

SPACE-CENT: Physiological Monitoring of Fluid Shifts during Orthostatic Tilt

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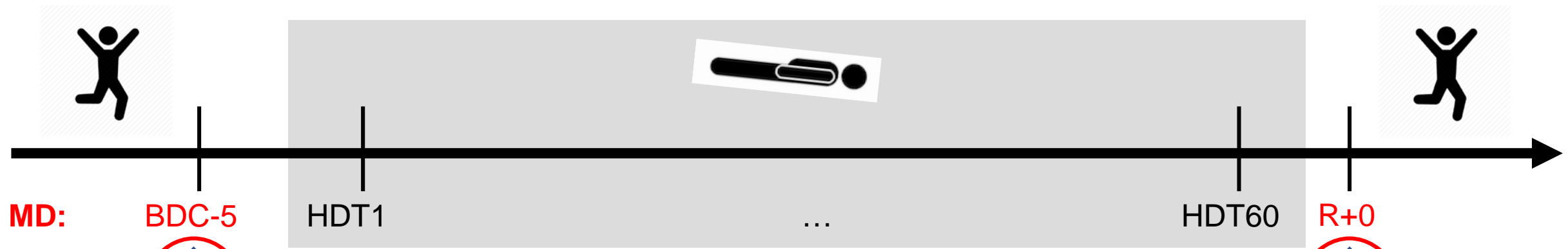
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Motivation Topics

1. Quantify fluid re-distribution along the body axis during orthostatic tilt testing.
2. How does 60 days of -6° HDT affect this re-distribution?
3. Does centrifugation alter the effects of 60-day HDT at -6° ?
4. Can any of our hemodynamic measures help predict survival time during orthostatic tilt tests?

Experimental Design



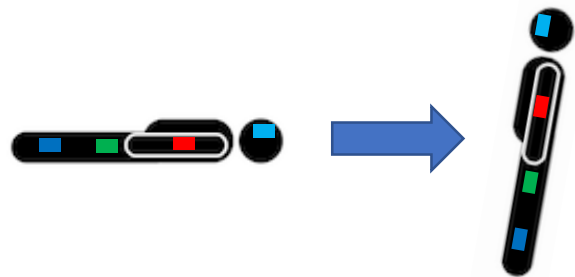
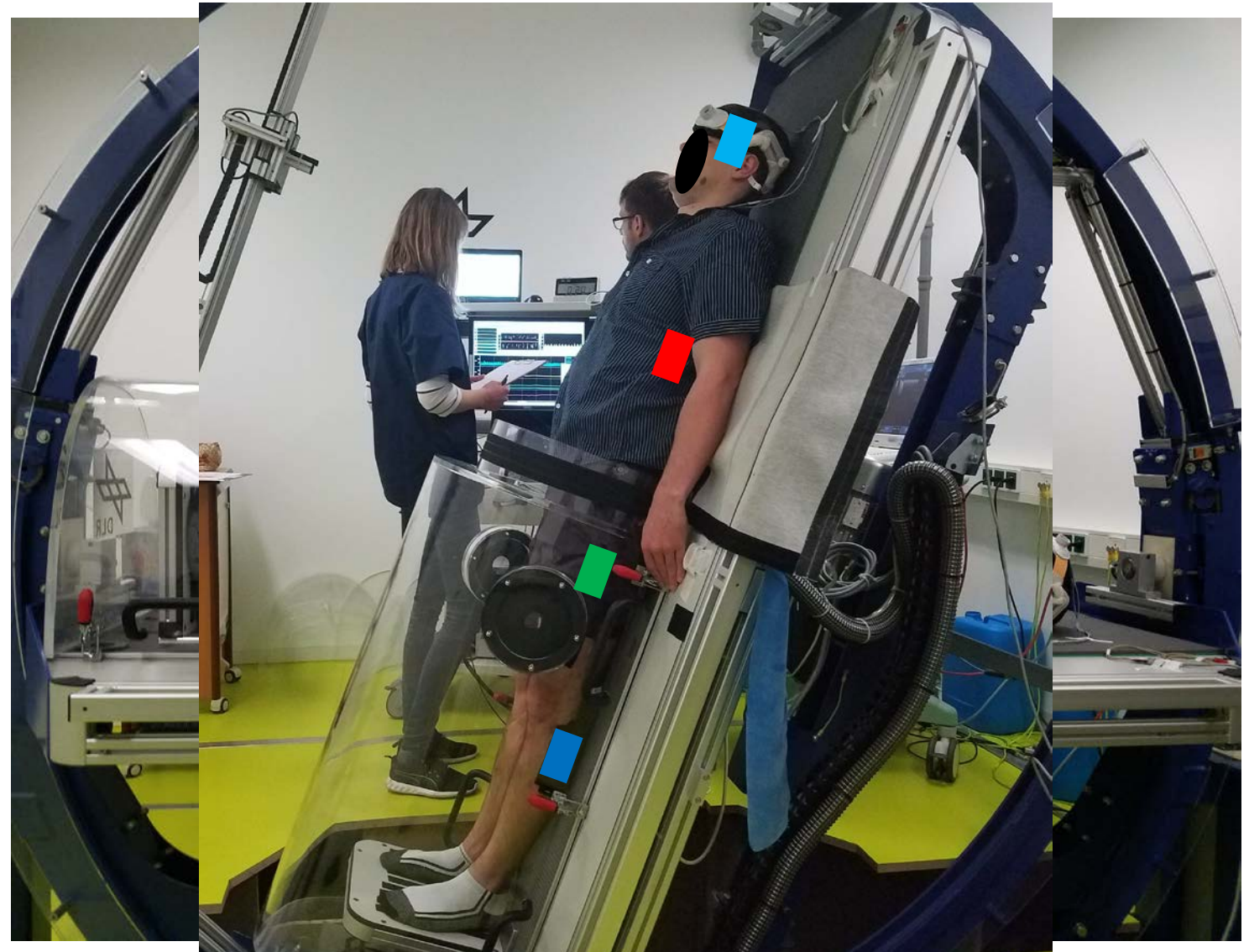
Centrifugation: (iAG, cAG, Ctrl)



