Microgravity Exposure Alters Sympathetic Modulation of Ventricular Repolarization Quantified from the ECG via Periodic Repolarization Dynamics

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Biomedical Signal Interpretation & Computational Simulation

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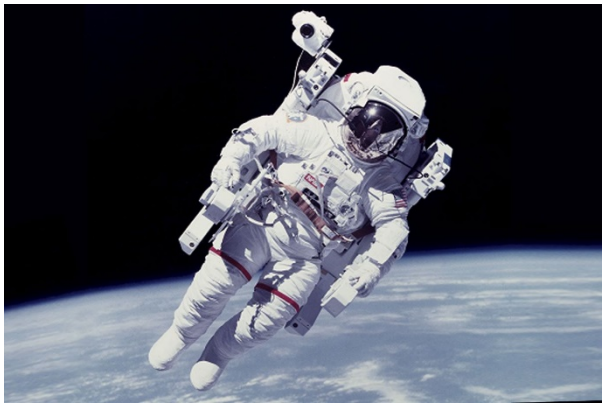
Introduction

Effects after microgravity exposure

- Muscular
- Bone
- Autonomic Nervous System
- Cardiac



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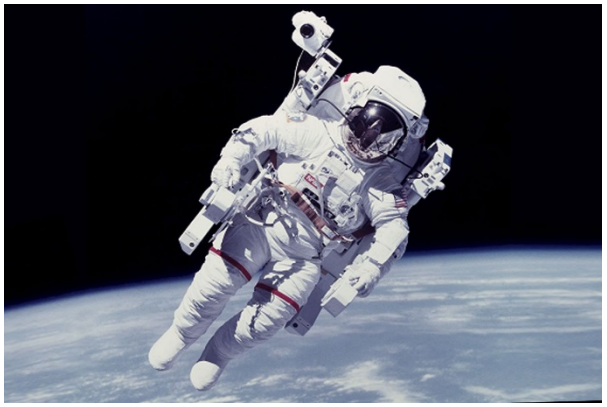

Hypothesis

Microgravity-induced changes in cardiac electrical activity and the Autonomic Nervous System could be quantified from ECG ventricular repolarization

Introduction

Periodic Repolarization Dynamics (PRD) [*]

Novel index to assess sympathetic modulation of ventricular repolarization by measuring low-frequency oscillations in the T-wave morphology

[*] Rizas et al. 2014.

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Periodic Repolarization Dynamics (PRD) [*]

Novel index to assess sympathetic modulation of ventricular repolarization by measuring low-frequency oscillations in the T-wave morphology

Our goal

Quantify PRD in ECGs before and after prolonged simulated microgravity, both at baseline and following increased sympathetic activity

[*] Rizas et al. 2014.

Study population

Simulated microgravity

- 60-day -6º Head-Down Best Rest (HDBR) experiment
- ESA bed rest studies
- DLR, Köln, Germany

PRE-bed rest	HDBR	POST-bed rest
15 days	60 days	15 days

Study population

Population

- 22 healthy male volunteers
- Two groups: Control (CTRL) and Countermeasure (JUMP)

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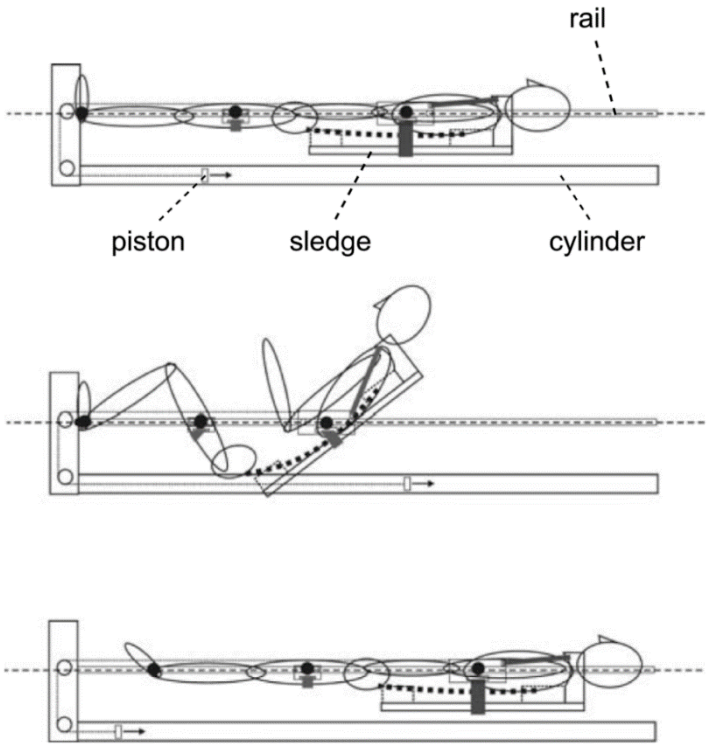

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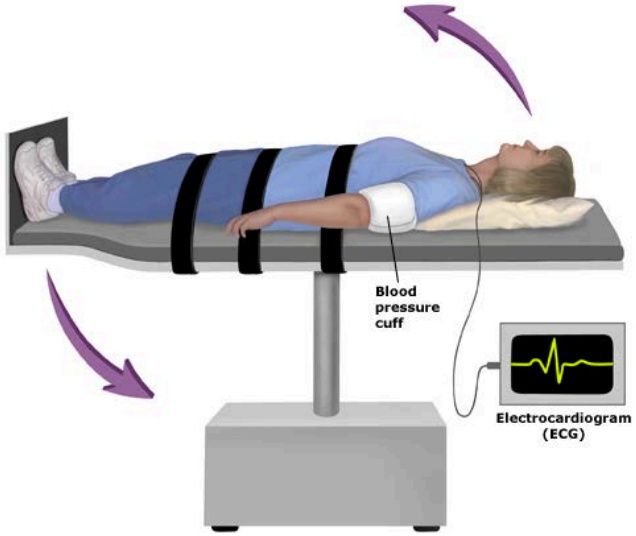
Tilt-Table Test (TTT)



