral and axial involvement
2: Bilateral or midline involvement without impairment of balance	2.0: Bilateral involvement without impairment of balance
	2.5: Mild bilateral disease with recovery on pull test
3: Bilateral disease: mild to moderate disability with impaired postural reflexes; physically independent[a]	3.0: Mild to moderate bilateral disease; some postural instability; physically independent
4: Severely disabling disease; still able to walk or stand unassisted	4.0: Severe disability; still able to walk or stand unassisted
5: Confinement to bed or wheelchair unless aided	5.0: Wheelchair bound or bedridden unless aided

[a]Stage 3 is a summary of the authors' original, more narrative description.

Goetz et al., Movement Disorders, 2004

FREQUENCY OF FALLS IN PD

Falls occur in 35-90% (average 60.5%) of individuals with PD

- Of these individuals 18-65% (average 39%) fell recurrently
- Recurrent fallers fell between 5 and 68 times per year

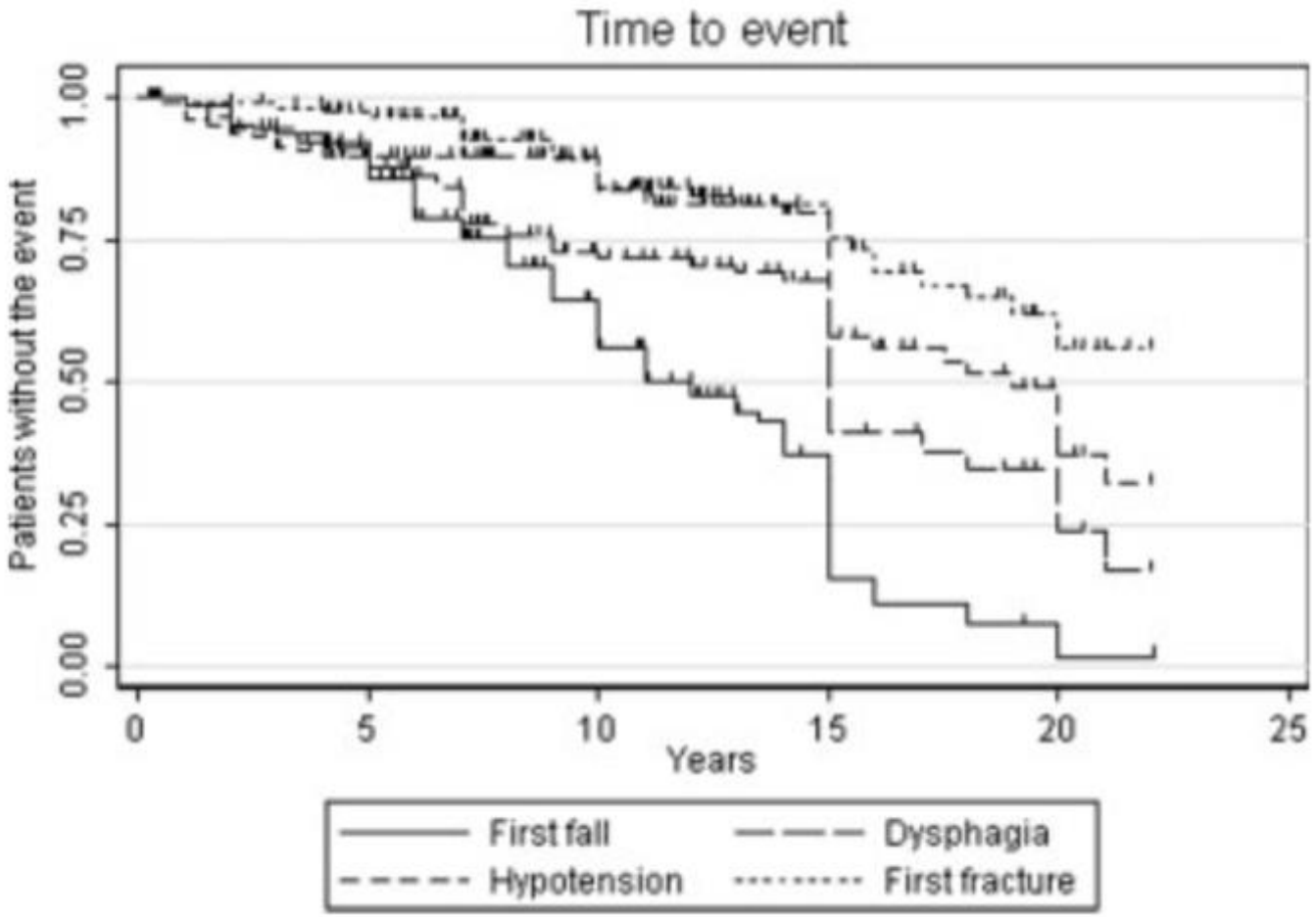
(Allen et al., Parkinson's disease, 2013)

Individuals with PD are 3 times more likely to fall than age-matched controls

(Bloem et al., 2001)

https://svgsilh.com/image/151850.html

LIKELIHOOD OF FALLS VS DISEASE DURATION



Hely et al., Movement Disorders, 2008

FALLS IN THE EARLY STAGES OF PD

Postural instability found in 34% of individuals with PD within 2 years of diagnosis
(Hely et al., Journal of Neurology, Neurosurgery, and Psychiatry, 1989)

Falls reported by 23% of individuals with PD within 5 years of their diagnosis

- 20% experienced a fall within 2 years of diagnosis
- 45% experienced a fall within 2 to 4 years of diagnosis

(Voss et al., Parkinsonism & Related Disorders, 2012)

Therefore, falling is prevalent even in individuals with PD in the early stages of the disease

CAUSES OF FALLS IN PD

Table 2. Fall rates, circumstances and consequences of falls.

	Patients (N = 59)	Controls (N = 55)	Significance
Fall rates			
Time to first fall (months)	1.7 ± 1.7	2.5 ± 2.0	p = 0.35
Fallers (≥1 fall)	30 (50.8%)	8 (14.5%)	p < 0.001
Recurrent fallers (≥2 fall)	15 (25.4%)	2 (3.6%)	p = 0.001
Characteristics [a]			
Falls indoors	124 (82.7%)	2 (20.0%)	p < 0.001
Lach classification (25)			
Intrinsic falls	105 (70.0%)	4 (40.0%)	
Extrinsic falls	20 (13.3%)	5 (50.0%)	p = 0.02
Non-bipedal falls	2 (1.3%)	0 (0.0%)	
Non-classifiable falls	23 (15.3%)	1 (10.0%)	
Maki classification (29)			
Base of support falls	21 (14.0%)	5 (50.0%)	
Center of mass falls	108 (72.0%)	4 (40.0%)	p = 0.02
No obvious perturbation falls	8 (5.3%)	0 (0.0%)	
Non-classifiable falls	13 (8.7%)	1 (10.0%)	

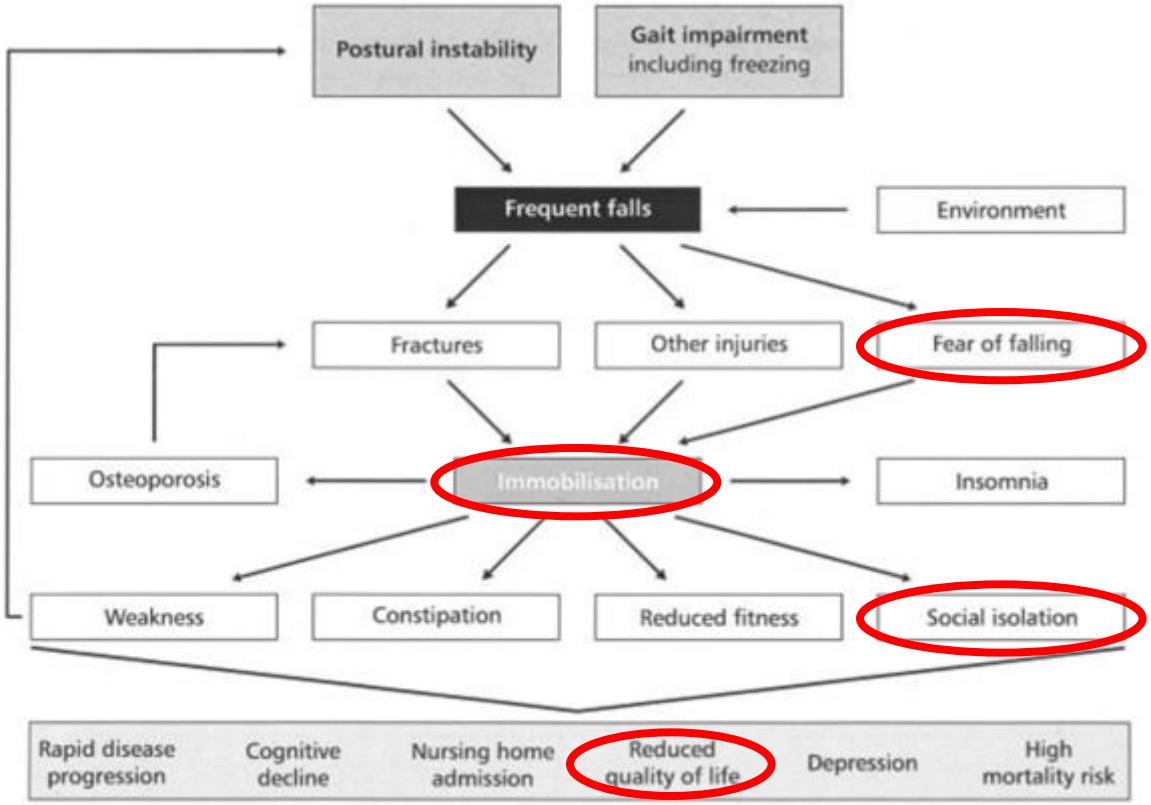
Bloem et al., Journal of Neurology, 2001

NEGATIVE OUTCOMES OF FALLS IN PD

Falls are major sources of morbidity and mortality

- Injuries due to a fall occur in 24-39% of individuals with PD
- Individuals with PD have 51% greater risk for injury mortality

(Pickering et al., Movement Disorders, 2007; Allyson Jones et al., Parkinsonism & Related Disorders, 2012; Gazibara et al., Geriatric Nursing, 2014)