Red = primary interventions

Head-to-Toe Hemodynamic Shifts

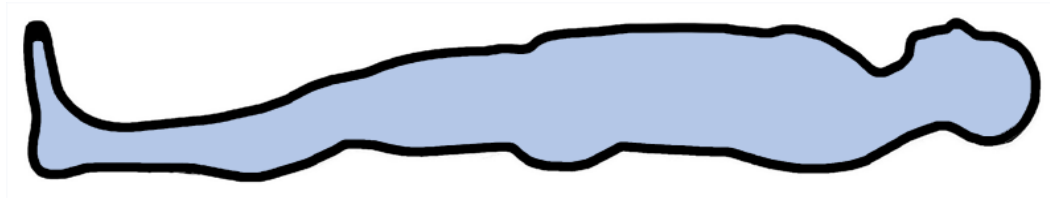
NINscan System



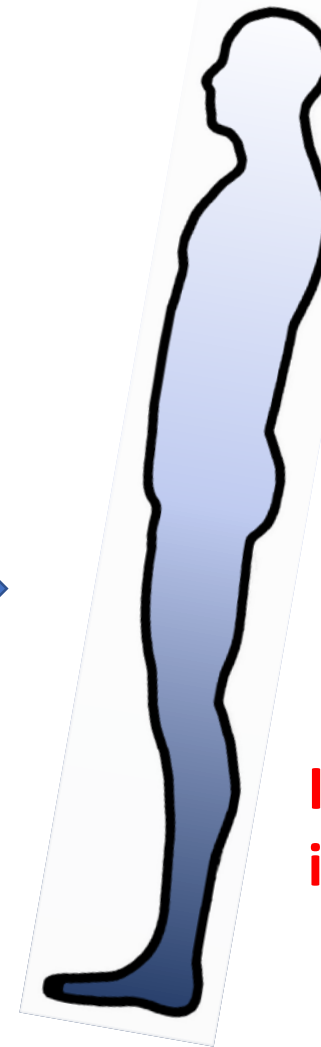
Tilt Protocol and Predictions

Protocol:

- Tilt up from 0° to $+80^\circ$ for 900s
- If not yet presyncopal, add -10mmHg LBNP every 180 sec until presyncope