Study population

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- 22 healthy male volunteers
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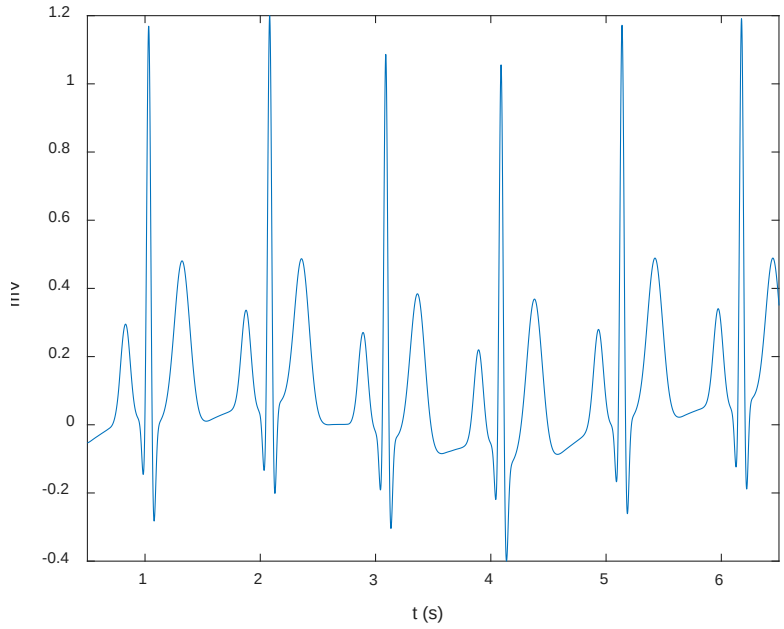
Tilt-Table Test (TTT)

- 12-lead ECG during TTT (1000 Hz, 3.75 µV resolution)

Preprocessing

Noise and artifacts removal

QRS detection and multilead wavelet-based delineation [1]



[1] Martínez et al. 2004.

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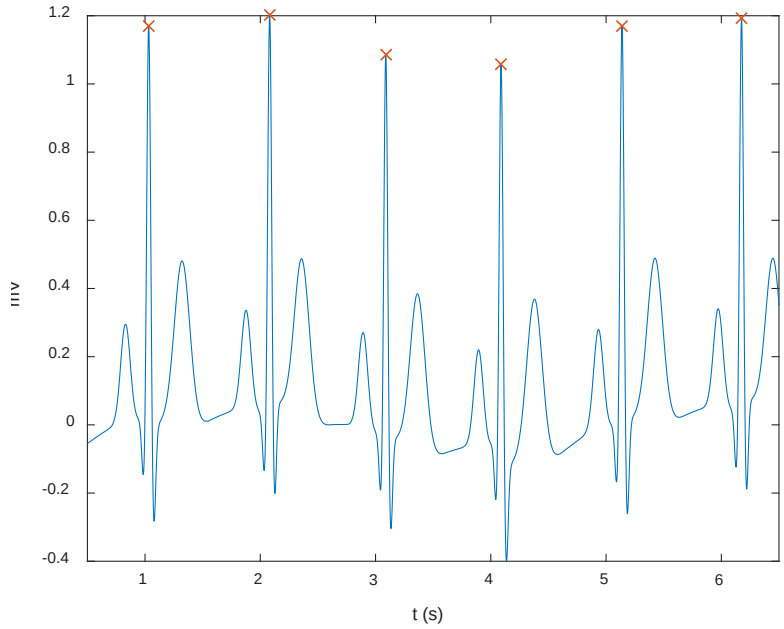

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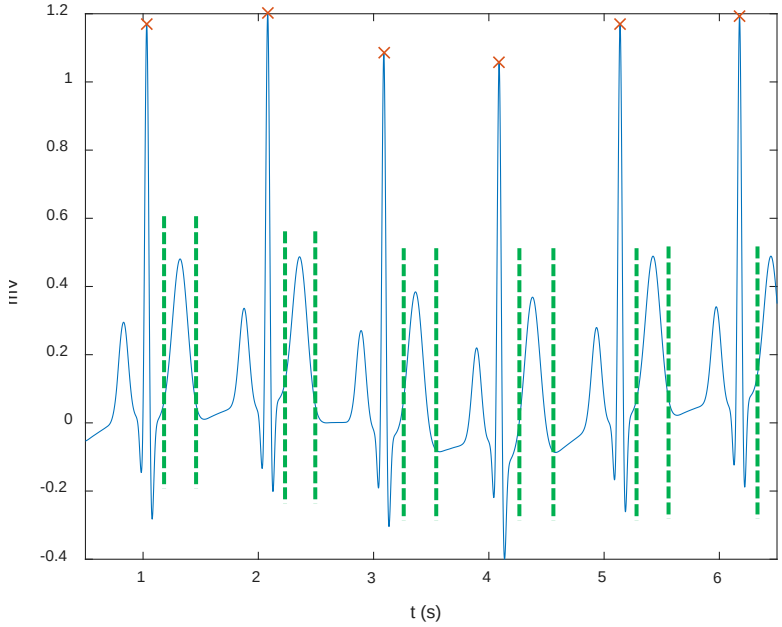


[1] Martínez et al. 2004.