Bloem et al., Movement Disorders, 2004

PREDICTORS OF FALL RISK IN PD

Prior falls

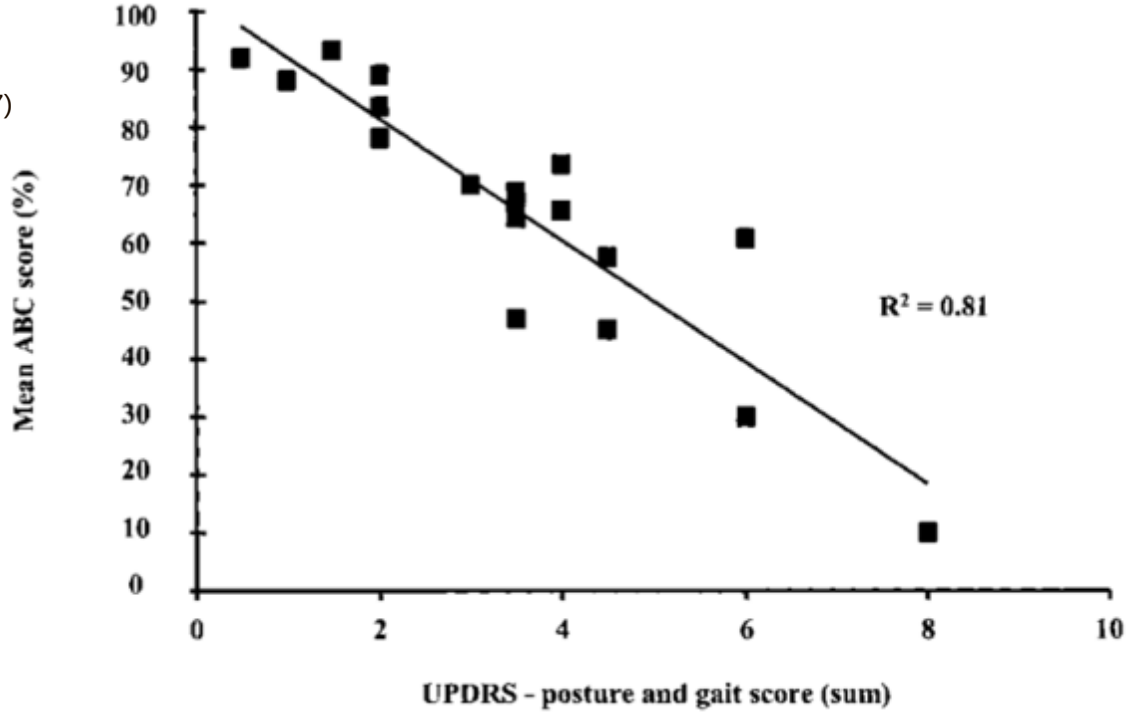
57% of individuals with PD who had a history of falls in the past year fell within a 3-month follow-up period
(Pickering et al., Movement Disorders, 2007)

Fear of falling

(Adkin et al., Movement Disorders, 2003;
Mak & Pang, Journal of Neurology, 2009)

Postural instability

(Fasano et al., Movement Disorders, 2017)

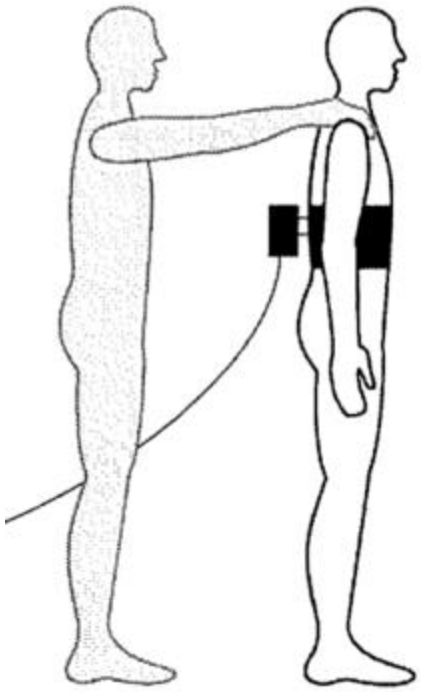


Adkin et al., Movement Disorders, 2003

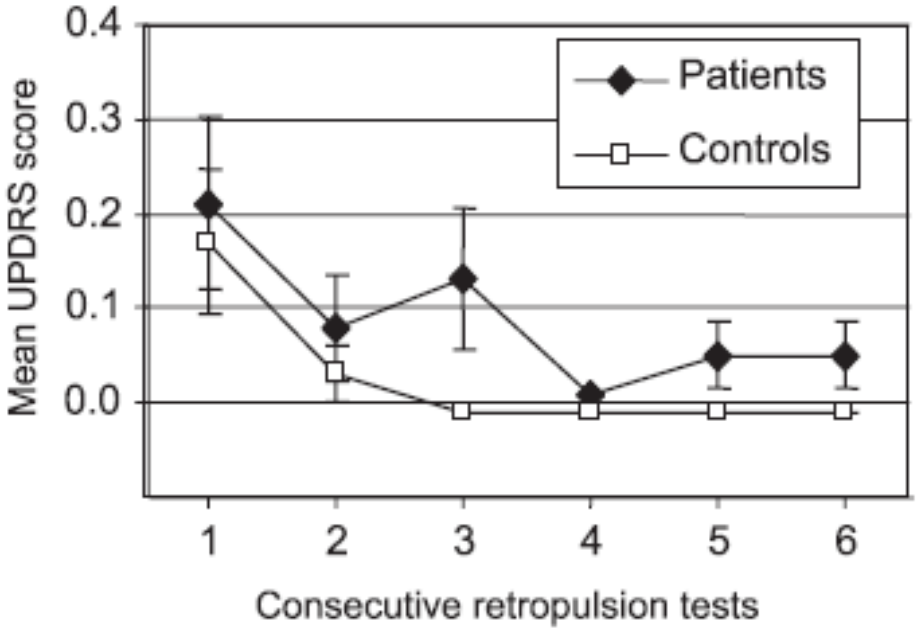
CLINICAL TESTS OF POSTURAL INSTABILITY

Retropulsion (or pull) test

- Integral part of the UPDRS clinical rating scale



Bloem et al., Handbook of Clinical Neurophysiology, Ch 20, 2003



Bloem et al., Journal of Neurology, 2001

CLINICAL TESTS OF POSTURAL INSTABILITY

Functional balance measurement scales

- Community Balance and Mobility Scale
- Berg Balance Scale
- Tinetti Mobility Test

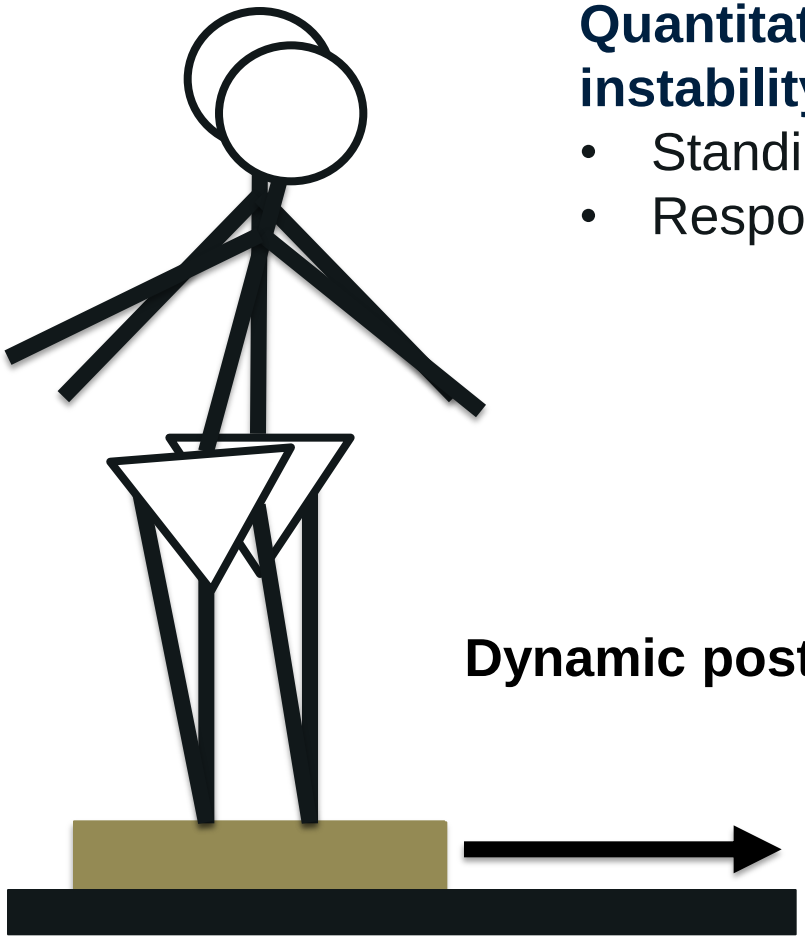
- BESTest and Mini-BESTest

I Biomechanical constraints	*II Stability limits*	*III Anticipatory- transitions*
1. Base of Support	6. a. Lateral Lean L	**9. Sit to Stand**
2. Alignment	b. Lateral Lean R	**10. Rise to Toes**
3. Ankle Strength	c. Sitting Verticality L	**11. Stand on One Leg (both right and left)**
4. Hip Strength	d. Sitting Verticality R	12. Alternate Stair Touch
5. Sit on Floor and Stand Up	7. Reach Forward	13. Standing Arm Raise
	8. a. Reach L	
	b. Reach R	
IV Postural responses	*V Sensory orientation*	*VI Dynamic gait*
14. In-place forward	**19. a. Stance EO (firm surface)**	21. Gait Natural
15. In-place backward	b. Stance EC (firm surface)	**22. Change Speed**
16. Stepping forward	c. Foam EO	**23. Head Turns**
17. Stepping backward	d. **Foam EC**	**24. Pivot Turns**
18. Lateral stepping (both right and left)	**20. Incline EC**	**25. Obstacles**
		26. Get Up and Go
		27. Cognitive Get Up and Go

L: left; R: right; EO: eyes open; EC: eyes closed.