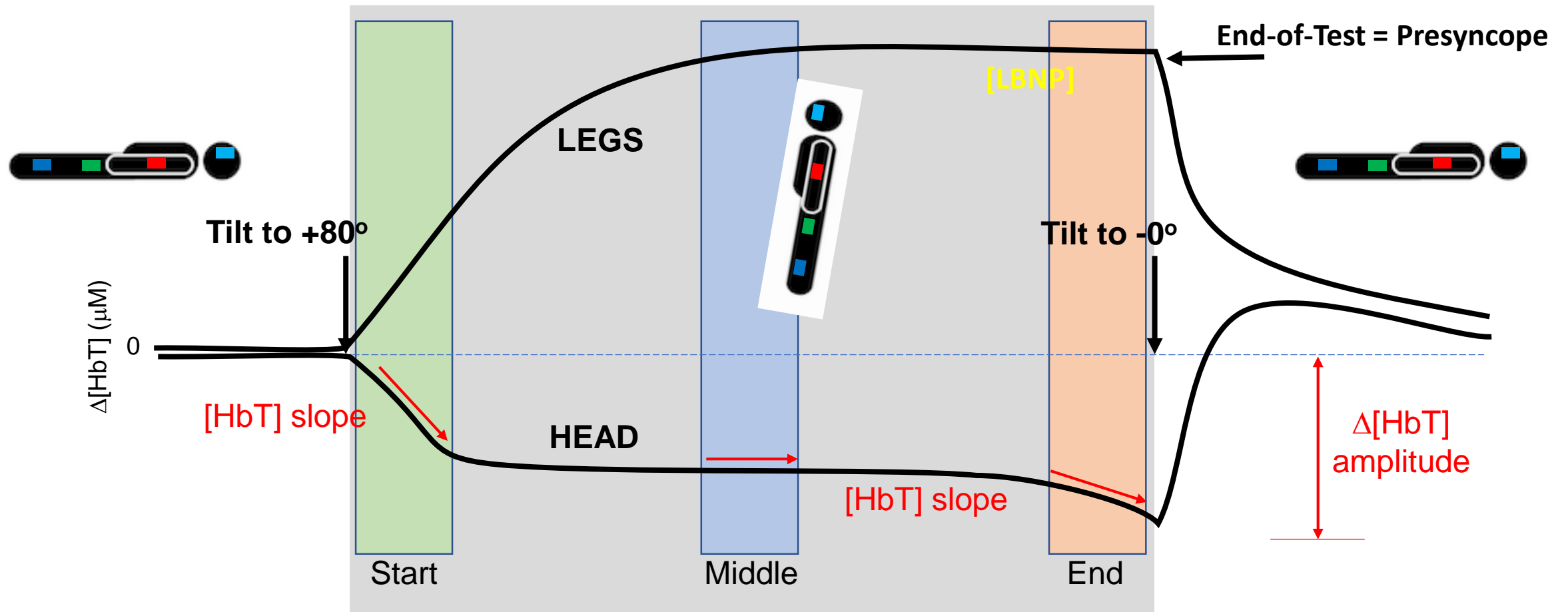
Uniform blood distribution



**Decreased blood
in head**

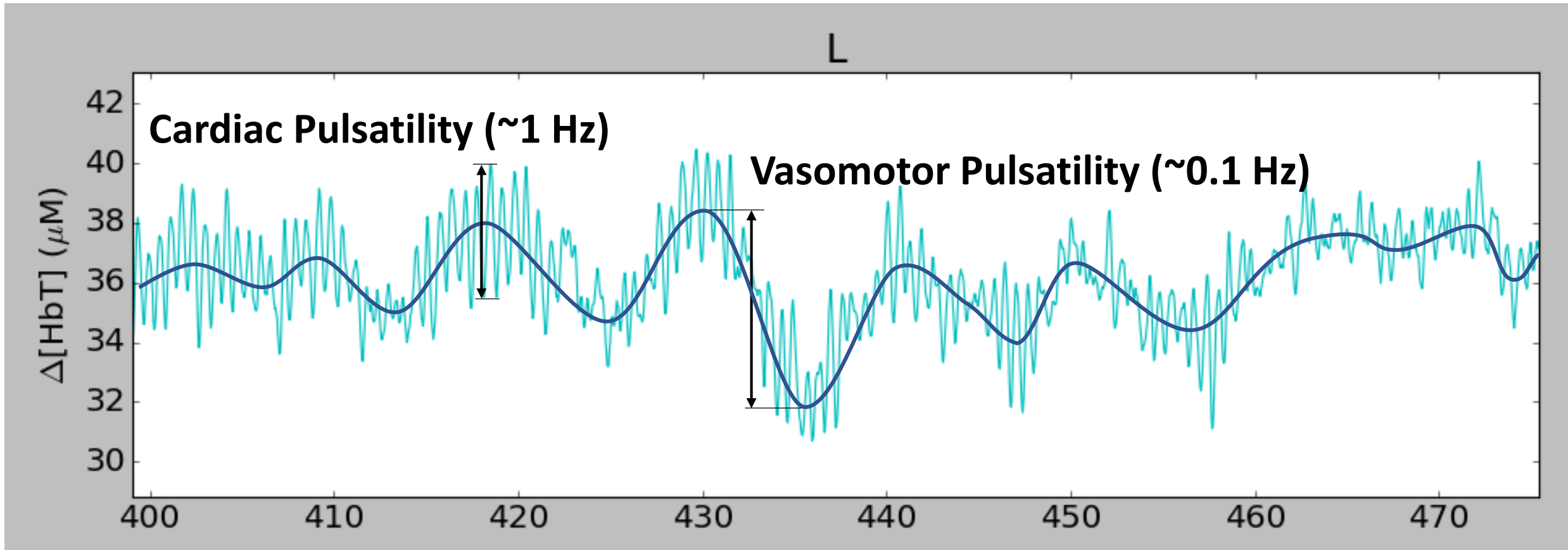
**Increased blood
in legs**

Hemodynamic Metrics – $\Delta[\text{HbT}]$



[HbT] Metrics ... Amplitude ($[\text{HbT}]$), Variability (std), and Slope (change over time)

Hemodynamic Metrics – Pulsatility



Pulsatility Metrics ... Amplitude ([HbT]), Variability (std), and Slope (change over time)

Tilt Table Survival Times

Campaign 1

Subject	BDC-5	R+0
A	1550	1154
B	345	262
C	475	311
D	745	195
E	716	118
F	1746	607
G	986	319
H	989	357
J	1533	481
K	1585	1127
L	1375	163
M	1131	369
Mean (SD)	1098 (465)	455 (347)

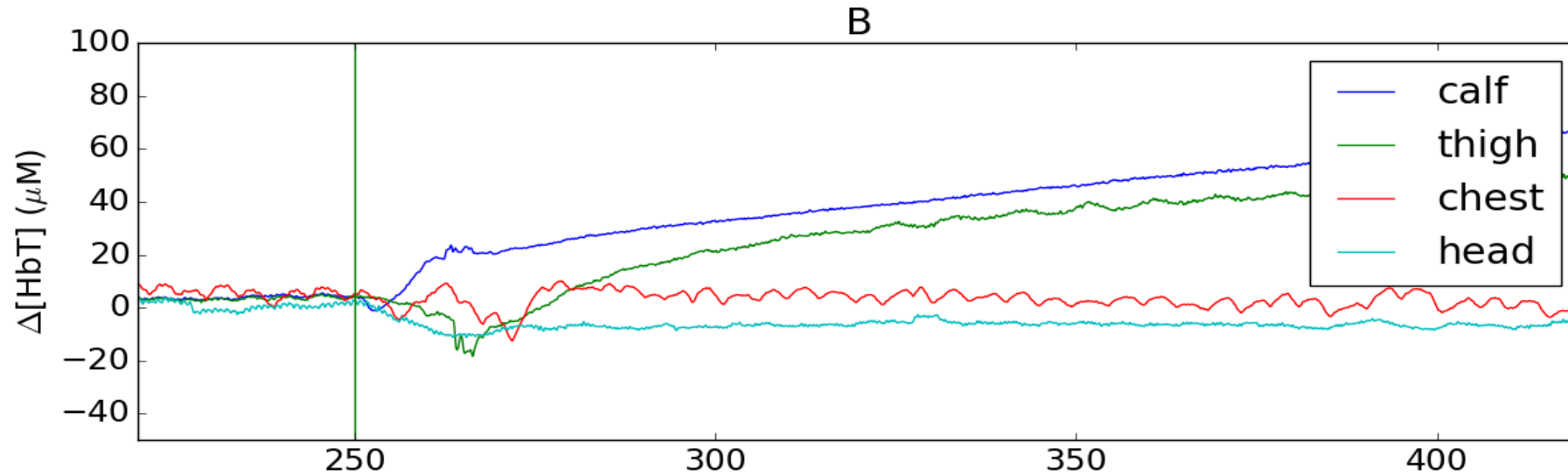
Campaign 2

Subject	BDC-5	R+0	
N	117	145	*
P	861	453	
Q1	1517	1229	
R1	1402	927	
S1	348	568	*
T	1237	473	
U	1432	1451	*
V	379	577	*
W	1598	784	
X	1448	1327	
Y	211	77	
Z	1632	764	
Mean (SD)	1015 (592)	731 (440)	

Example 1: Head "DOWN at start"