Methods

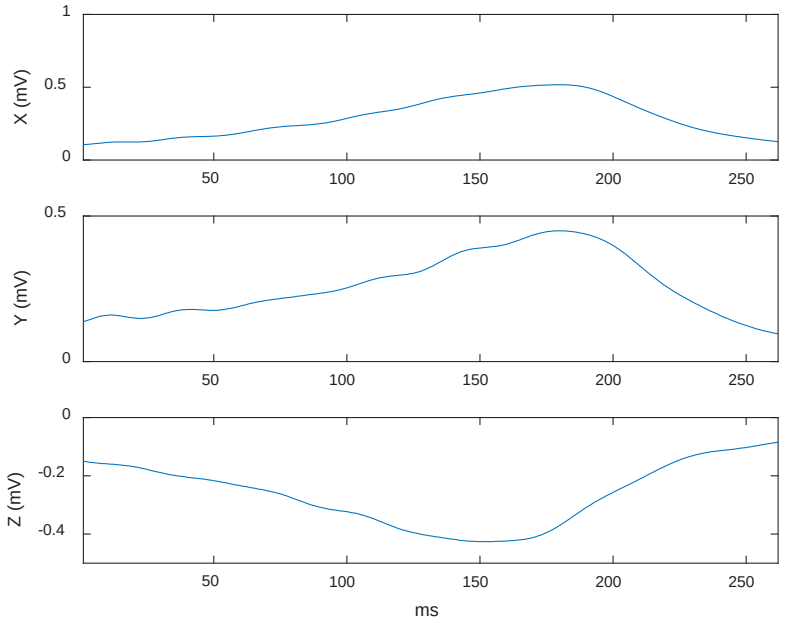
PRD index[2]

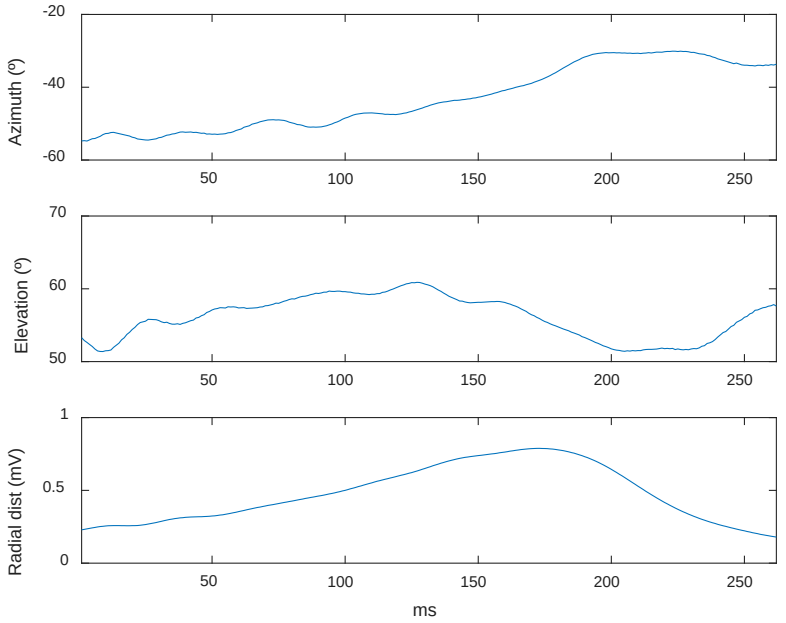
1. Convert into orthogonal leads

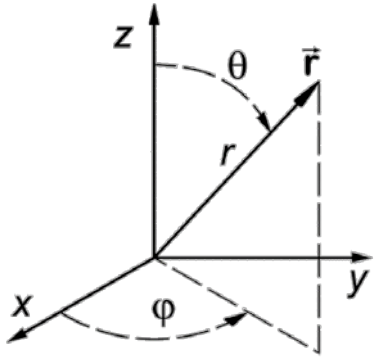
[2] Rizas et al. 2014.

Methods

2. Transformation into spherical coordinates







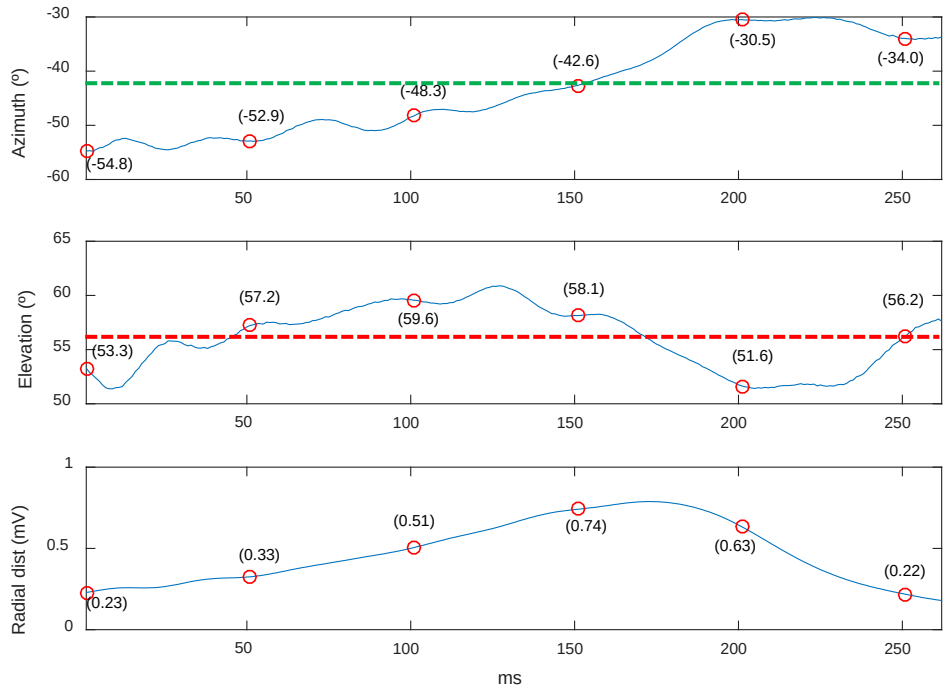
$$r = \sqrt{x^2 + y^2 + z^2}$$

$$\theta = \arctan\left(\frac{\sqrt{x^2 + y^2}}{z}\right)$$

$$\phi = \arctan\left(\frac{x}{y}\right)$$

Methods

3. Calculation of weight-averaged azimuth (WAA) and weight-averaged elevation (WAE)



$$WAA = \frac{\sum_{t=T_{start}}^{T_{end}} (r_t \cdot \phi_t)}{\sum_{t=T_{start}}^{T_{end}} r_t}$$