Franchignoni et al., Journal of Rehabilitation Medicine, 2010

POSTUROGRAPHY



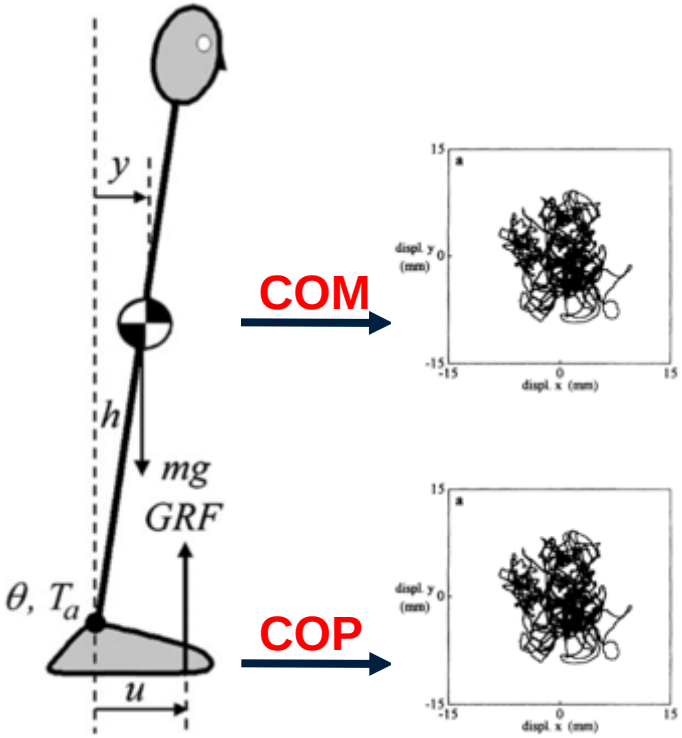
Quantitative measurement of postural instability when:

- Standing quietly
- Responding to balance perturbations

Dynamic posturography

STATIC POSTUROGRAPHY

The measurement of body sway and how it is controlled during upright quiet standing



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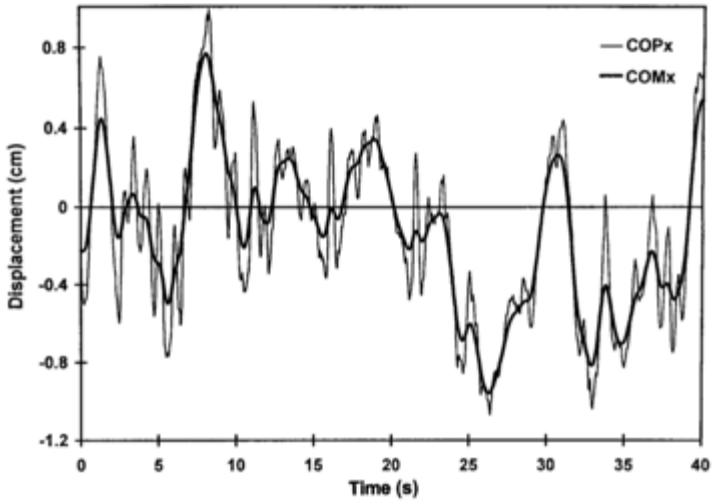


(3)

(1) Bottaro et al., Human Movement Science, 2005
(2) Collins & De Luca, Physical Review Letters, 1994
(3) Winter et al., Journal of Neurophysiology, 1998

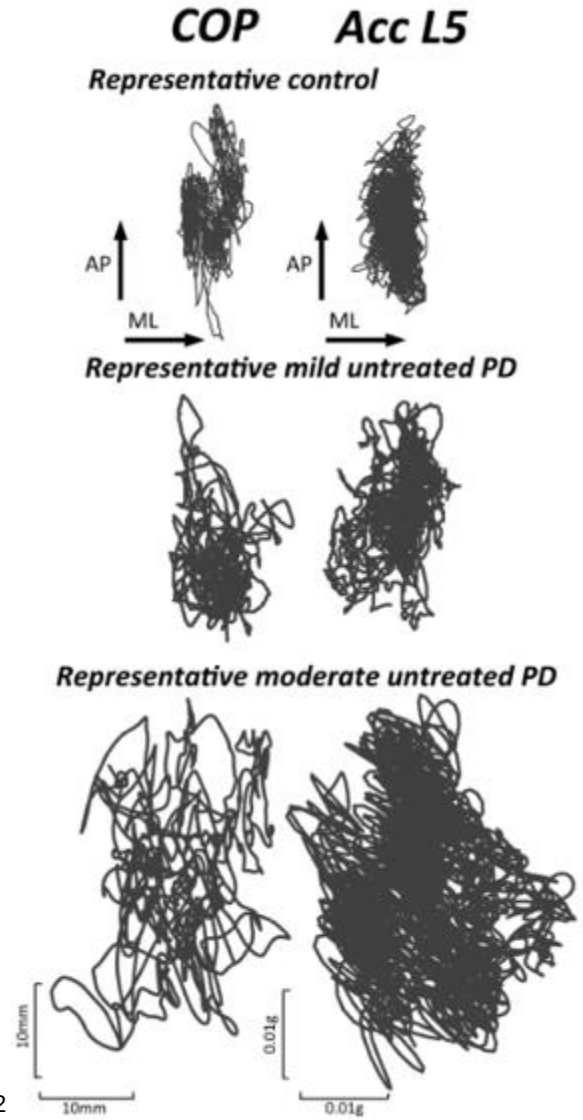
STATIC POSTUROGRAPHY – EFFECTS OF PD

Effects of PD on COP and COM*

- Increased amplitude of sway
- Increased frequency or velocity of sway

(Waterston et al., Journal of Neurology, Neurosurgery, and Psychiatry, 1993; Rocchi et al., Journal of Neurology, Neurosurgery, and Psychiatry, 2002; Viitasalo et al., Movement Disorders, 2002; Maurer et al., Brain, 2003; Mancini et al., Parkinsonism & Related Disorders, 2011; Mancini et al., Journal of NeuroEngineering and Rehabilitation 2012; Cruz et al., Neuroscience Letters, 2018)

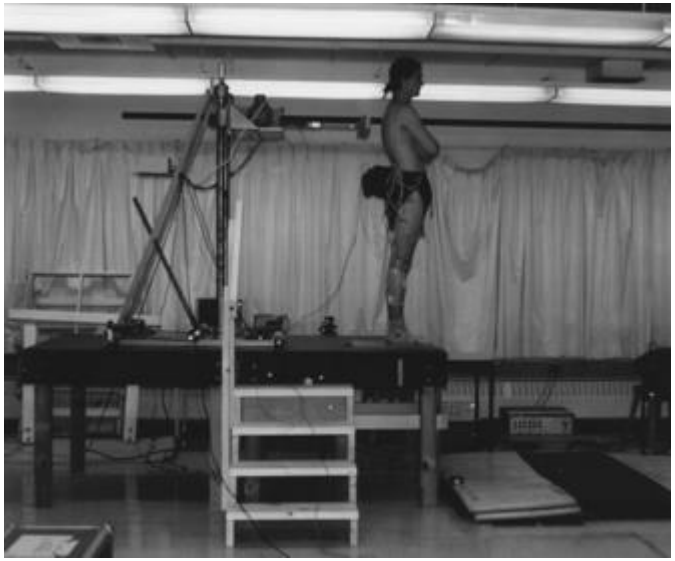
*Based on studies with 60s trial duration and age-matched controls



Mancini et al., Journal of NeuroEngineering and Rehabilitation 2012

DYNAMIC POSTUROGRAPHY

The measurement of dynamic postural responses to expected or unexpected external balance perturbations



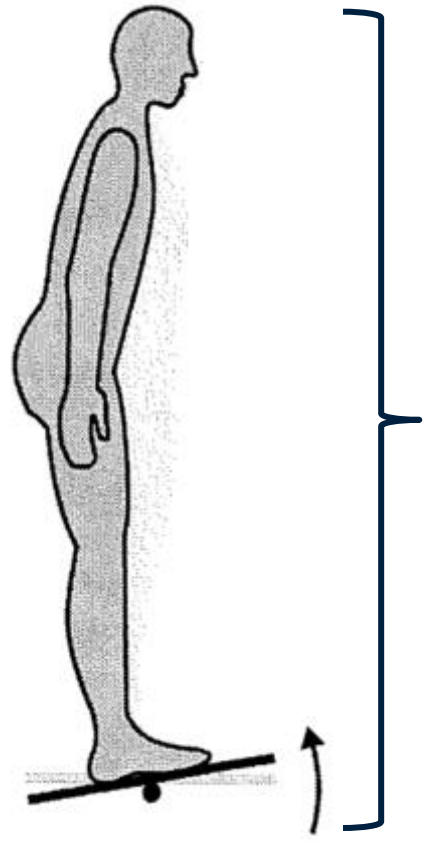
Push or pull

Translation

Rotation

Brown & Frank, Gait & Posture, 1997

DYNAMIC POSTUROGRAPHY



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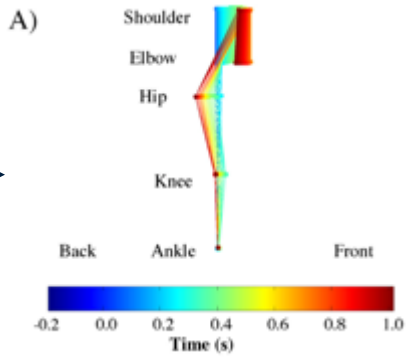

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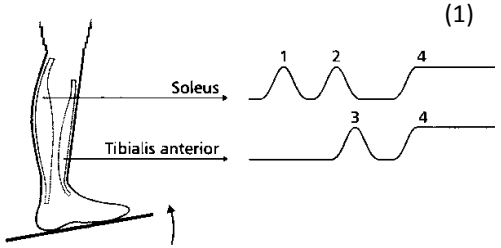

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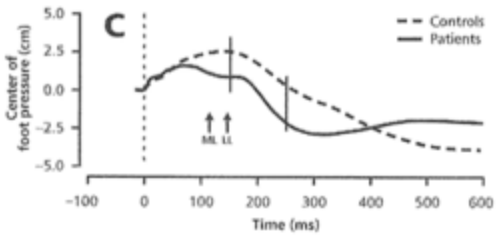


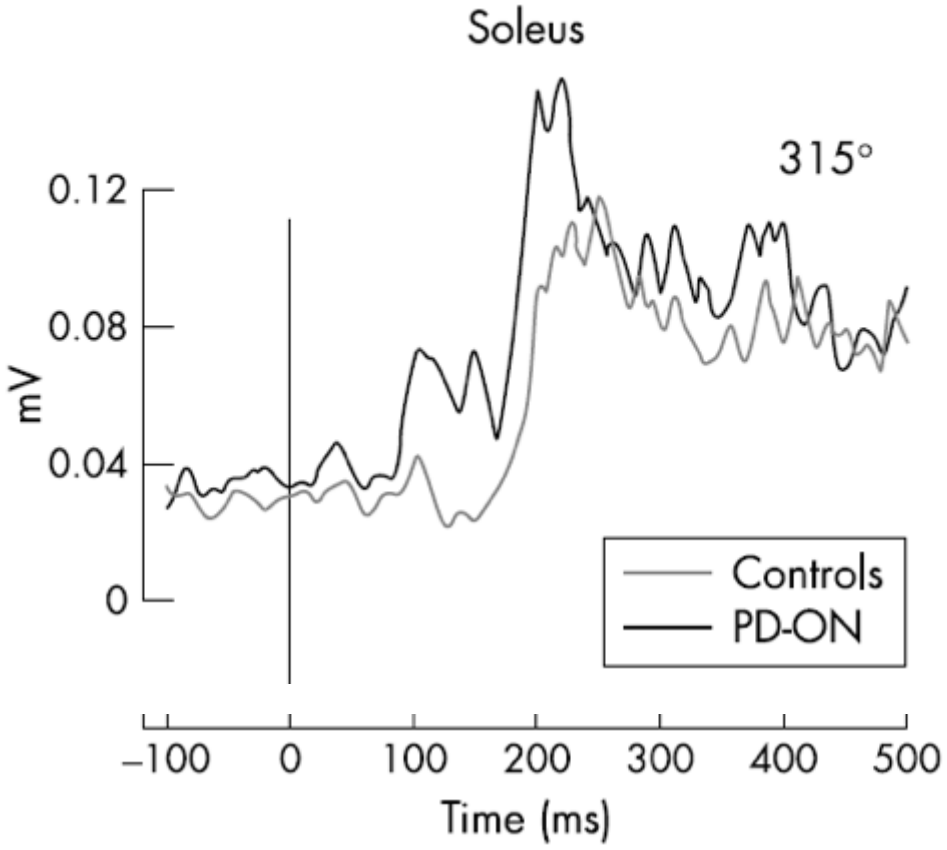
(5)