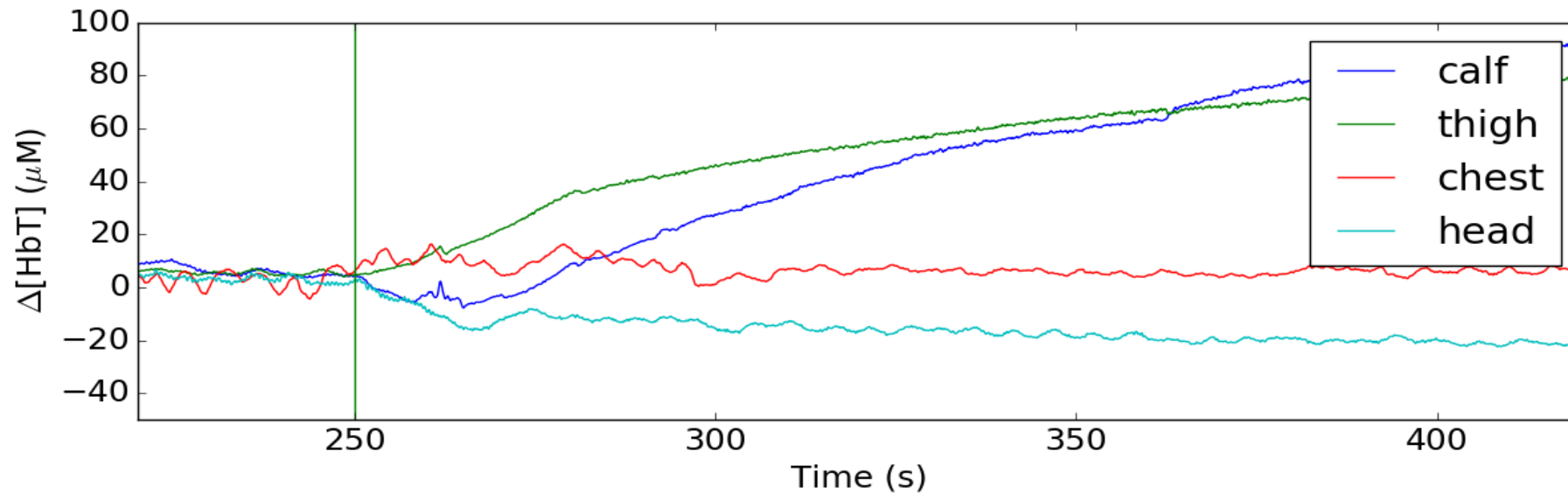


BDC-5



N=16

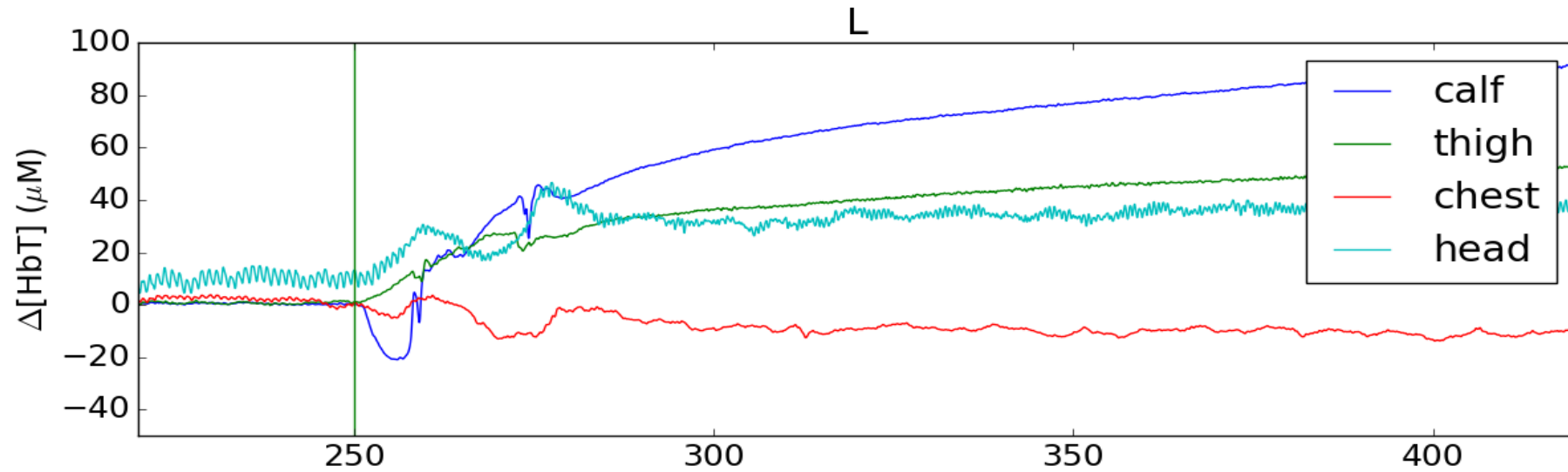
R+0



Example 2: Head "UP at start"