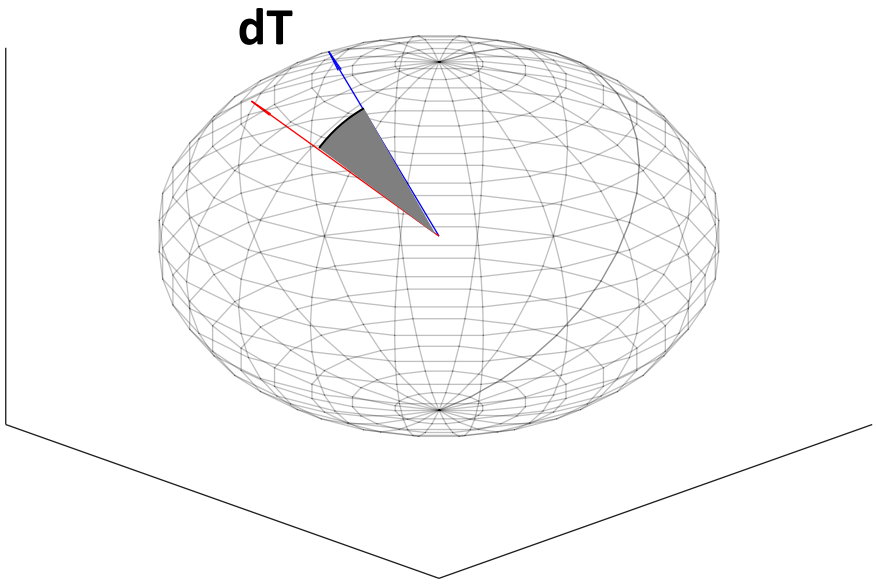
$$WAA = -42.45º$$

$$WAE = \frac{\sum_{t=T_{start}}^{T_{end}} (r_t \cdot \theta_t)}{\sum_{t=T_{start}}^{T_{end}} r_t}$$

$$WAE = 56.16º$$

Methods

4. Computation of angle dTº