(1) Modified from: Bloem et al.,Handbook of Clinical Neurophysiology, Ch 20, 2003
(2) Modified from: Geerse et al., PLoS One, 2015
(3) Modified from: Cleworth et al., Gait & Posture, 2016
(4) Source: https://commons.wikimedia.org/wiki/File:AMTI_OPT464508_force_plate.png
(5) Modified from: Bloem et al., Balance at All Times, Long-term timescale: Compensatory postural strategies in patients with longstanding balance impairment, 2001

DYNAMIC POSTUROGRAPHY – EFFECTS OF PD

Larger amplitude of postural responses

(Carpenter et al., Journal of Neurology, Neurosurgery, and Psychiatry, 2004; Dimitrova et al., Journal of Neurophysiology, 2004)

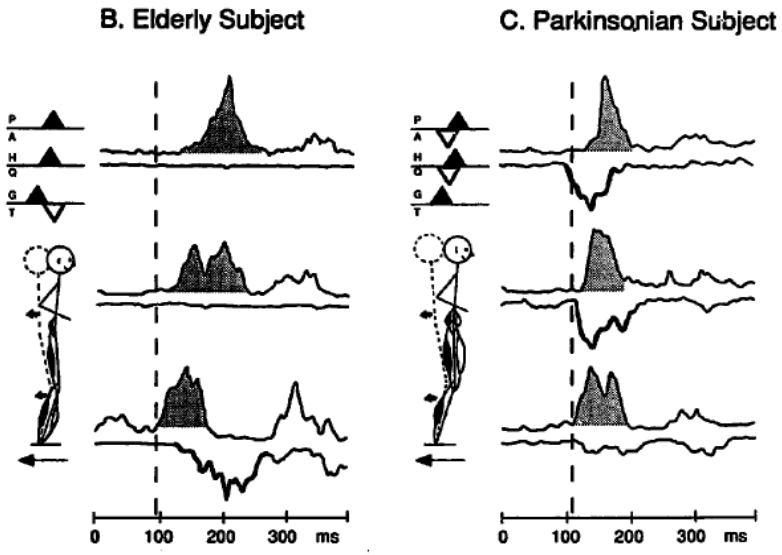


Modified from: Carpenter et al., Journal of Neurology, Neurosurgery, and Psychiatry, 2004

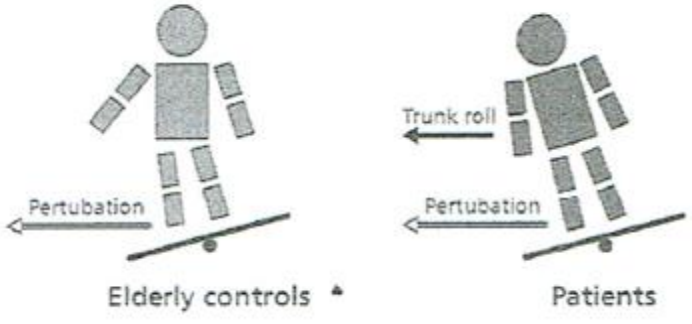
DYNAMIC POSTUROGRAPHY – EFFECTS OF PD

Co-contraction/stiffening

(Horak et al., Journal of the Neurological Sciences, 1992; Carpenter et al., Journal of Neurology, Neurosurgery, and Psychiatry, 2004)



Modified from: Horak et al., Journal of the Neurological Sciences, 1992



Modified from: Bloem et al., Balance at All Times, Long-term timescale: Compensatory postural strategies in patients with longstanding balance impairment, 2001

DYNAMIC POSTUROGRAPHY – EFFECTS OF PD

Poor adaptability ('postural inflexibility')

- Between amplitudes

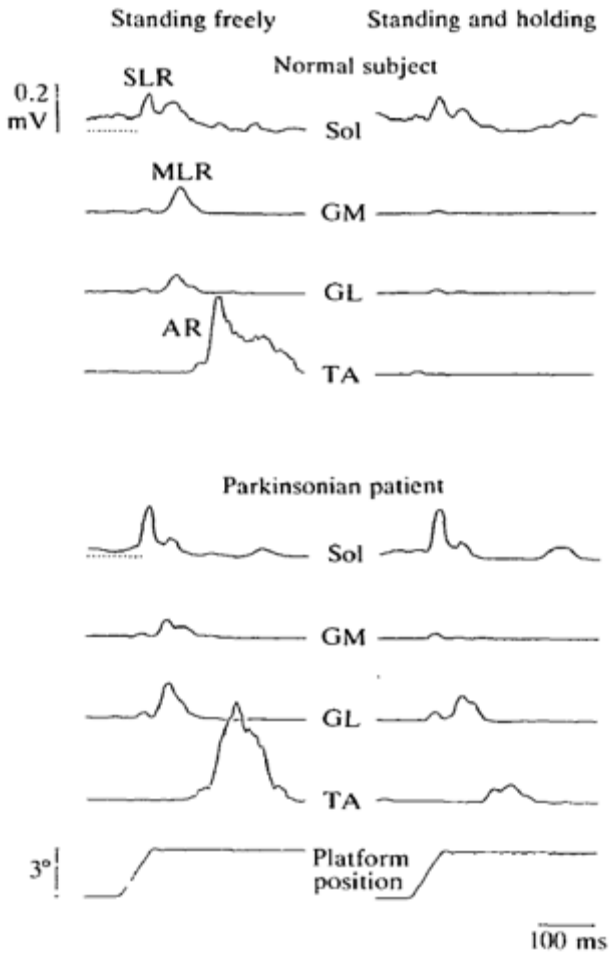
(Beckley et al., Electroencephalography and clinical Neurophysiology, 1993)

- Between types of perturbations

(Chong et al., Journal of the Neurological Sciences, 2000)

- Between postures

(Schieppati & Nardone, Brain, 1991;
Horak et al., Journal of the Neurological Sciences, 1992;
Chong et al., Journal of the Neurological Sciences, 2000)

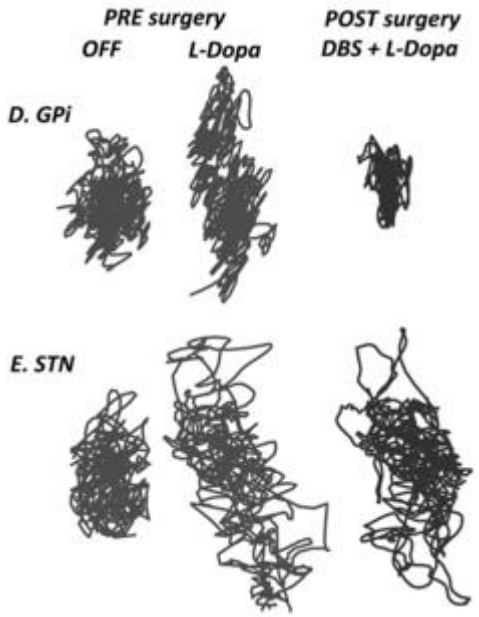


Modified from: Schieppati & Nardone, Brain, 1991

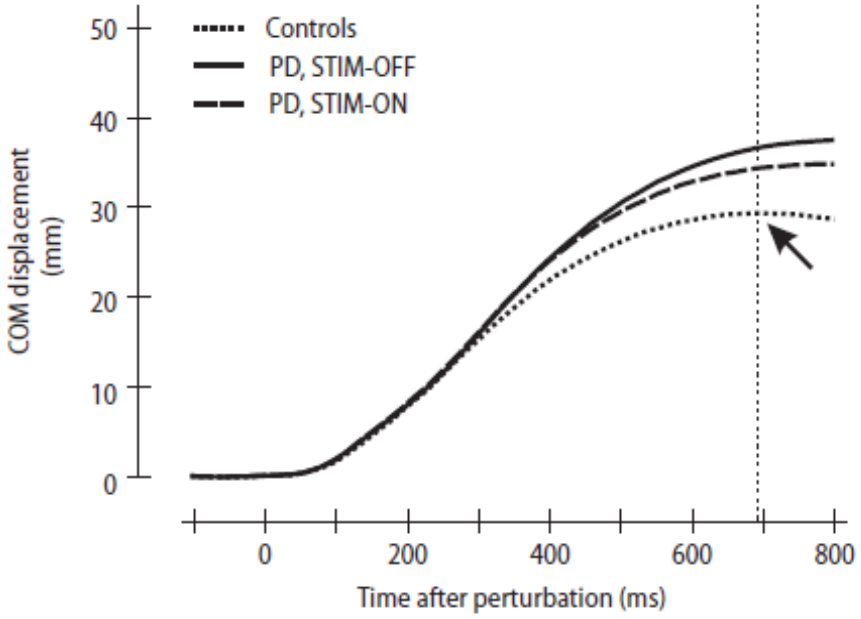
EFFECTIVENESS OF TREATMENT

Postural instability not alleviated, and in some cases aggravated, by medication and surgical treatments for PD

(Bloem et al., Movement Disorders, 2004; Sethi et al., Movement Disorders, 2008; Visser et al., Journal of Neurology, 2008; St. George et al., Neurology, 2010)