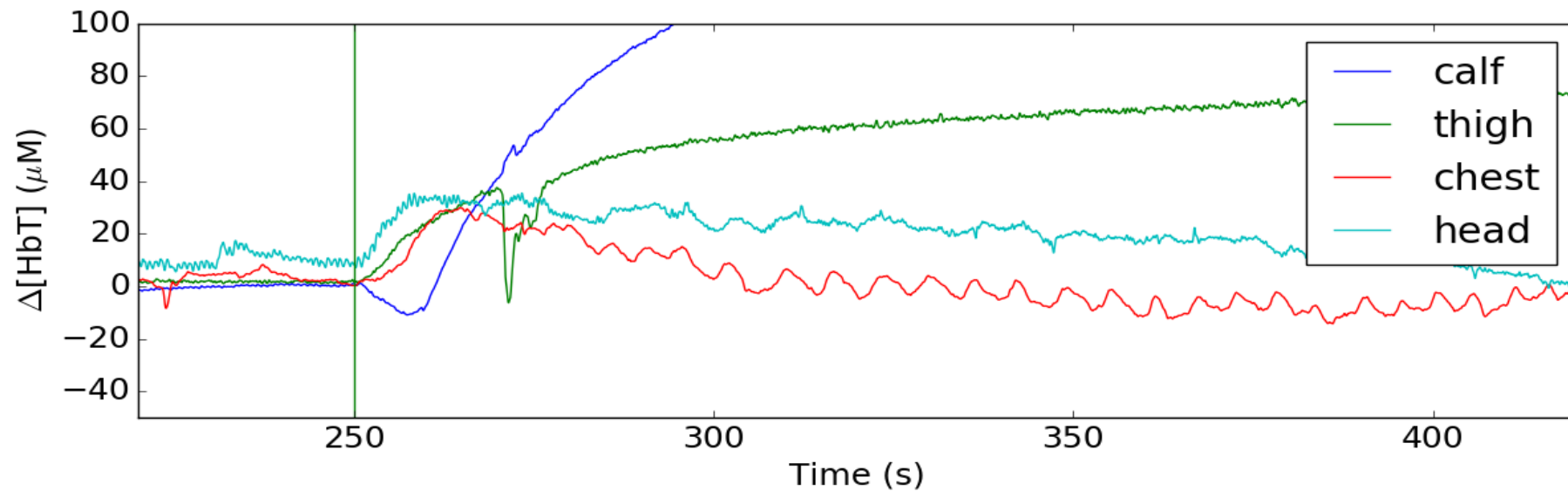


BDC-5



N=8

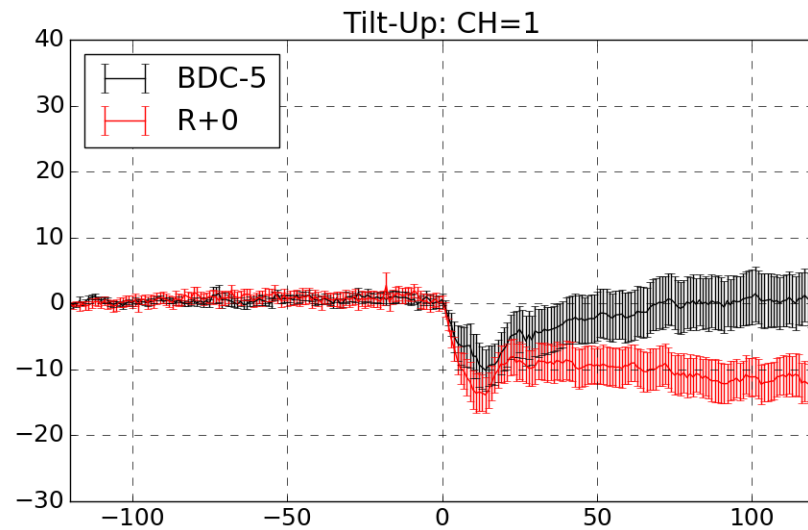
R+0



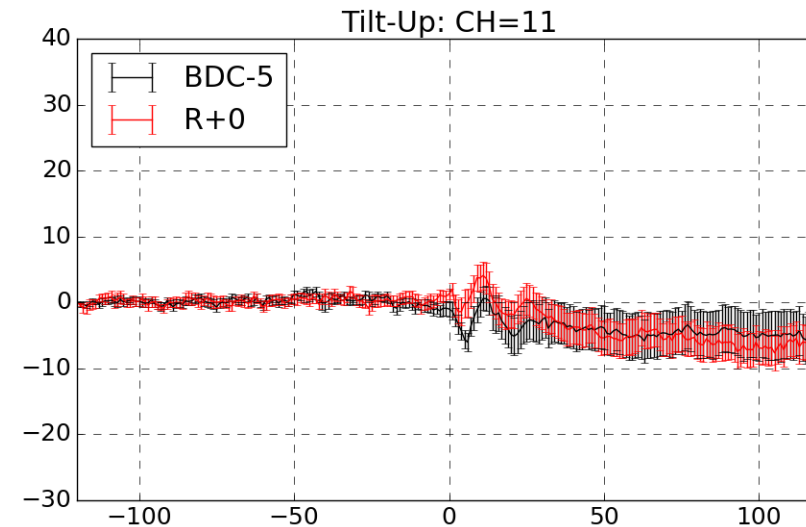
Redistribution: Tilt UP ($0^\circ \rightarrow 80^\circ$), $\Delta[\text{HbT}]$