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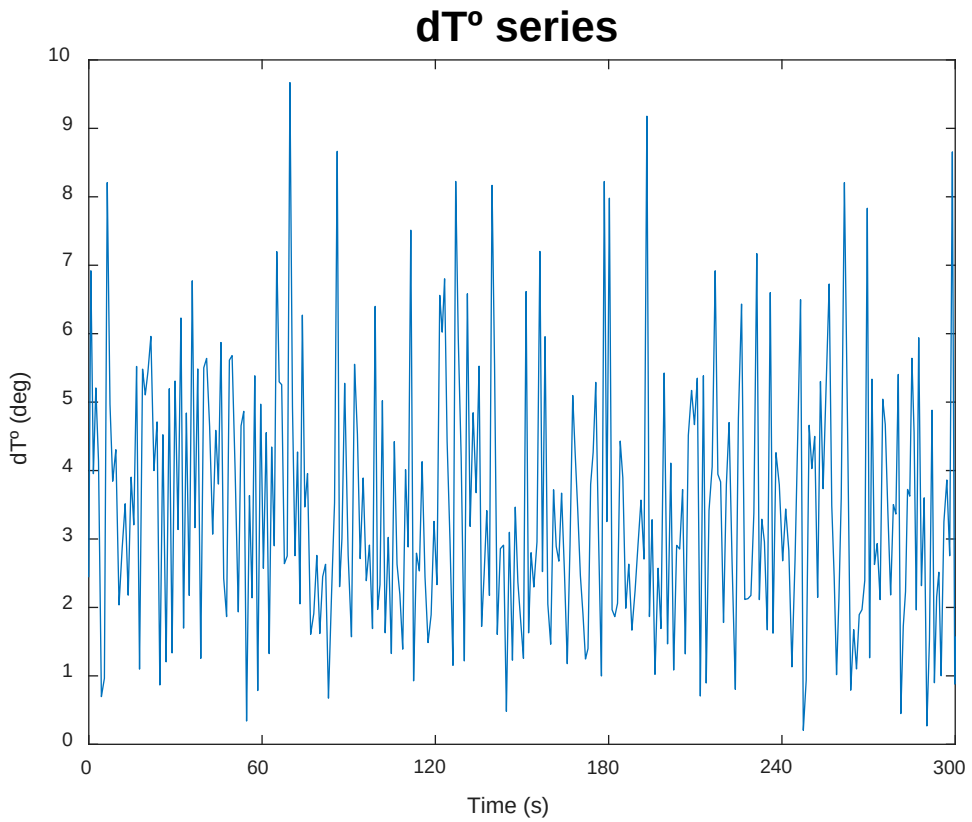
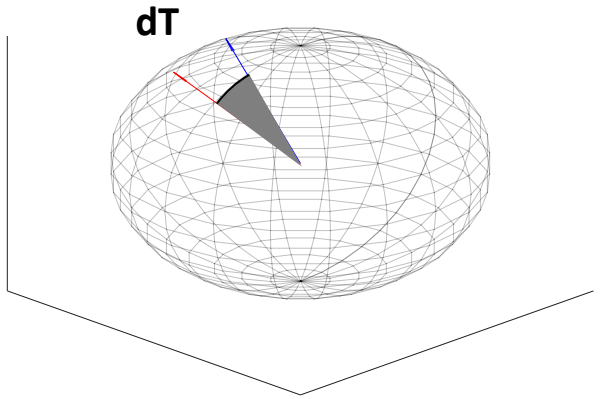
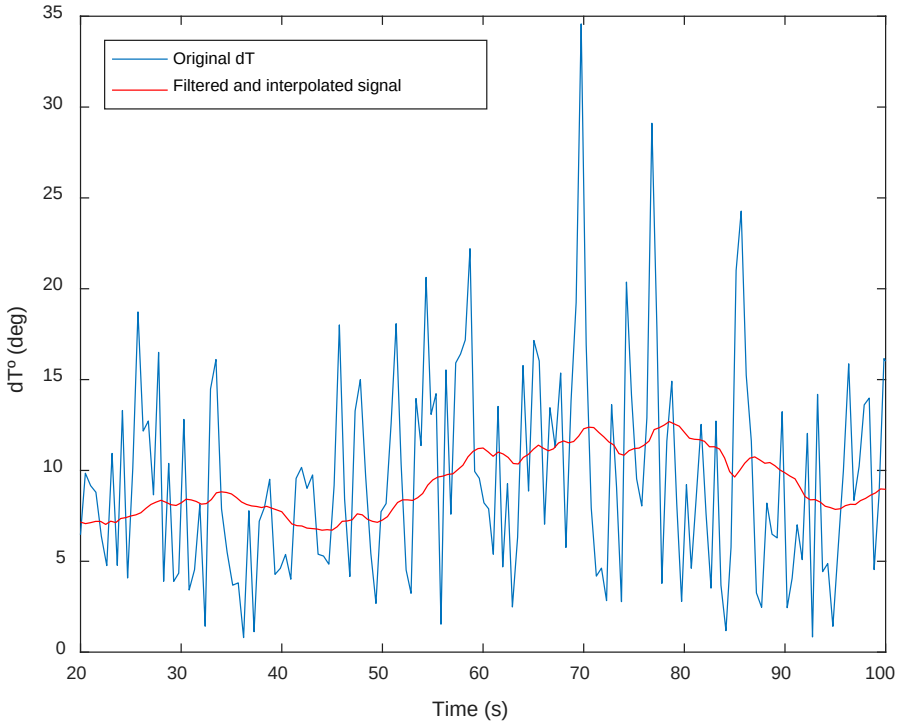
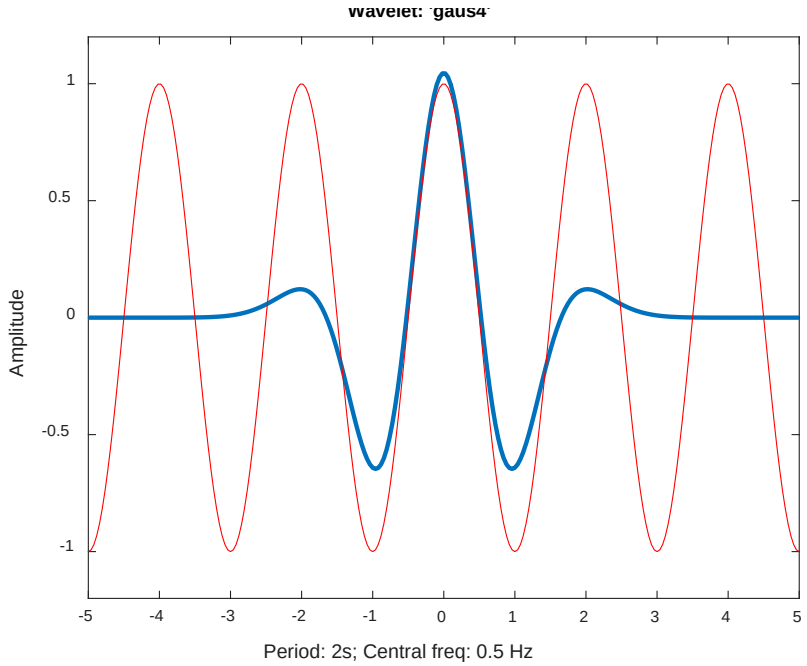