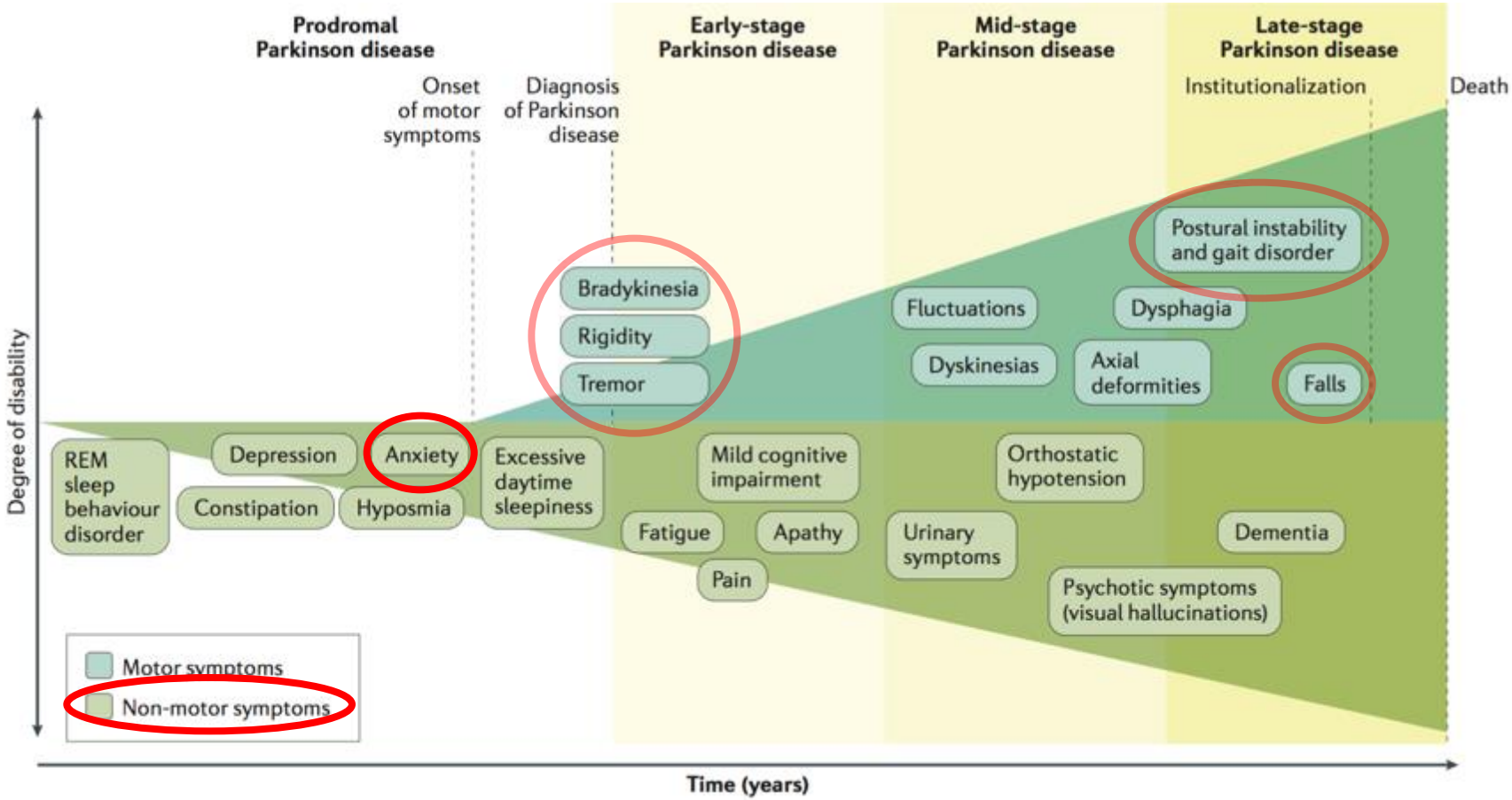


Modified from: Schoneburg et al, Movement Disorders, 2013



Visser et al., Journal of Neurology, 2008

NON-MOTOR SYMPTOMS OF PD



Poewe et al., Nature reviews. Disease primers., 2017

FREQUENCY OF FEAR/ANXIETY IN PD

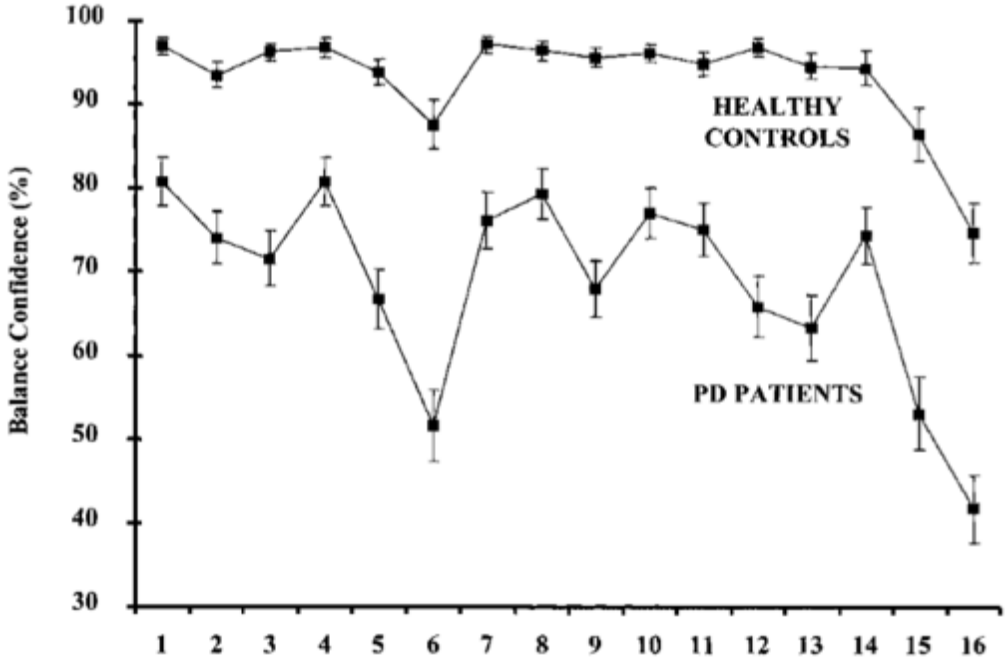
Anxiety affects up to 60% of individuals with PD

(Schrag & Taddei, International Review of Neurobiology, 2017; Schapiro et al., Nature Reviews. Neuroscience., 2017)

Fear of falling reported by 46% of individuals with PD

- Associated with limitations in daily activities, physical inactivity and recurrent future falls

(Bloem et al., Journal of Neurology, 2001; Mak et al., Journal of Neurology, 2009; Bryant et al., Journal of Ageing and Physical Activity, 2015)

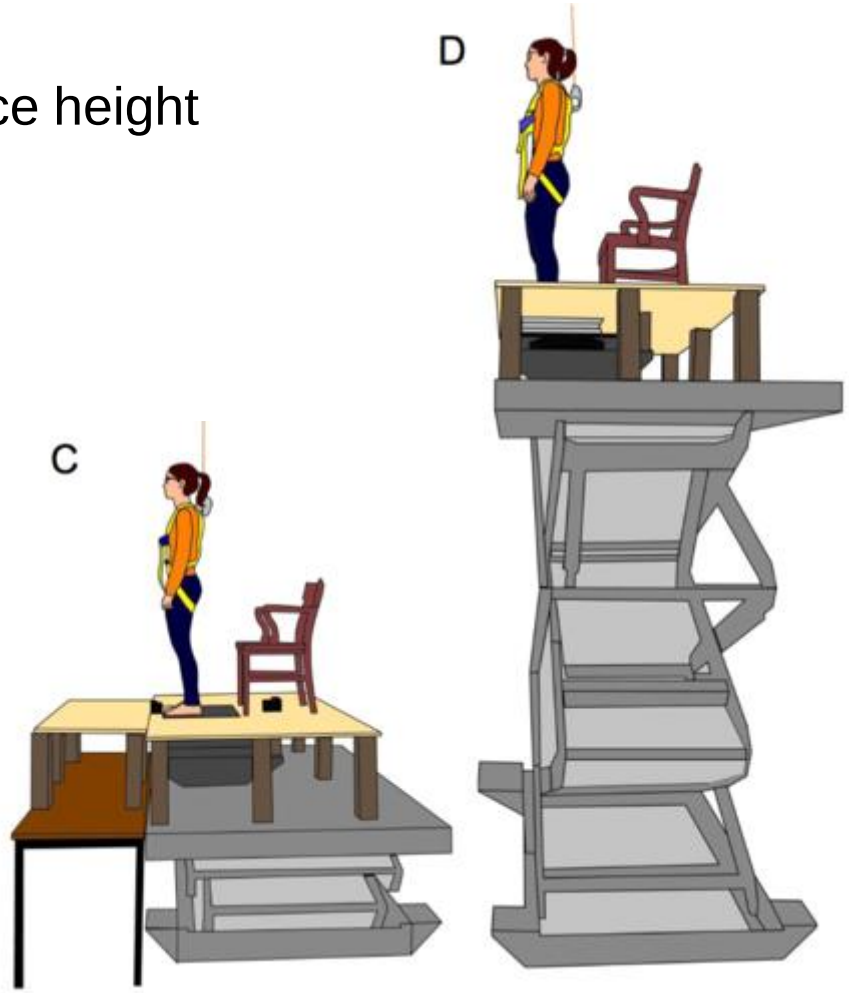


Adkin et al., Movement Disorders, 2003

EFFECTS OF FEAR/ANXIETY ON BALANCE

Several methods used to investigate effects of fear/anxiety on postural control

- Social anxiety associated with clinical balance assessment
- Threat of perturbation
- Manipulation of support surface height



Modified from: Cleworth et al., Neuroscience, 2019

EFFECTS OF FEAR/ANXIETY ON BALANCE

Participants standing at the edge of an elevated platform

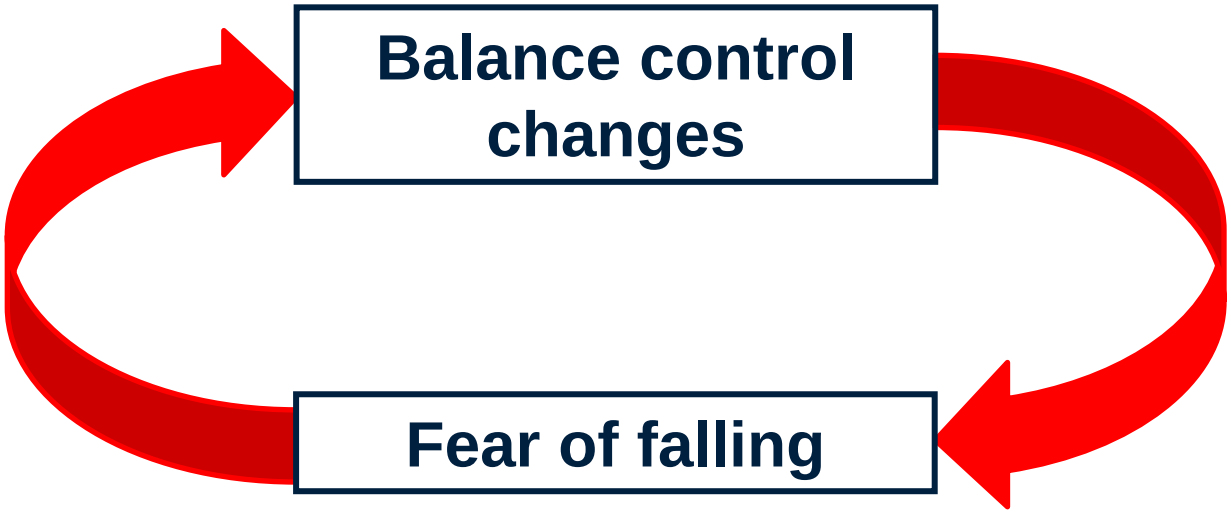
- Lean away from the platform edge
- Increase sway frequency
- Decrease sway amplitude

