Cardiovascular rhythms in human physiology and pathophysiology

An insight into the physiological meaning of different cardiovascular rhythms in pathophysiological conditions such as vasovagal syncope

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May 3rd 2017

Background

The Autonomic Nervous System (ANS) is a *tool* enabling proper cardiovascular adaptations to changes in the environment, i.e. ANS is the mean to promote the adaptation to different functional states of the body.

Autonomic nervous system and arterial baroreceptor activities result in spontaneous fluctuations of the cardiovascular parameters (heart rate and arterial pressure).

Vasovagal syncope is a benign type of transient loss of conscousness which however, being associated with a loss of postural tone, can be hazardous in high-risk working environments.

Abnormal cardiovascular rhythms characterize pathophysiology, including vasovagal syncope.

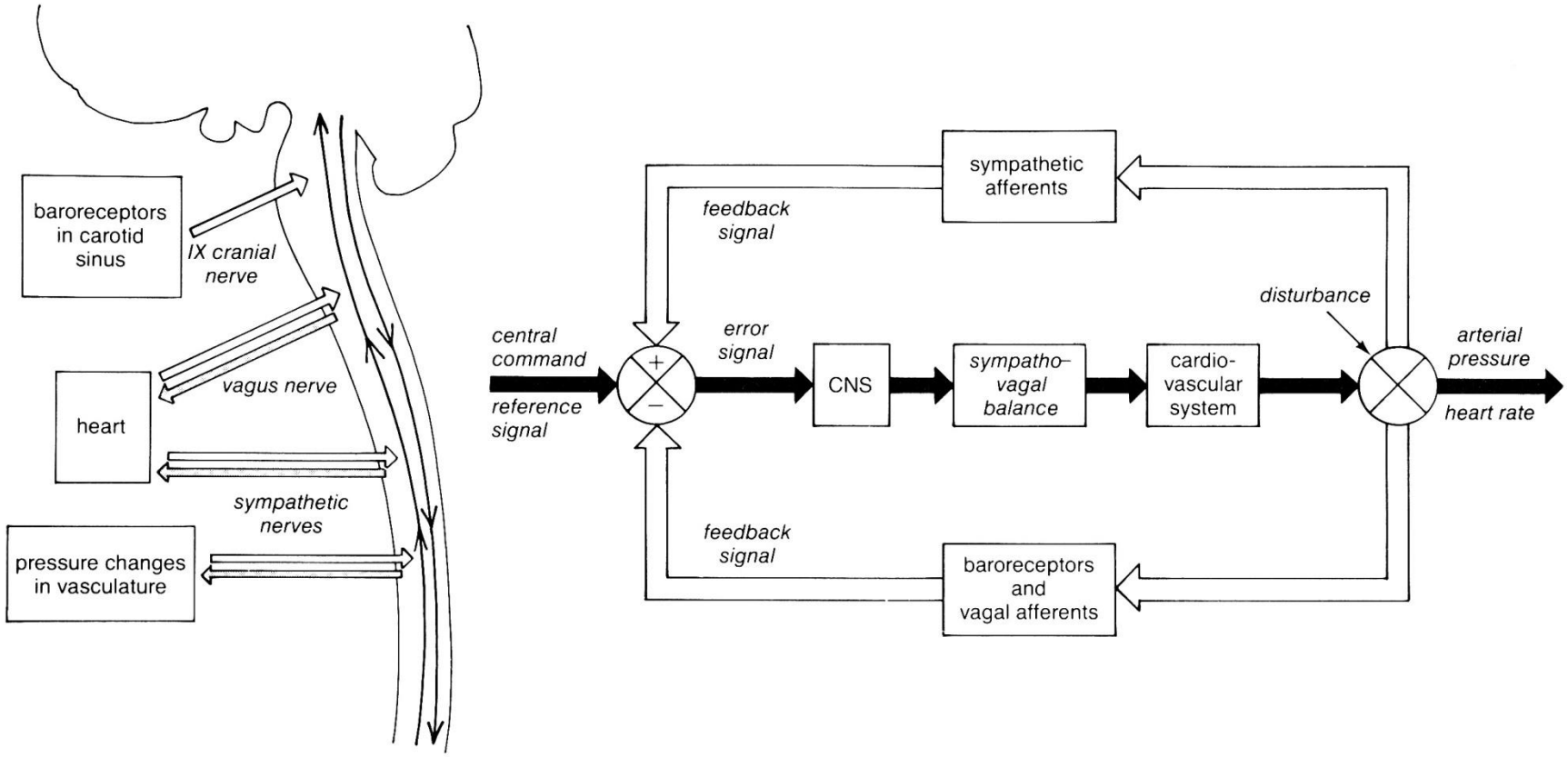
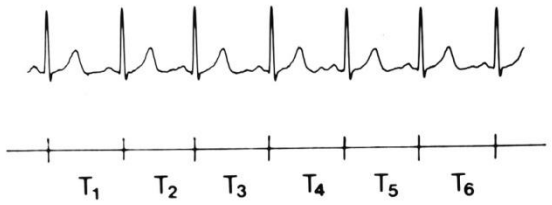
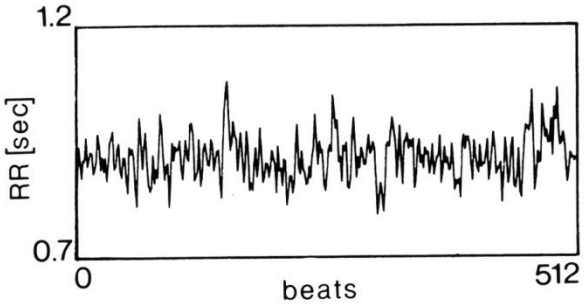