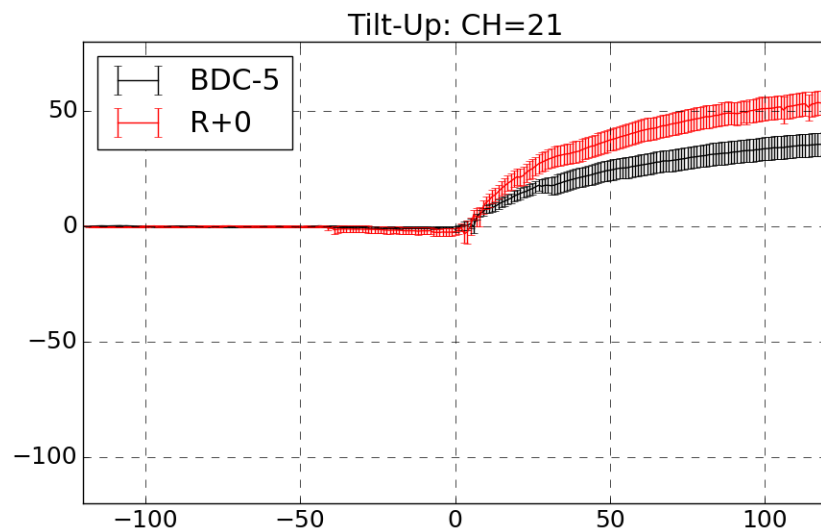
HEAD



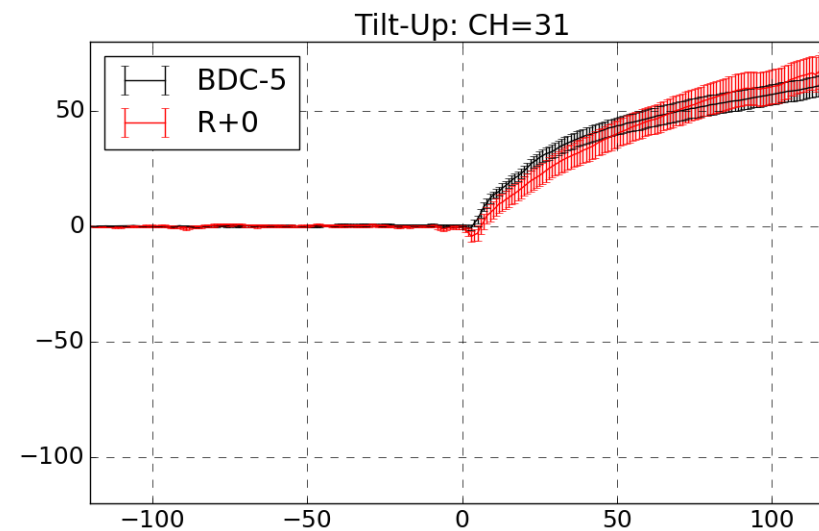
CHEST



THIGH



CALF

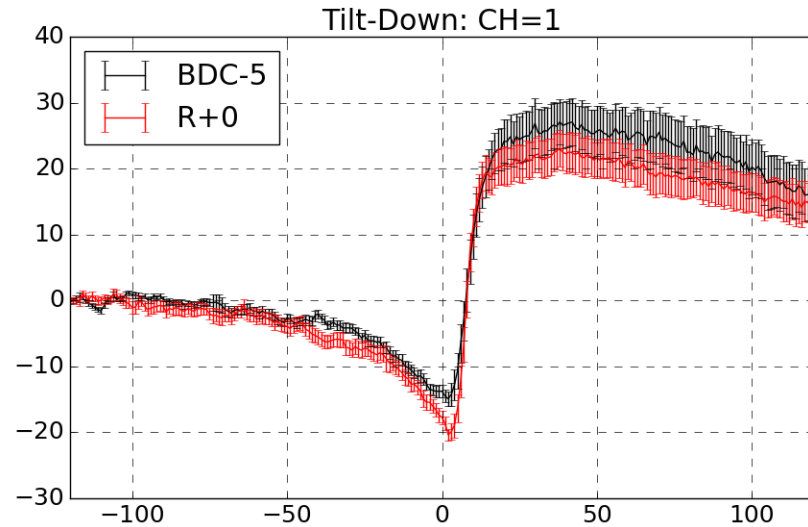


Errorbars represent bootstrapped 95% conf. int.

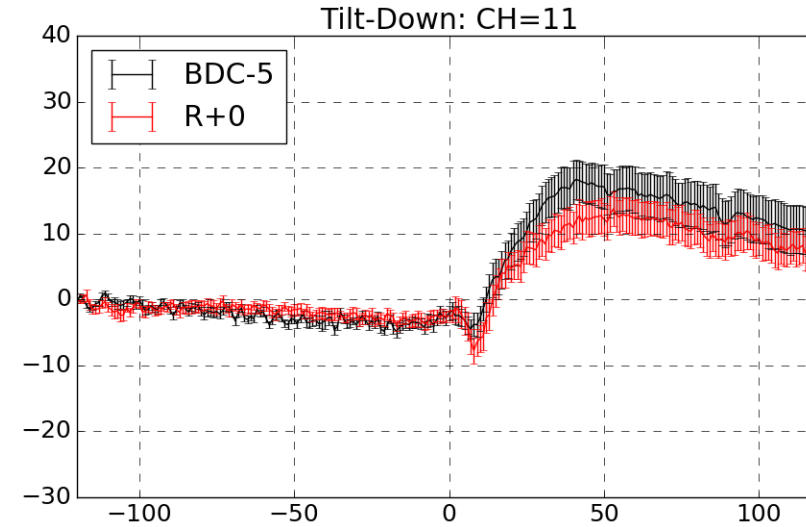
Redistribution: Tilt DOWN ($80^\circ \rightarrow 0^\circ$), [HbT]