Study	Group	Maximum threat	Sampling duration	AP COP MP	AP COP MPF	AP COP RMS
Carpenter et al. (25)	14 YA	1.6 m	120 s	Posterior lean	Increased	Decreased
	13 OA	1.6 m	120 s	Posterior lean	Increased	Decreased
Hauck et al. (28)	31 YA	1.4 m	60 s	Posterior lean	Increased	Decreased
Davis et al. (29)	26 YA	3.2 m	60 s	Posterior lean	Increased	Decreased
Huffman et al. (30)	48 YA	3.2 m	60 s	Posterior lean	Increased	*No change*
Pasman et al. (39)	14 OA	1.6 m	120 s	Posterior lean	Increased	*No change*
Cleworth et al. (32)	18 YA	3.2 m	120 s	Posterior lean	Increased	Decreased
Zaback et al. (34)	82 YA	3.2 m	60 s	Posterior lean	Increased	Decreased
Cleworth et al. (35)	20 YA	3.2 m	60 s	Posterior lean	Increased	Decreased

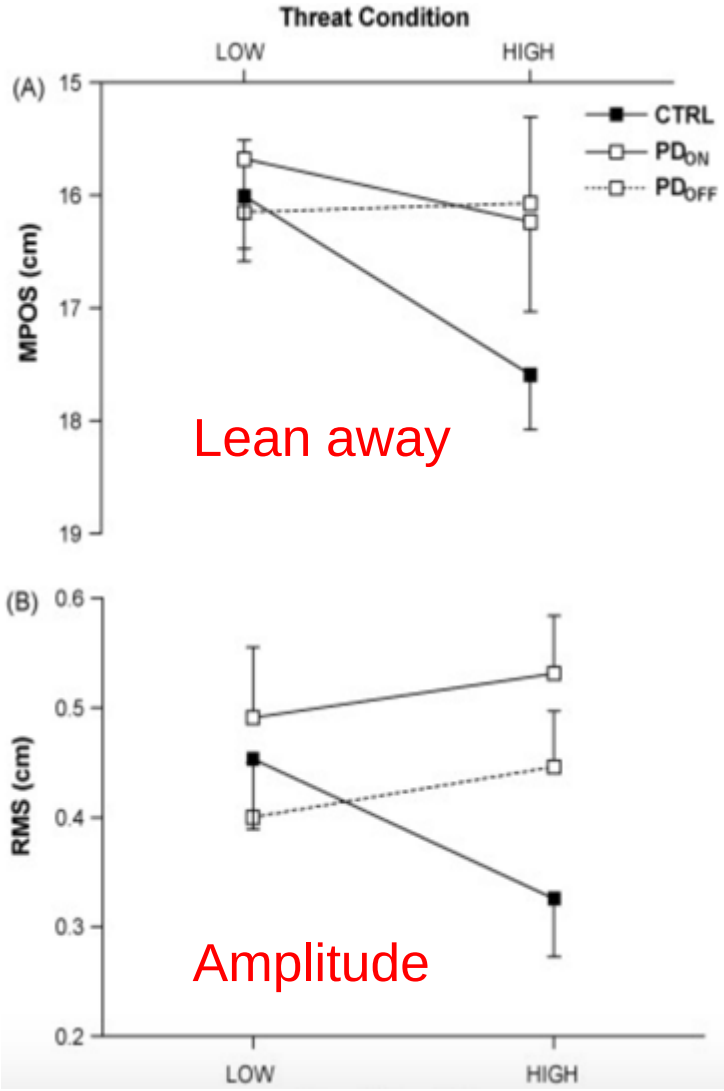
Adkin & Carpenter, Frontiers in Neurology, 2019

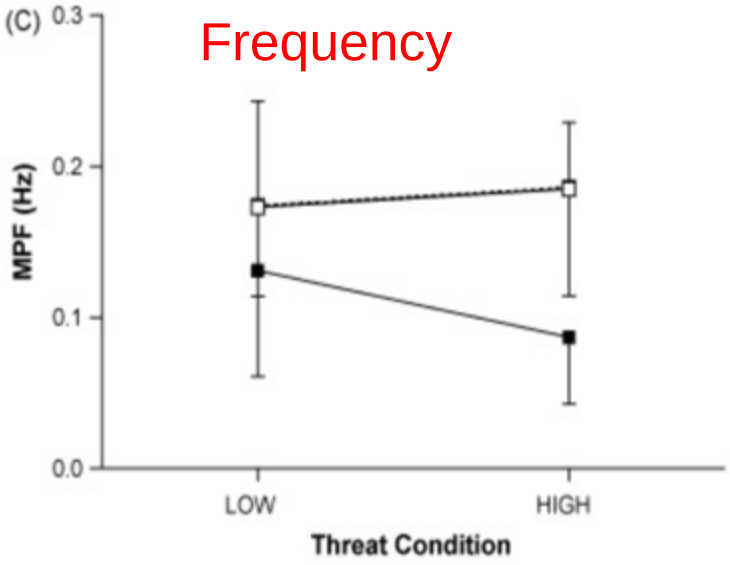
EFFECTS OF FEAR/ANXIETY ON BALANCE

Which comes first?



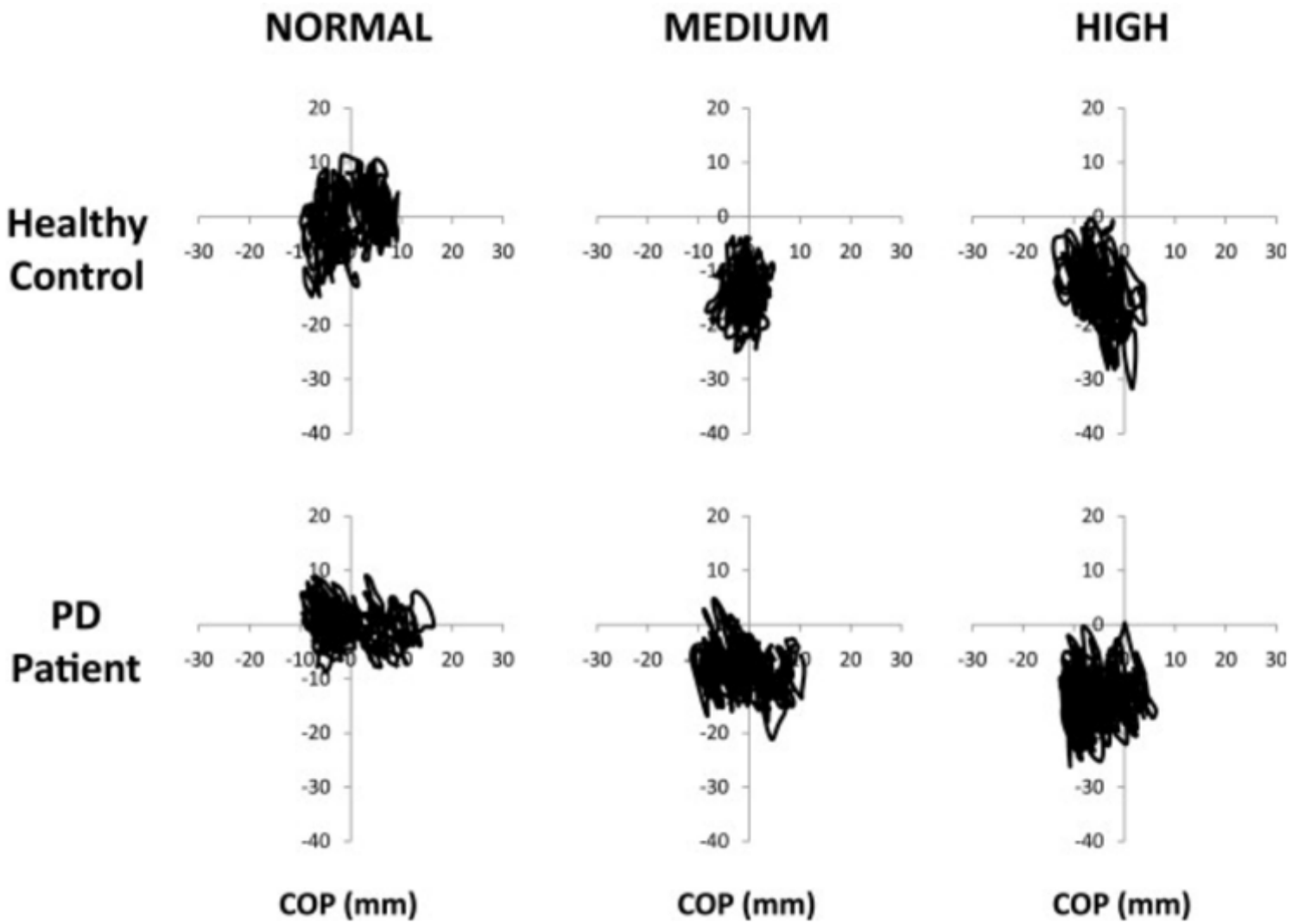
EFFECTS OF FEAR/ANXIETY ON BALANCE IN PD