5. Time series smoothing and interpolation



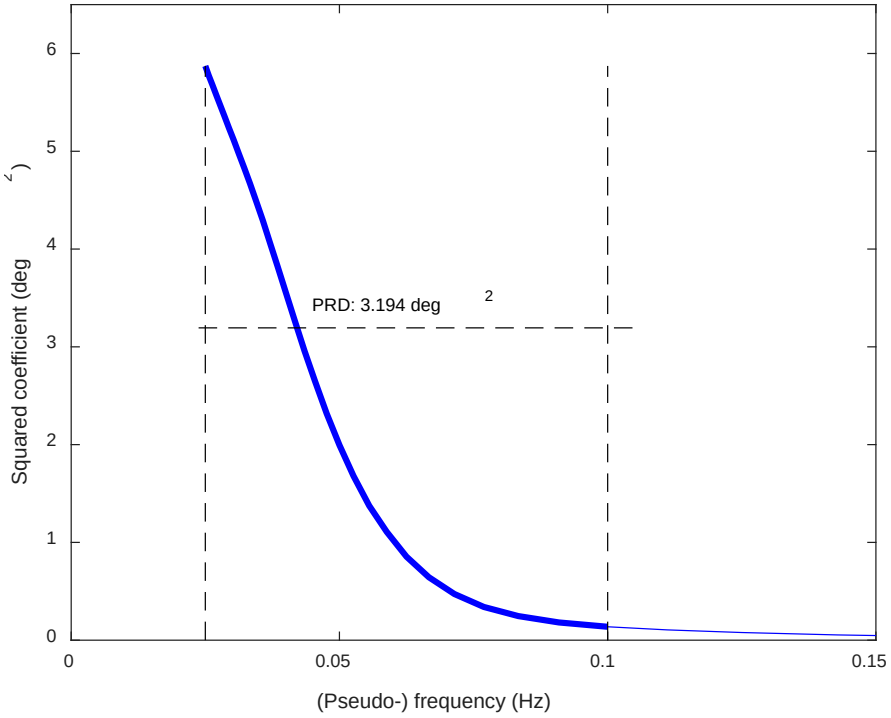
6. Continuous Wavelet Analysis



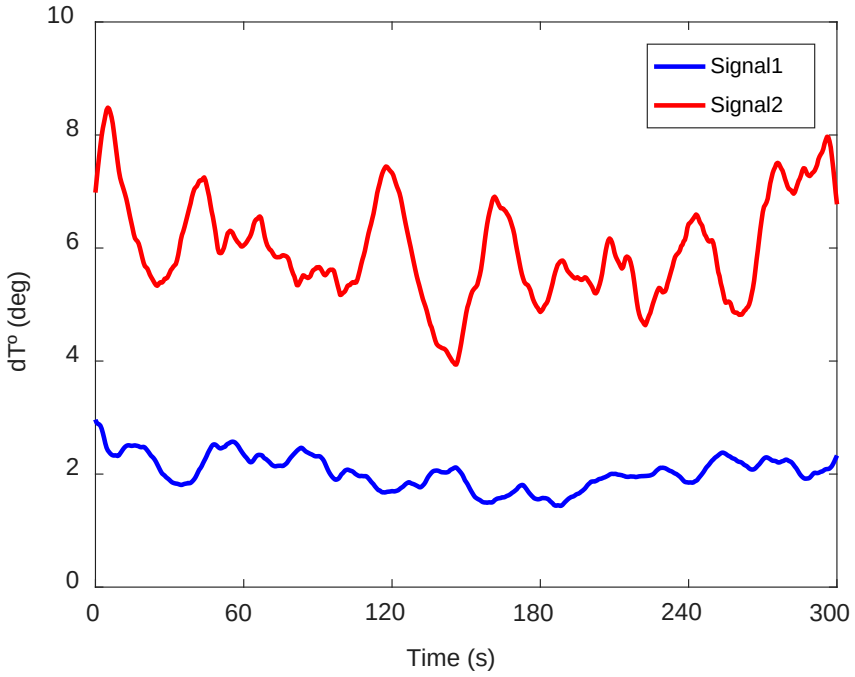
$$F_a = \frac{F_c}{a \cdot \Delta}$$

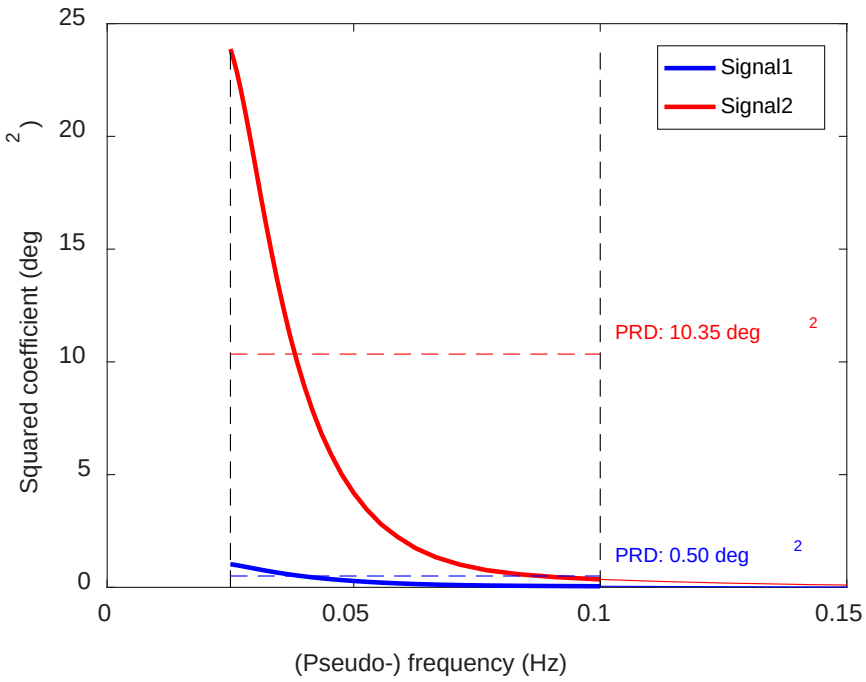