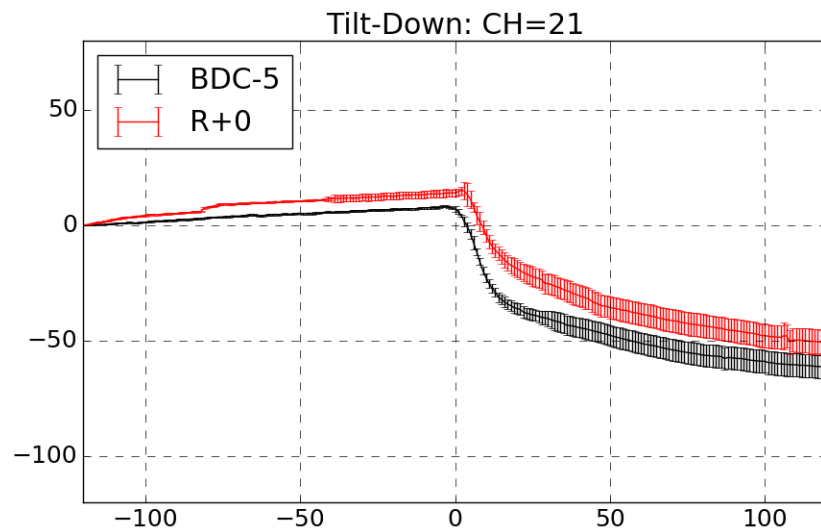
HEAD



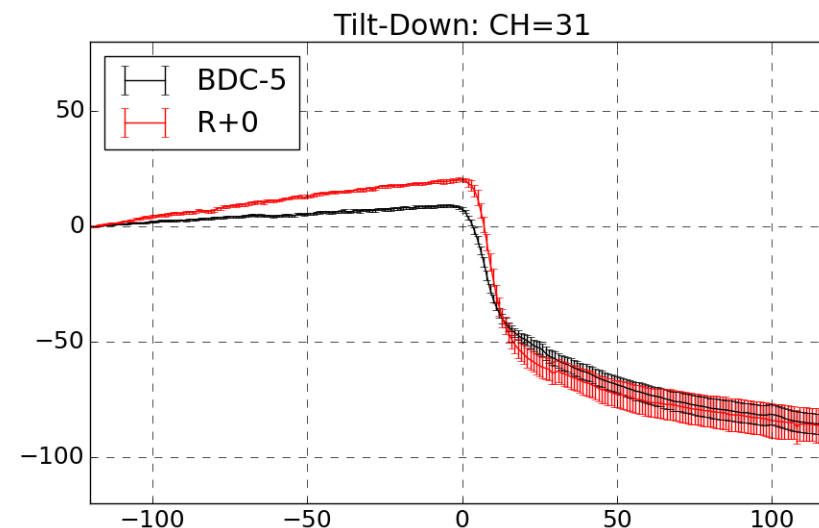
CHEST



THIGH



CALF

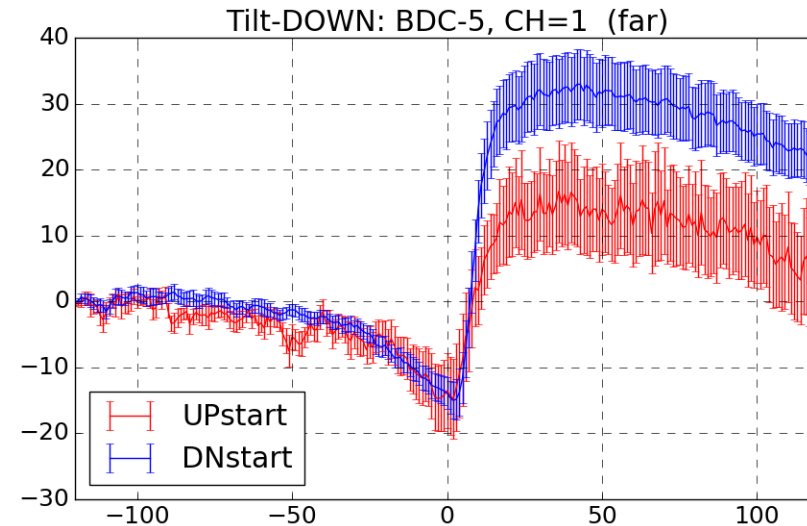
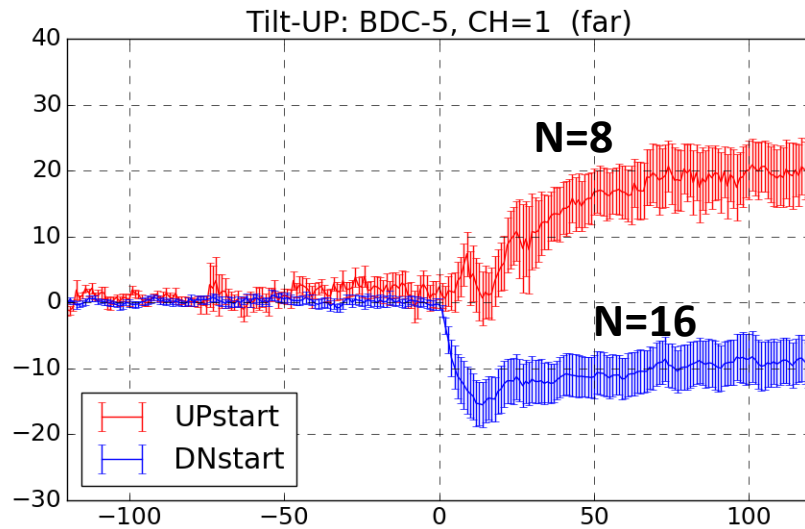


Errorbars represent bootstrapped 95% conf. int.

Head UPstart vs. DOWNstart, [HbT]

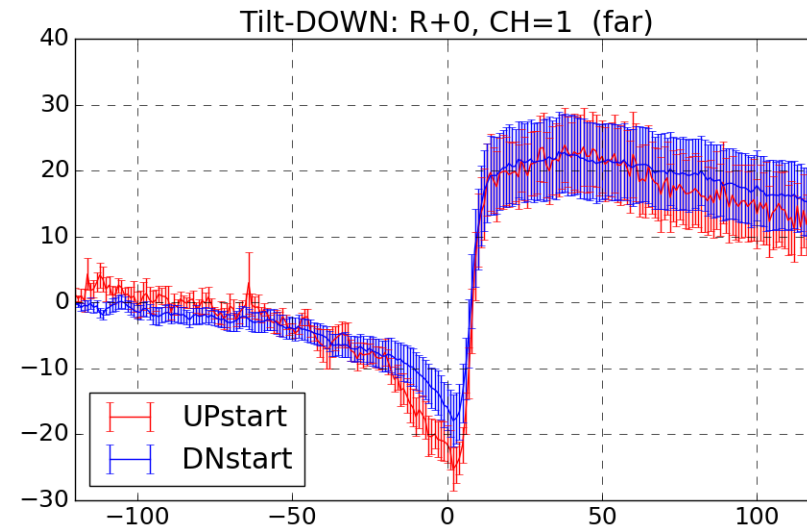
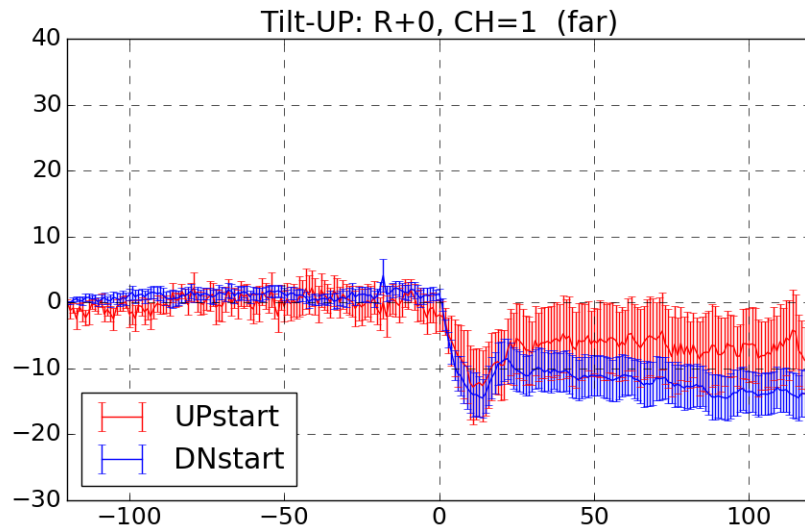


**Tilt-UP,
BDC-5**



**Tilt-DN,
BDC-5**

**Tilt-UP,
R+0**



**Tilt-DN,
R+0**

Errorbars represent bootstrapped 95% conf. int.