Modified from: Brown et al., Neuroscience Letters, 2007

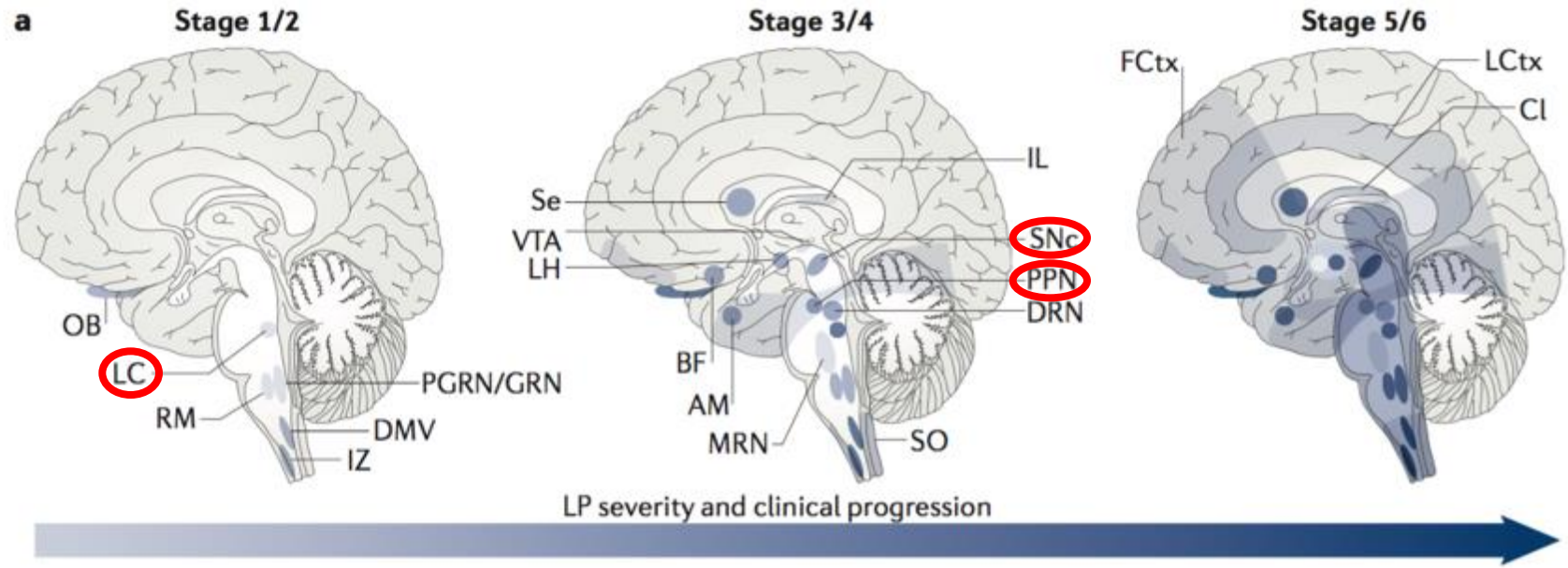
EFFECTS OF FEAR/ANXIETY ON BALANCE IN PD



Pasman et al., Neuroscience, 2011

IS ONLY THE DOPAMINE SYSTEM AFFECTED?

Spread of Lewy pathology (LP) within different brain structures



LC: locus coeruleus (norepinephrine)
PPN: pedunculopontine nucleus (acetylcholine)
SNc: substantia nigra pars compacta (dopamine)

Modified from: Surmeier et al., Nature Reviews. Neuroscience., 2017

FUNCTIONAL NEUROIMAGING

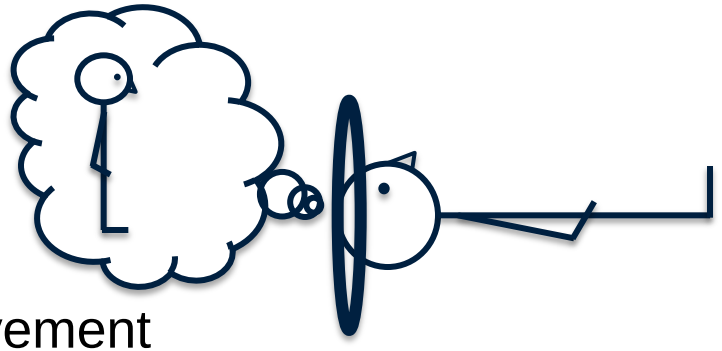
Investigating the brain regions involved in balance control using functional neuroimaging

- Functional magnetic resonance imaging (fMRI)
- Positron emission tomography (PET)

Challenges to investigating 'balance' using fMRI and PET

- Most standard scanners require participants to lie horizontally
- Movement of the head must be strictly minimized

FUNCTIONAL NEUROIMAGING



Motor imagery (MI) of balance

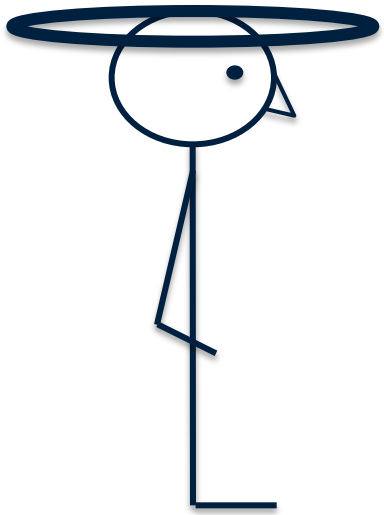
- Variability MI ability
- Incomplete overlap of brain activity during MI compared to actual movement

(McAvinue & Robertson, Journal of Mental Imagery, 2009; Saimpont et al., Journal of Motor Behavior, 2013; Saimpont et al., Brain Research, 2015; Kalicinski et al., Experimental Ageing Research, 2015)

Wearable PET scanner

- Poor temporal resolution
- Weight wearable PET device interfering with standing

(Bauer et al., Brain and Behavior, 2016; Melroy et al., Sensors (Basel), 2017)



BALANCE SIMULATOR

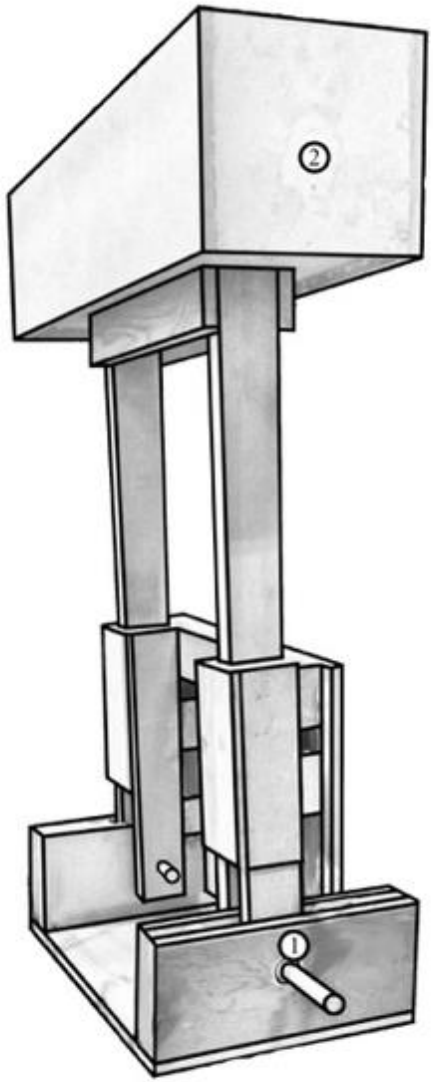
Free-standing inverted pendulum

Controlled by participants through activation of postural muscles around the ankle joint while supine