7. Definition of **PRD**

The average squared wavelet coefficient in the frequency range 0.025 and 0.1 Hz

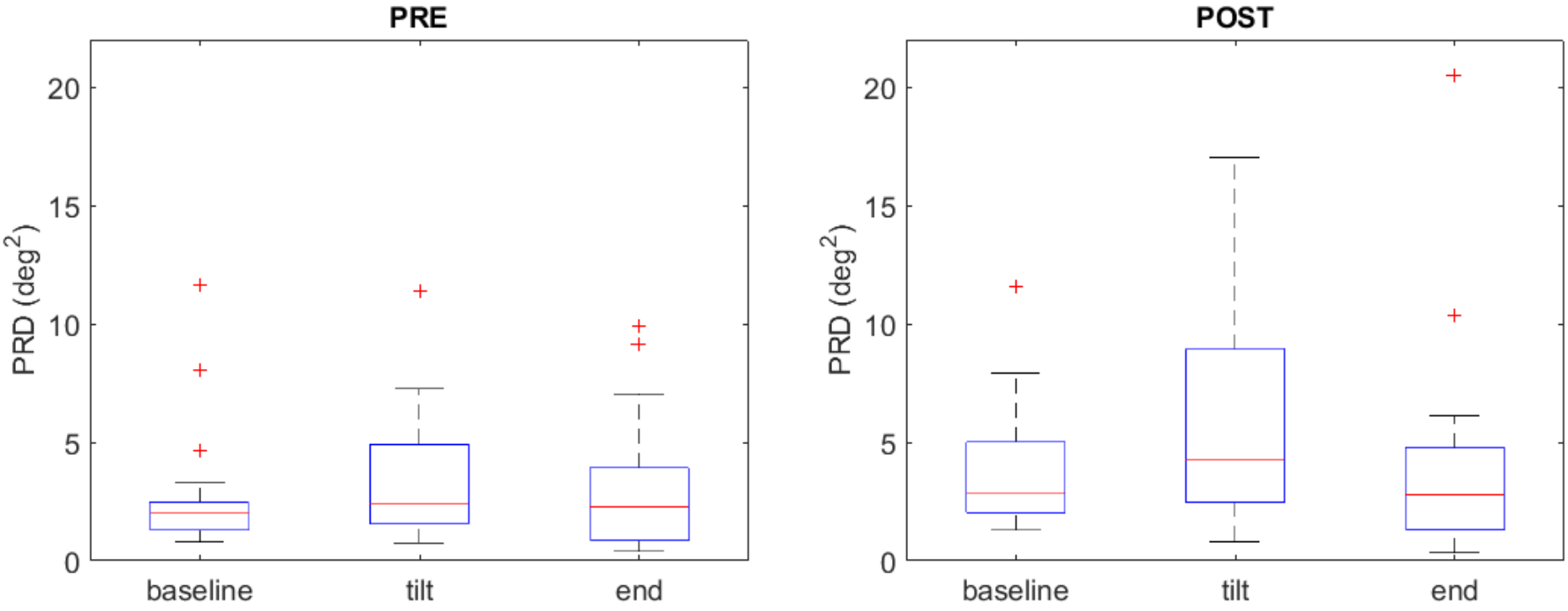


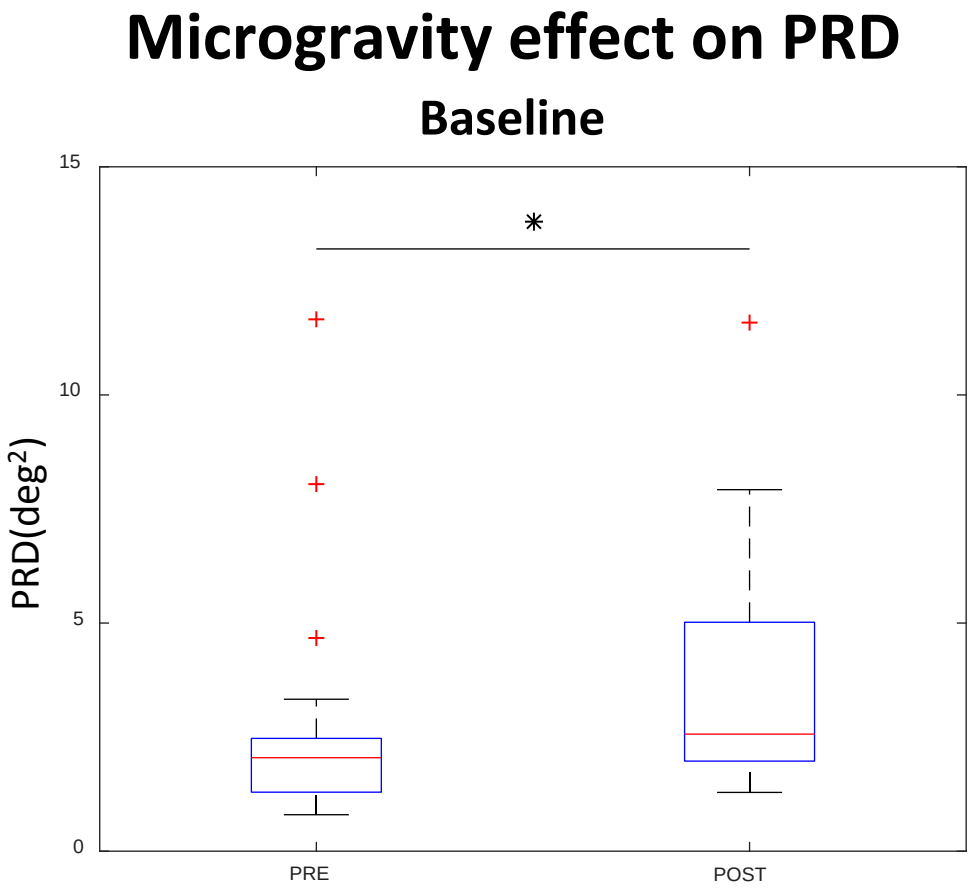
Periodic variations in ventricular repolarization