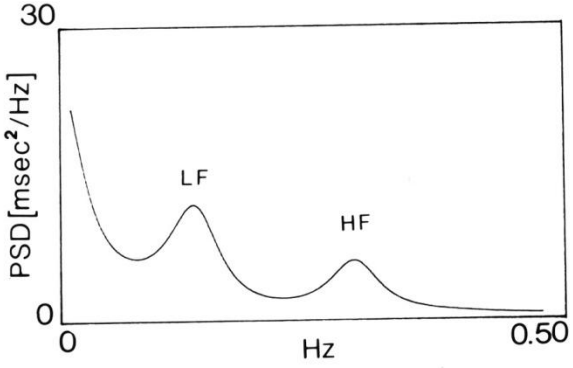
Fig. 1. Schematic representation of the neural control of circulation. The neural circuits **(left)** *are represented by vagal (and baroreceptor) nerves that connect the cardiovascular system with bulbar structures, while sympathetic innervation projects to the spinal cord. Notice that both nerve pathways contain both afferent (i.e. sensory) and efferent (i.e. motor) fibers. This complex neural circuit can be modelled as operating as a dual feedback system* **(right)**. *Excitatory positive feedback mechanisms depend upon sympathetic afferents, while inhibitory negative feedback mechanisms rely on (baroreceptor and) vagal afferents. (See Ref. 3 for more details.)*



TACHOGRAM

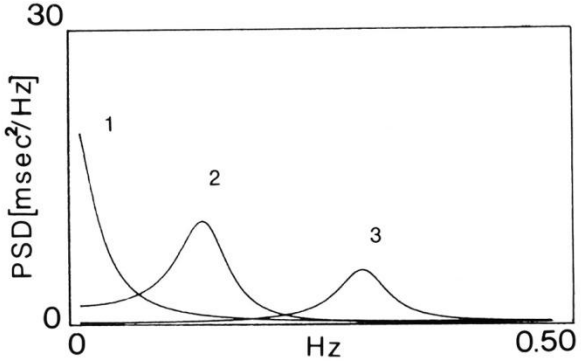


POWER SPECTRAL DENSITY



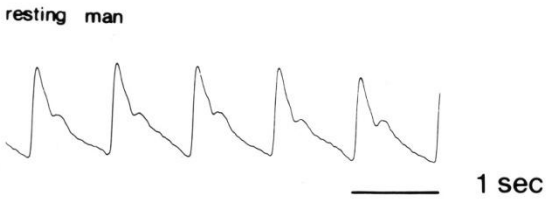
PSD ordinates $* 10^3$

SPECTRAL COMPONENTS

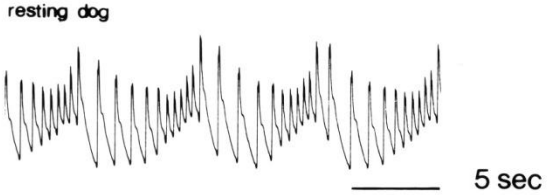


1) F = 0.00 Hz P = 758 msec²
2) F = 0.12 Hz P = 708 msec² P = 55 n.u.
3) F = 0.27 Hz P = 433 msec² P = 34 n.u.