Easy for participants to use

- Healthy older adults
- Individuals with PD

MRI compatible



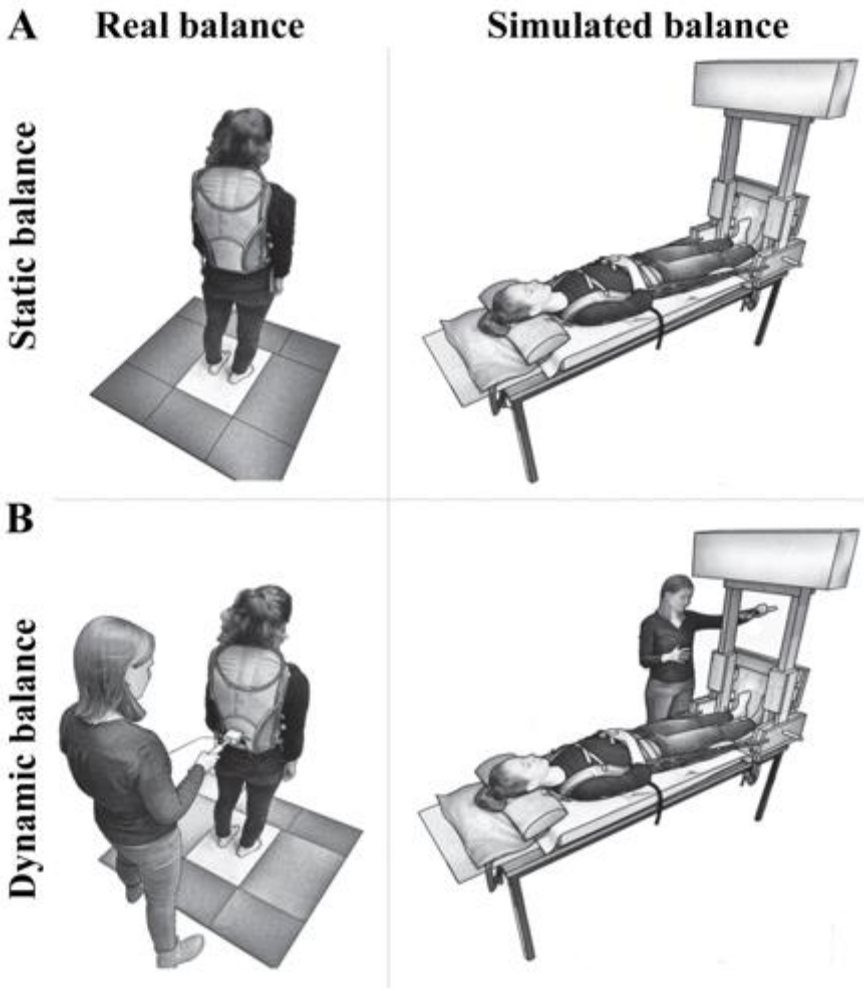
Modified from: Pasman et al., submitted

VALIDATION BALANCE SIMULATOR

Healthy older adults
Individuals with PD

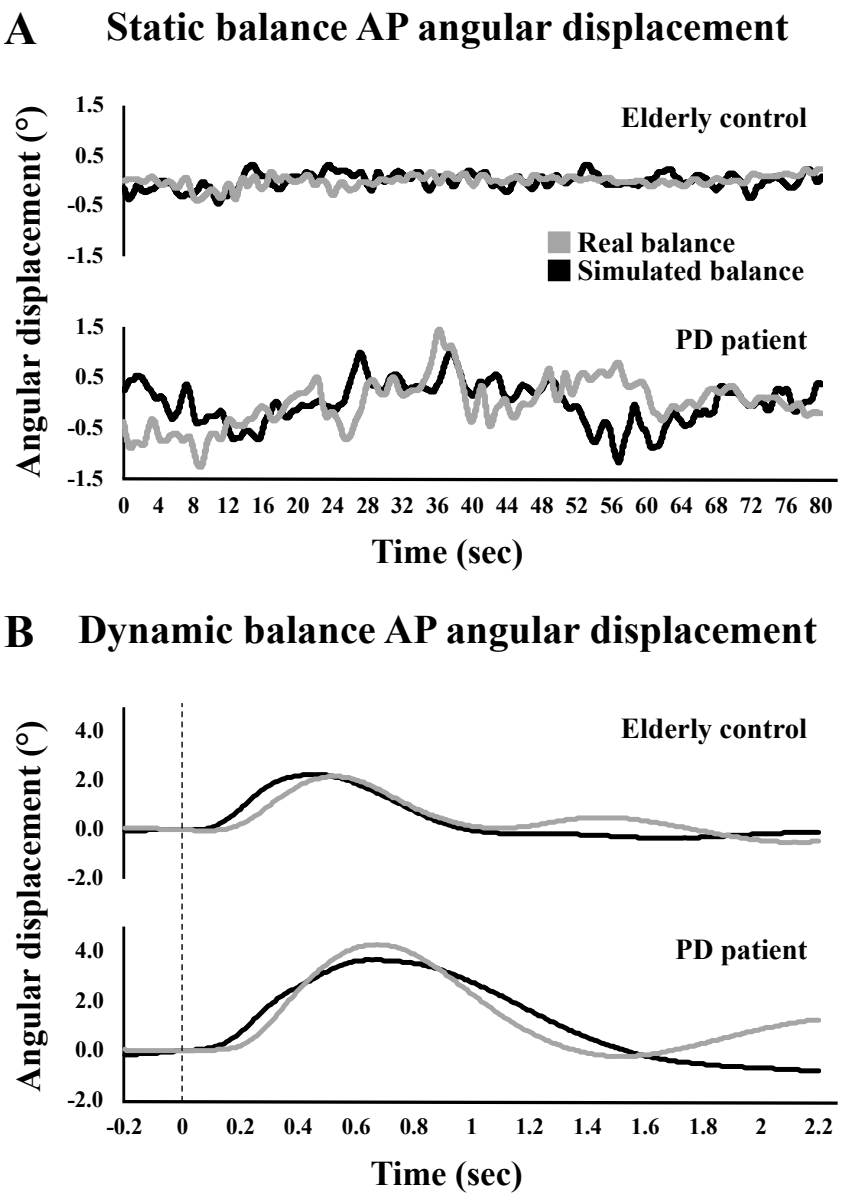
Recorded anterior-posterior angular displacements

- Body
- Balance simulator



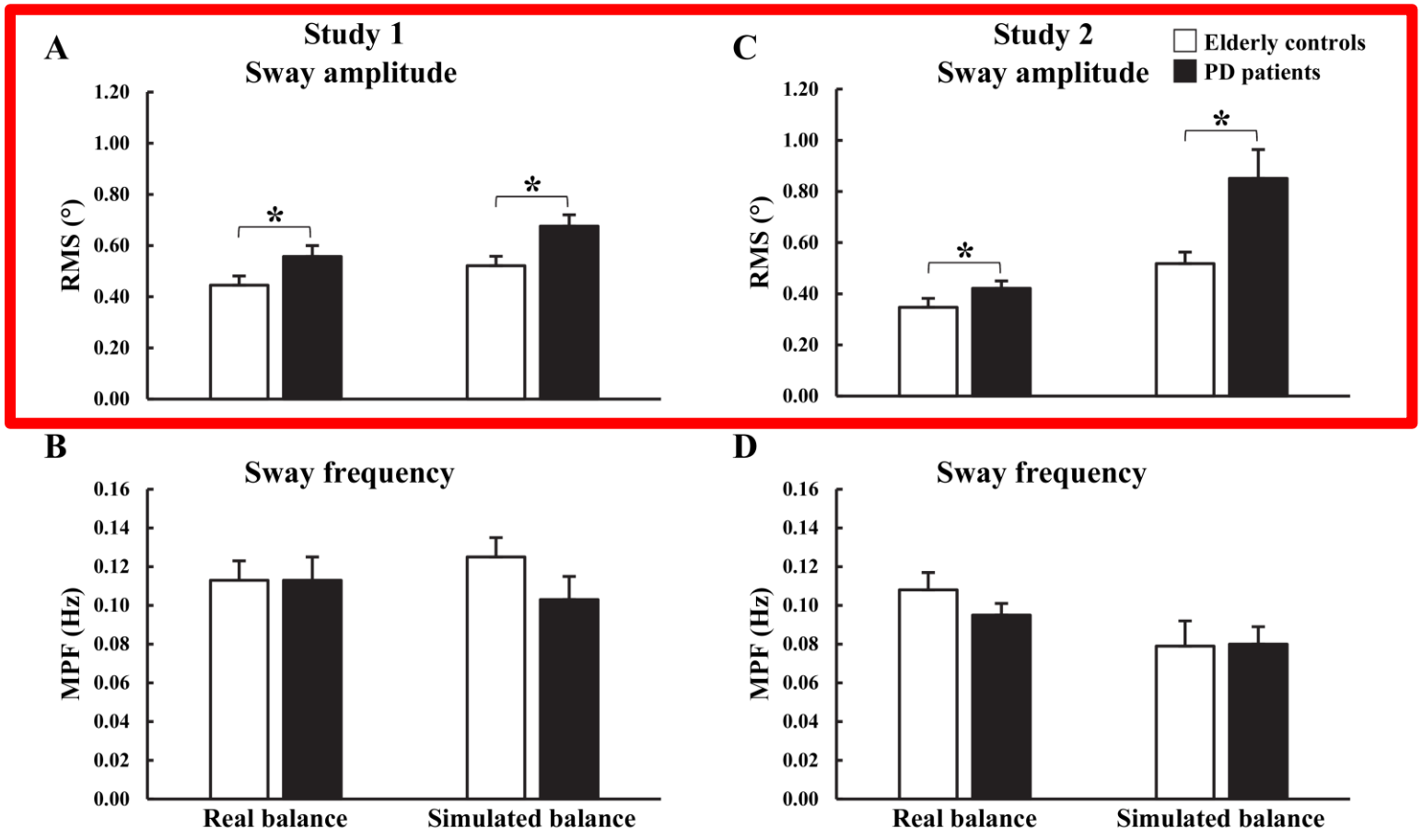
Modified from: Pasman et al., submitted

SIMILAR SWAY BEHAVIOR REAL VS SIMULATED



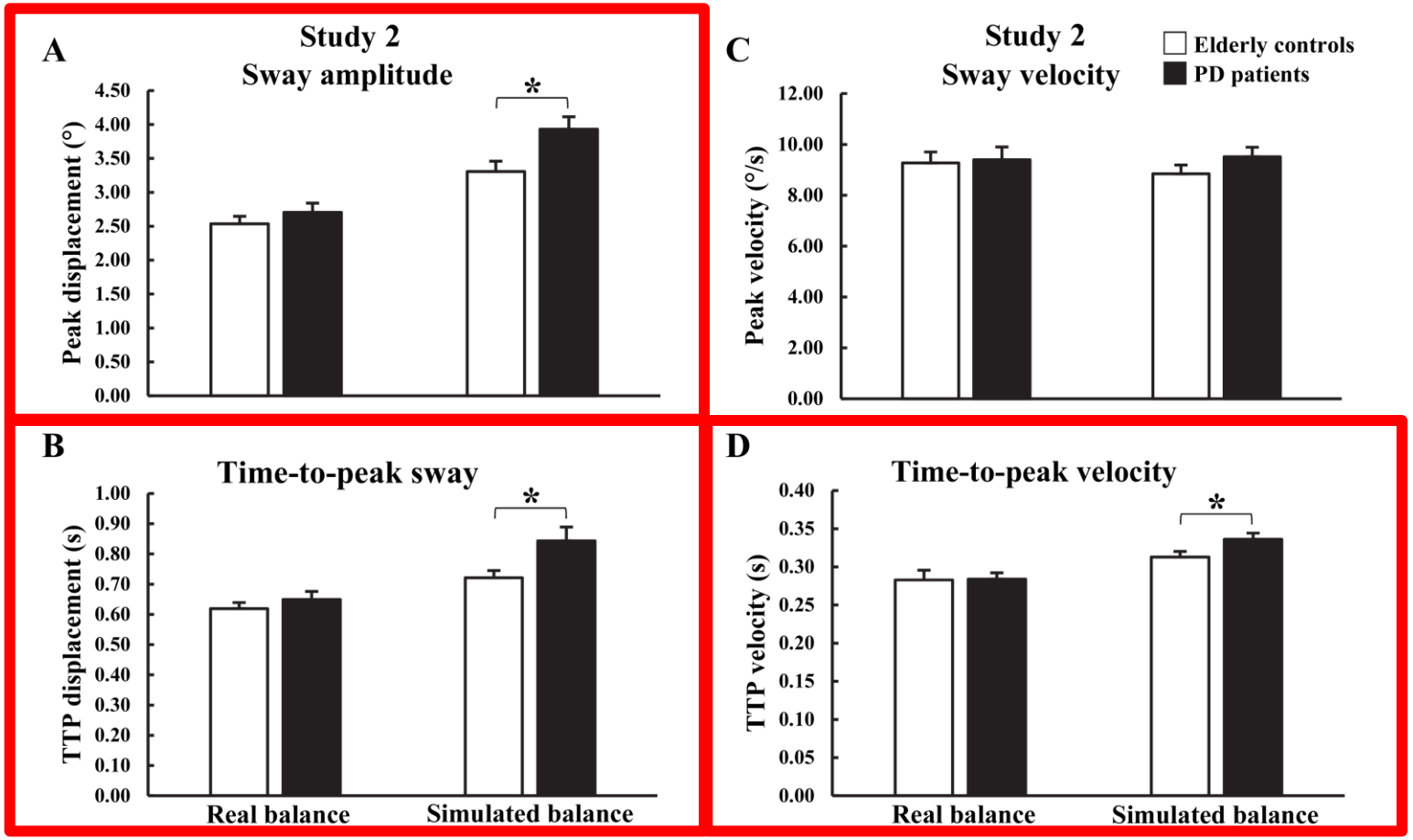
Pasman et al., submitted

LARGER SWAY AMPLITUDE IN PD



Pasman et al., submitted

LARGER PEAK SWAY IN PD IN THE SIMULATOR



Pasman et al., submitted

PRELIMINARILY RESULTS BALANCE SIMULATOR IN FMRI

BALANCE SIMULATOR IN THE MRI SCANNER

17 Healthy older adults
17 Individuals with PD

Static balance task
Dynamic balance task

Baseline conditions

- Rest (no task) with eyes closed
- Proprioceptive task

PRELIMINARY RESULTS BRAIN CONNECTIVITY

Healthy older adults
Dynamic balance

PRELIMINARY RESULTS BRAIN CONNECTIVITY

Individuals with PD
Dynamic balance

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QUESTIONS

If you are interested to participate in research, contact me at Eveline.Pasman@ubc.ca

For more information on our Balance Deficits & Falls Research Cluster
Website: https://balancefalls.ubc.ca/home
Twitter: @BalanceandFalls