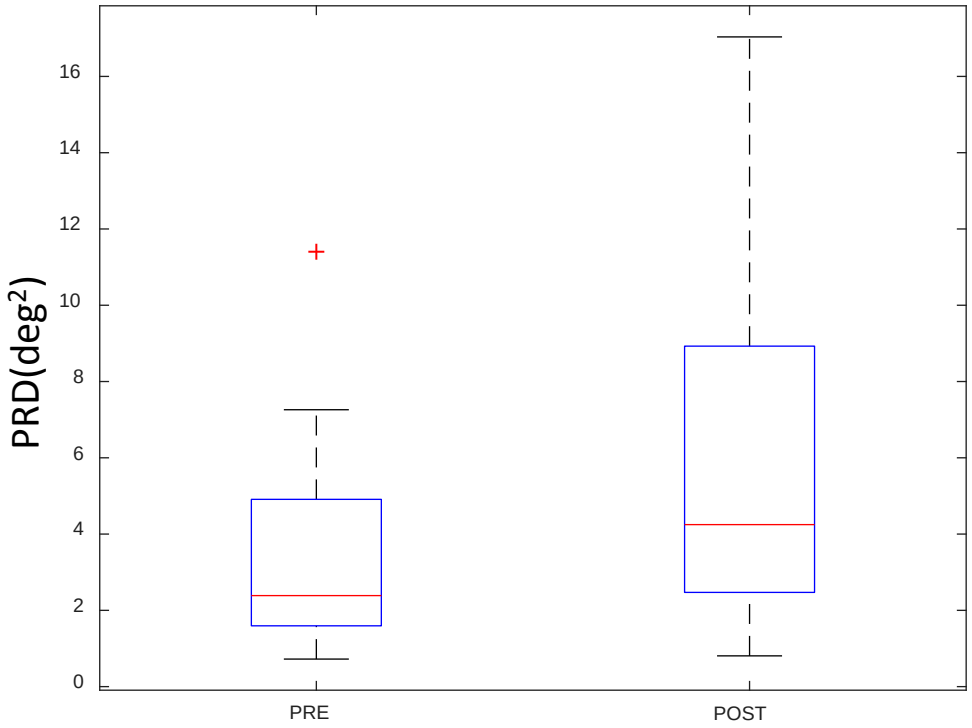
Tilt test effect on PRD



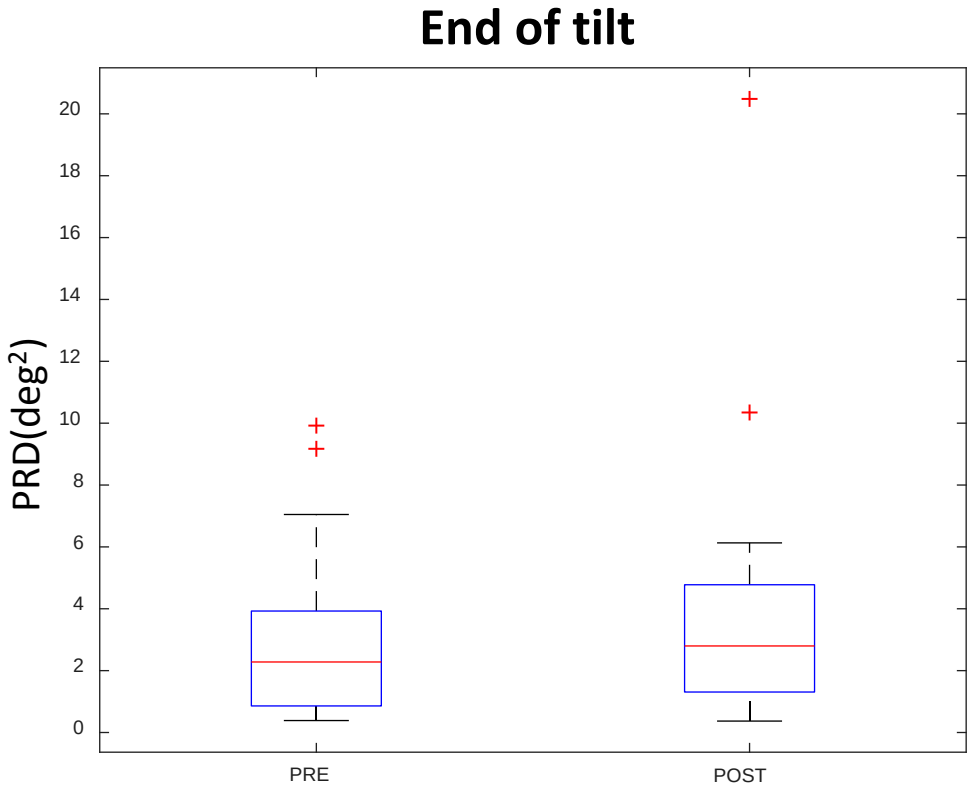

Microgravity effect on PRD
Baseline
15
10
5
0
PRD(deg²)
*
PRE
POST

Microgravity effect on PRD

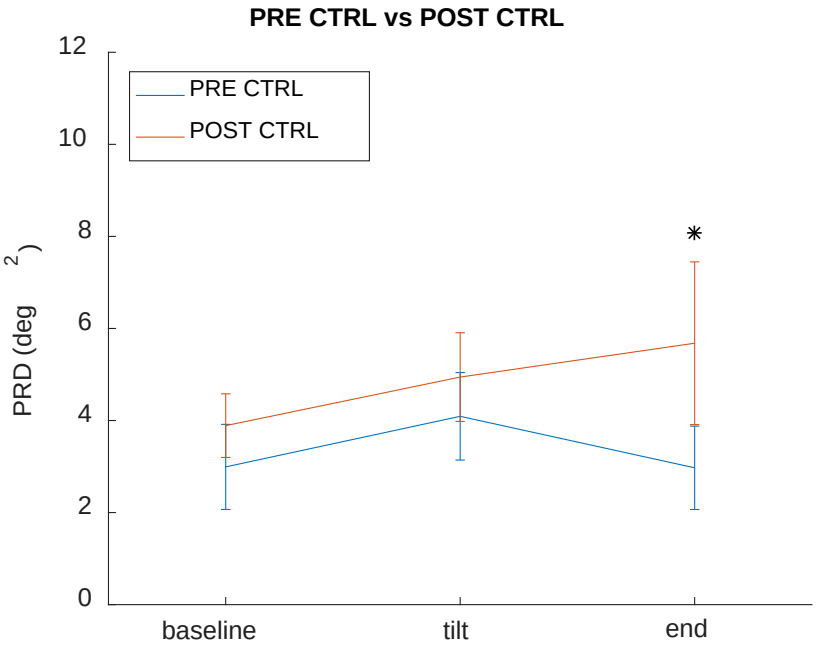
Beginning of tilt

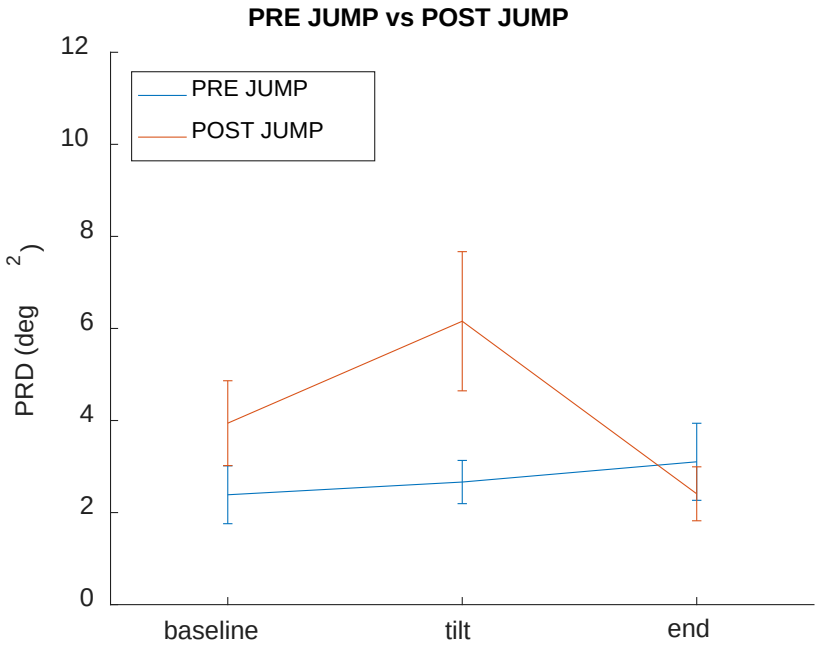


Microgravity effect on PRD



Countermeasure effect on PRD





Conclusions

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PRD index increases in response to Tilt Test

Simulated microgravity induces notable increases in PRD

PRD follows changes in sympathetic modulation of ventricular repolarization induced by tilt test and microgravity exposure

A jump-based countermeasure is not completely effective in counteracting microgravity effects

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