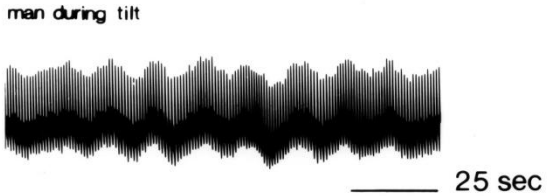
BLOOD PRESSURE WAVES



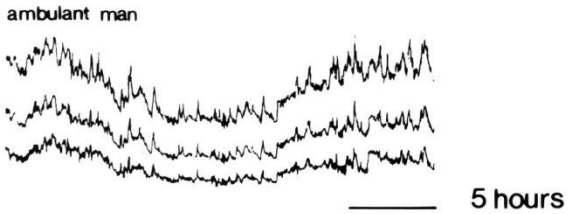
1 sec



5 sec



25 sec



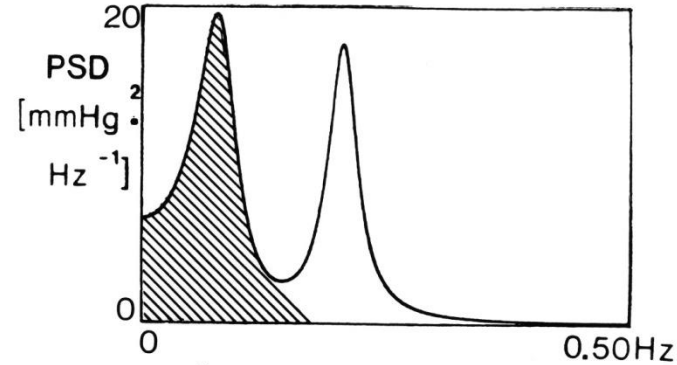
5 hours

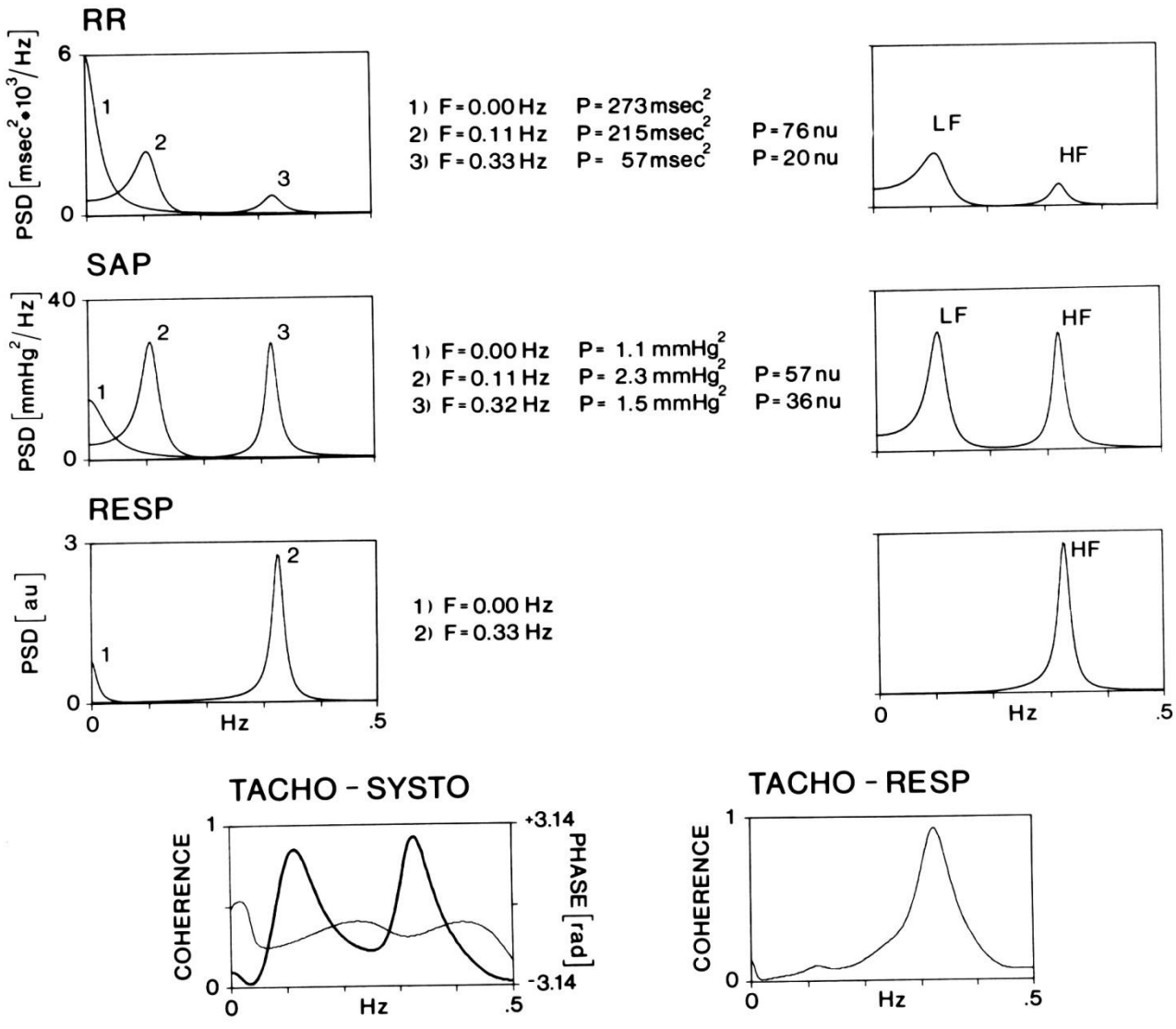
1st ORDER FLUCTUATIONS
(cardiac)