Cerebral Pulsatility

Vasomotor Pulsatility (VP) ... ~0.1 Hz (aka Mayer Waves)

- Start of tilt: No changes
- Middle: **cAG** and **iAG** significantly *reduced VP amplitudes* mid-tilt (-1.9 and -2.4 μM , respectively; $p < 0.05$)
- End: *reduced VP variability* at the end of tilt ($p < 0.05$)

Cardiac Pulsatility (CP) ... ~1 Hz

- Middle: significantly *increased CP amplitudes pre- vs. post-HDT* (0.3 μM , $p = 0.05$) and significantly *reduced CP variability* in **cAG** and **iAG** subjects (-0.3 μM for both; $p < 0.05$)
- All phases: Significantly *reduced CP amplitude and variability* with increasing **age** during all phases of the tilt test ($p < 0.05$)

Predicting Time Upright

2 Models where Hemodynamics Predicted

Time Upright:

**Brain
[HbT]**

	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	1178.538	146.137	8.065	0.000	892.114	1464.962
MD[T.R+0]	-370.179	91.290	-4.055	0.000	-549.104	-191.254
cAG	-197.776	195.417	-1.012	0.312	-580.786	185.235
iAG	-202.463	199.225	-1.016	0.310	-592.938	188.011
HBT_brain	7.622	3.039	2.508	0.012	1.666	13.579
Group Var	113095.507	245.509				

NOTE: UPstart coef=307.356, p=0.08

**Chest-level
Vasomotor
Pulsatility**

	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	801.378	189.087	4.238	0.000	430.774	1171.982
MD[T.R+0]	-481.411	80.962	-5.946	0.000	-640.094	-322.727
cAG	-133.261	188.229	-0.708	0.479	-502.184	235.661
iAG	-210.899	187.090	-1.127	0.260	-577.589	155.790
VPulsatility	55.903	26.009	2.149	0.032	4.926	106.881
UPstart	330.912	165.804	1.996	0.046	5.941	655.882
Group Var	101078.510	218.256				

Predicting Time Upright

ALWAYS Significant Predictors of Time Upright

- Mission Day (i.e., pre vs. post HDT)
- UPstart

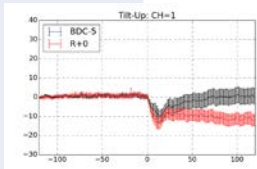
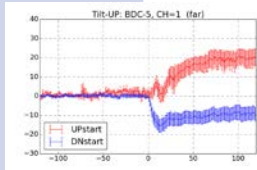
NON-Significant Predictors of Time Upright

- iAG, cAG
- Age
- Sex
- Cardiac Pulsatility

Note: Although never significant, iAG & cAG always exhibited large negative coefficients (-100 to -400 sec), suggesting AG tended to reduce time upright, but with quite substantial inter-subject variability.

Discussion

Motivation Questions	Results Summary
1. Quantify fluid re-distribution along the body axis during orthostatic tilt testing	MOSTLY head-to-toe Brain [HbT] loss ~60s before presyncope Unexpected “up first” in brain [HbT] in 1/3 of subjects; eliminated at R+0.
2. Effect of 60-day HDT?	Greater and earlier decreases in brain [HbT] on R+0.
3. Effect of centrifugation?	Reduced VP amplitudes and CP variability
4. Hemodynamics predicting tilt survival time?	Yes: (1) [HbT] “up first” in brain (2) [HbT] deviation from baseline



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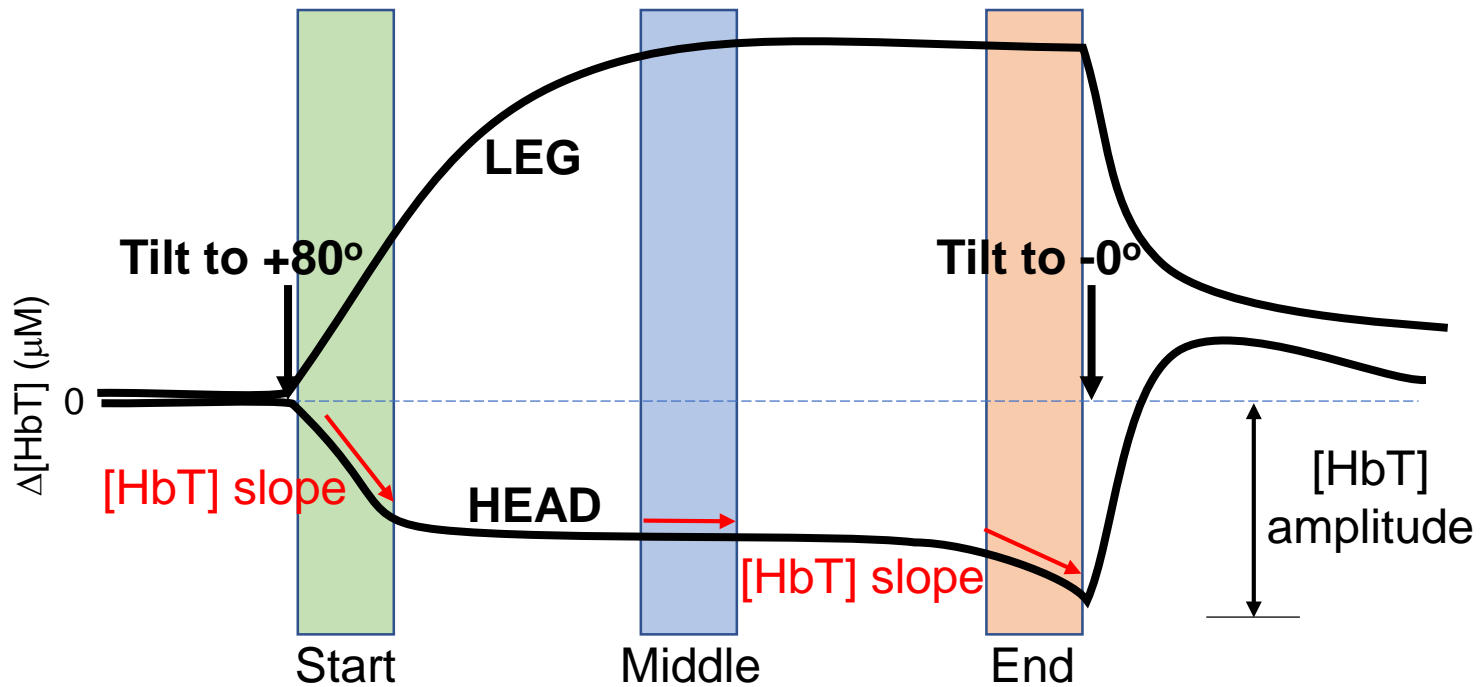
NASA grant #NNX17AE04G



DLR

:envihab

Summary of Findings



Head $\Delta[\text{HbT}]$ mean

+upstart=start/middle/end

-MD=middle/end

(-sex)=start/middle/end

Head $\Delta[\text{HbT}]$ std

-iAG=middle

(-cAG)=middle

(+MD)=middle

Head $\Delta[\text{HbT}]$ slope

+upstart=start

-MD=middle