2nd ORDER FLUCTUATIONS
(respiratory)

3rd ORDER FLUCTUATIONS
(slow)

DAY-NIGHT FLUCTUATIONS




RR
PSD [msec² • 10³/Hz]
6
0
1
2
3
1) F = 0.00 Hz P = 273 msec²
2) F = 0.11 Hz P = 215 msec²
3) F = 0.33 Hz P = 57 msec²
P = 76 nu
P = 20 nu
LF
HF
SAP
PSD [mmHg²/Hz]
40
0
1
2
3
1) F = 0.00 Hz P = 1.1 mmHg²
2) F = 0.11 Hz P = 2.3 mmHg²
3) F = 0.32 Hz P = 1.5 mmHg²
P = 57 nu
P = 36 nu
LF
HF
RESP
PSD [au]
3
0
1
2
1) F = 0.00 Hz
2) F = 0.33 Hz
HF
0
Hz
.5
TACHO - SYSTO
COHERENCE
1
0
+3.14
-3.14
PHASE [rad]
0
Hz
.5
TACHO - RESP
COHERENCE
1
0
0
Hz
.5

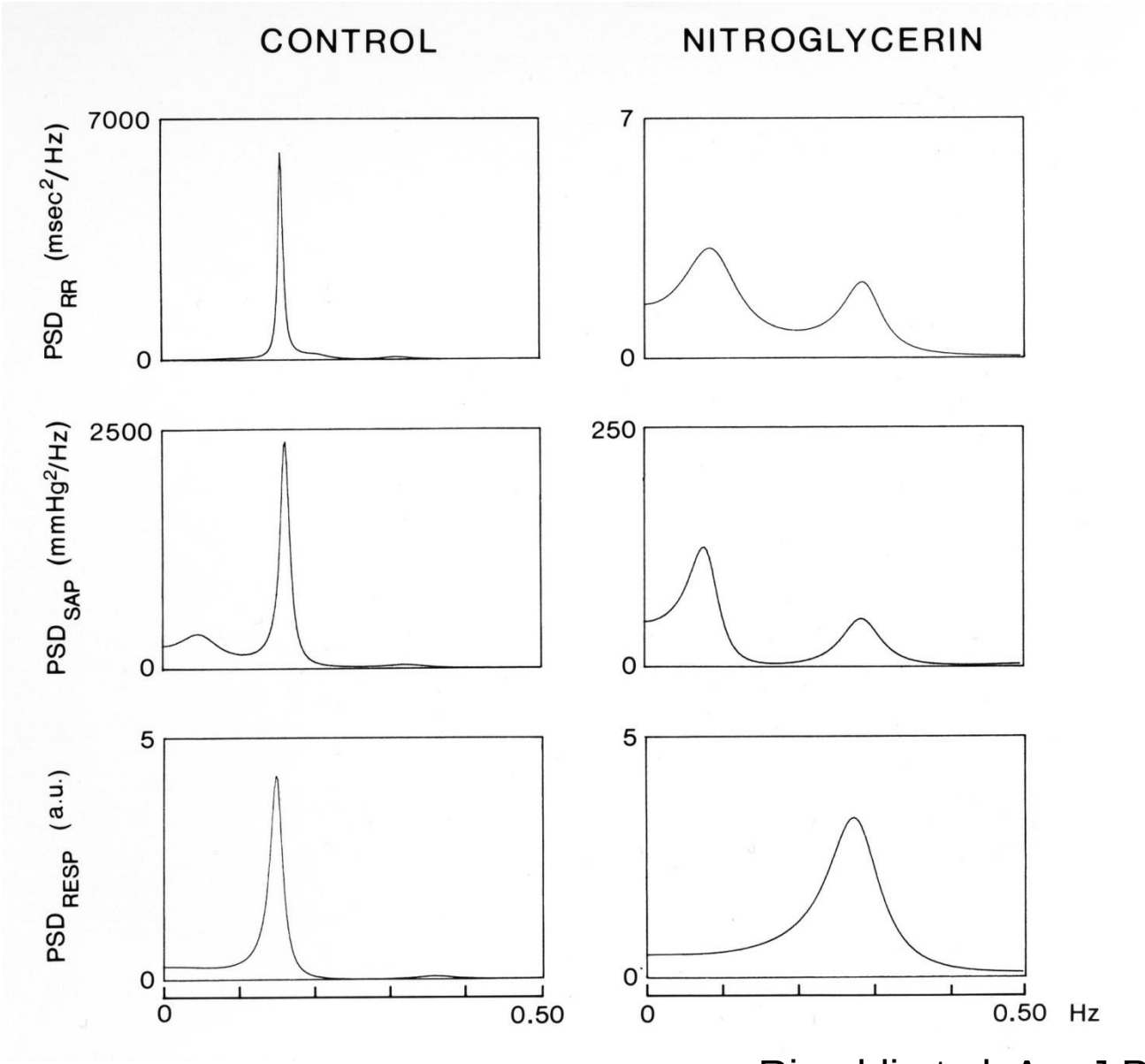
Outline

- Relationship between 0.1 Hz spontaneous fluctuations of CV parameters and the neural sympathetic modulation
  - Animal data
  - Human data

- Role of arterial baroceptors in physiology and pathophysiology (vasovagal syncope)

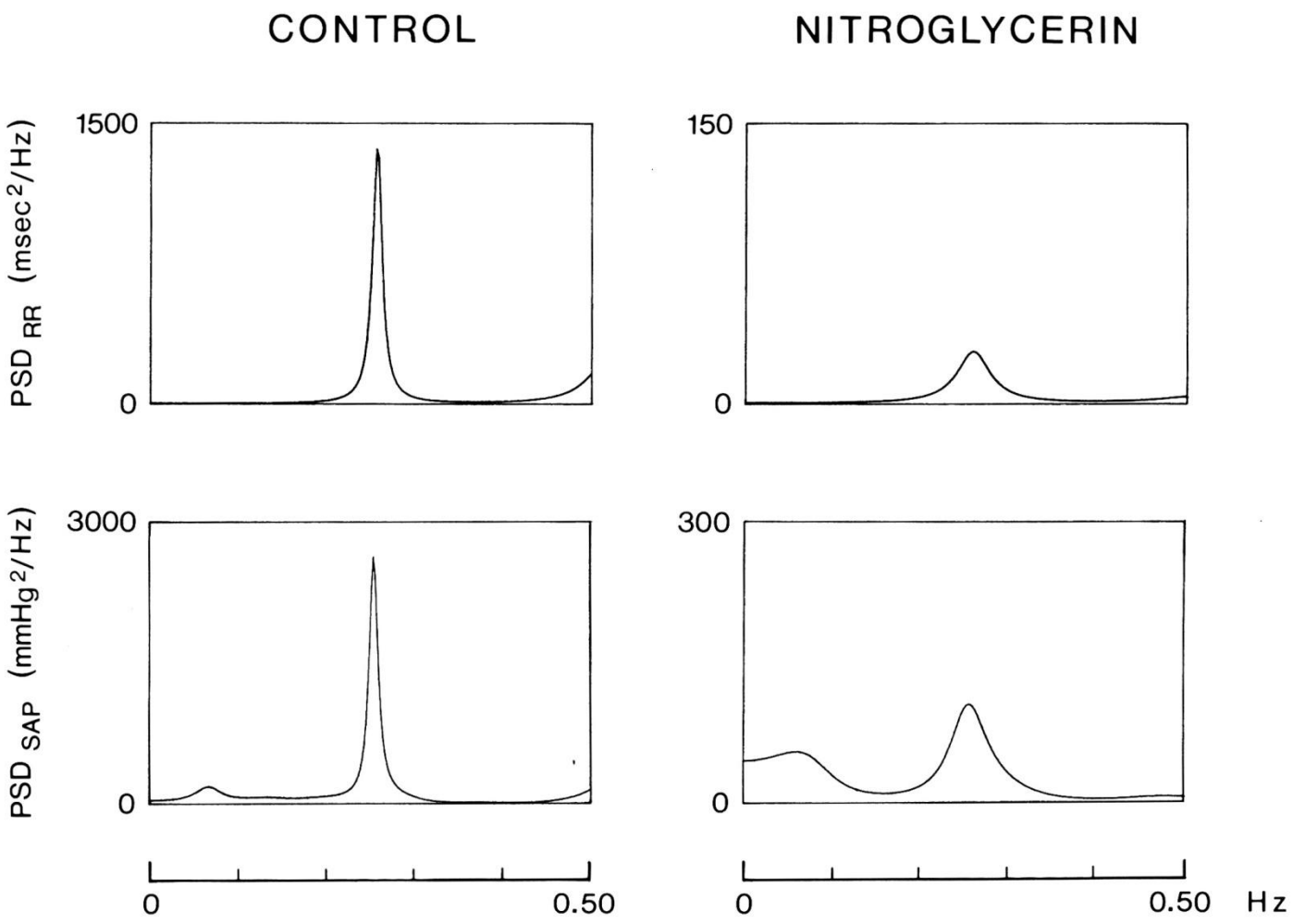
➢ Relationship between 0.1 Hz spontaneous fluctuations of CV parameters and the neural sympathetic modulation

- Animal data
- Human data

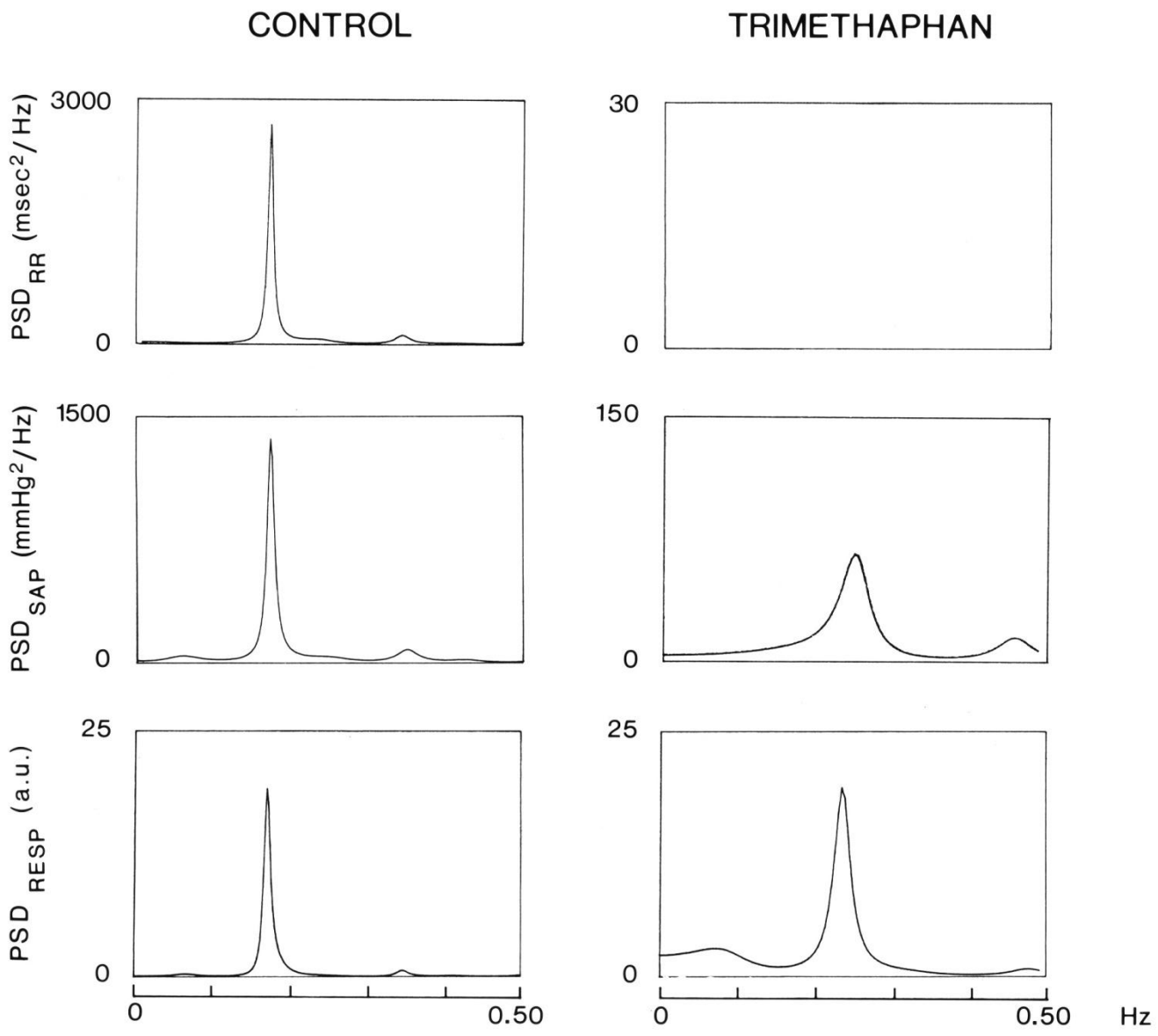


Rimoldi et al, Am J Physiol 1990; 258: H967

STELLECTOMY



Rimoldi et al, Am J Physiol 1990; 258: H976

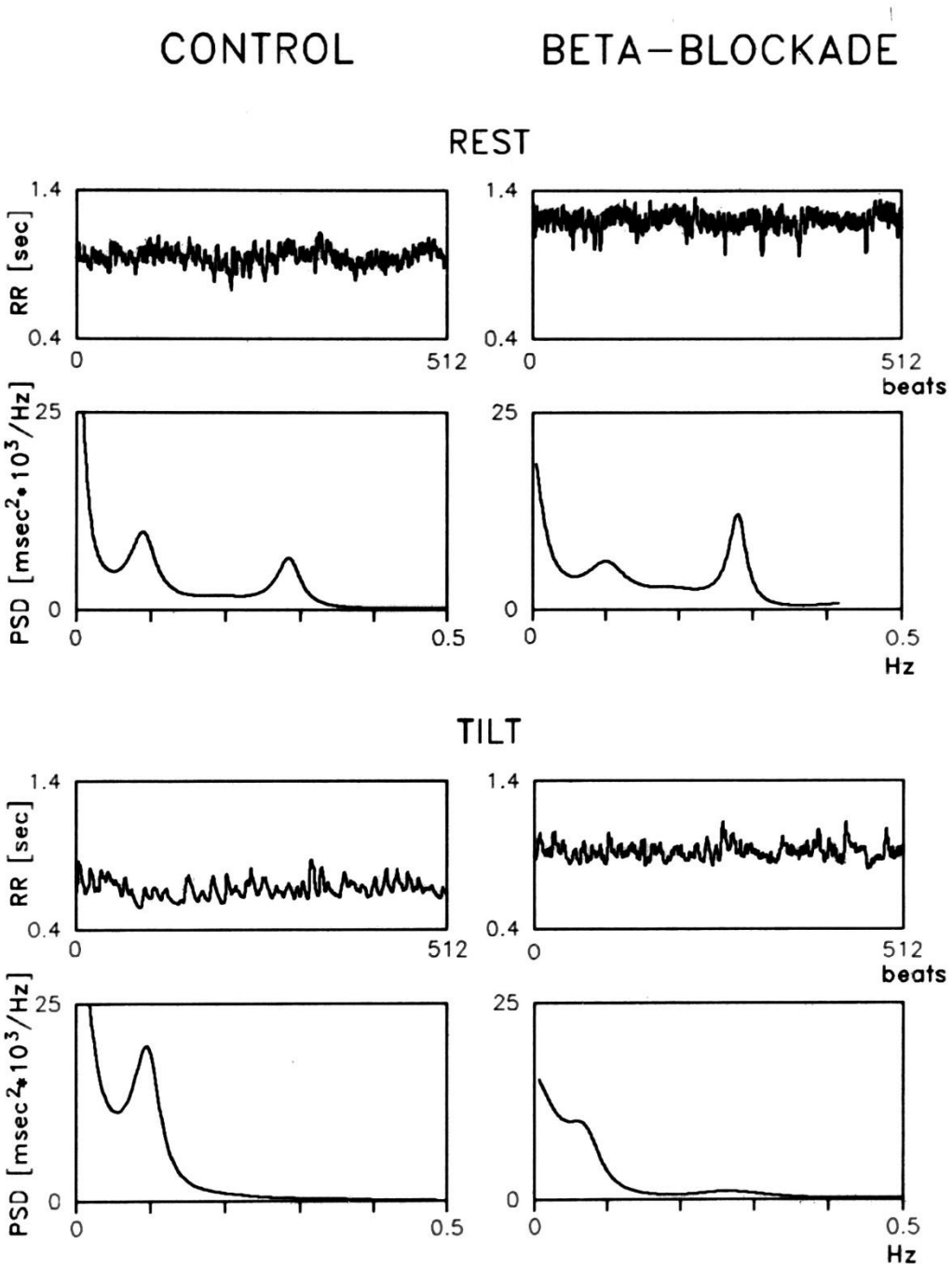


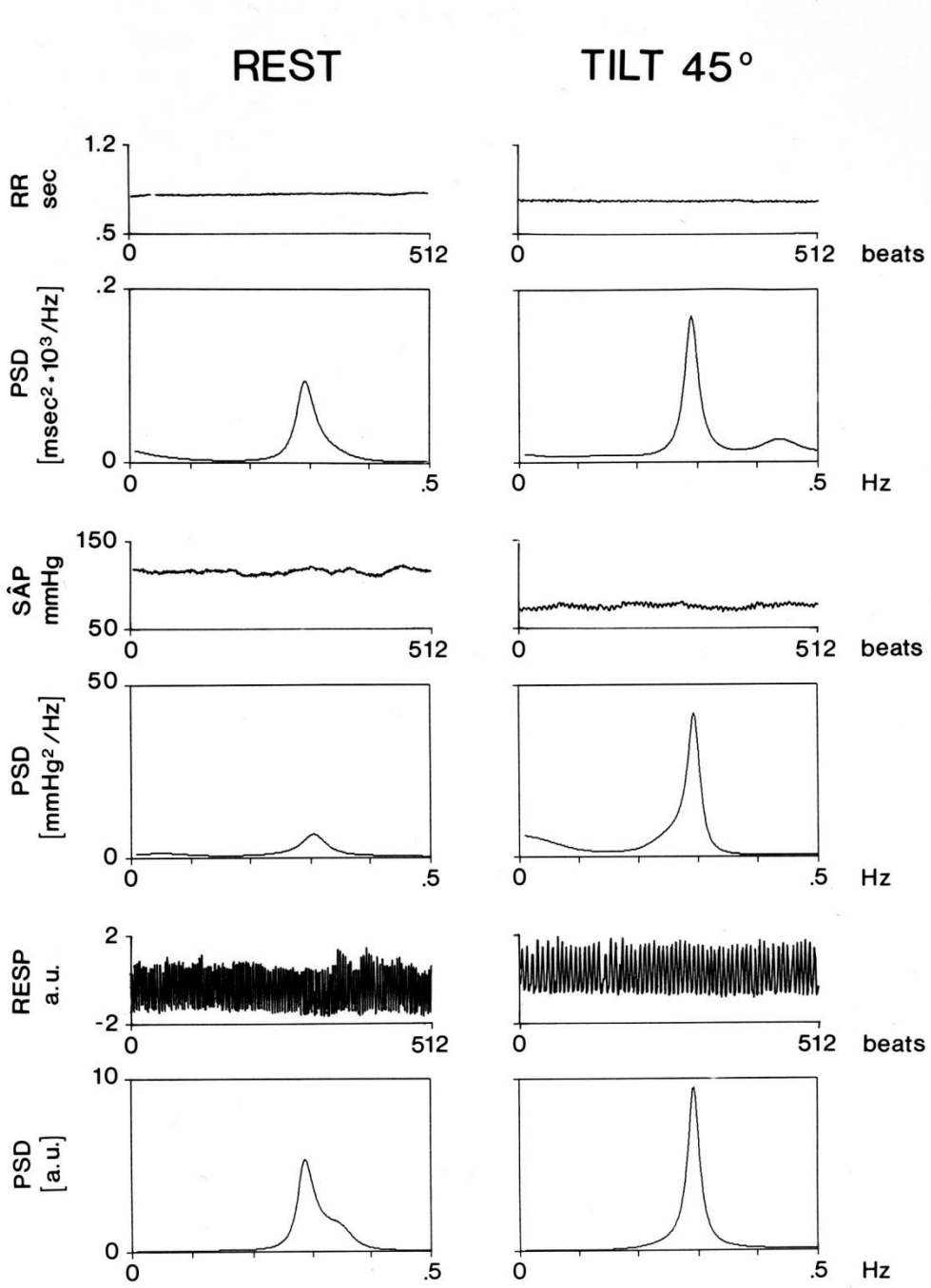
Rimoldi et al, Am J Physiol 1990; 258: H967

➢ Relationship between 0.1 Hz spontaneous fluctuations of CV parameters and the neural sympathetic modulation

- Human data


IS IT ME,
OR IS EVERYONE
AROUND HERE
STRANGE LOOKING?


CONTROL
BETA–BLOCKADE
REST
TILT
RR [sec]
1.4
0.4
0
512
beats
PSD [msec² • 10³/Hz]
25
0
0.5
Hz


REST
TILT 45°
RR
sec
1.2
.5
0
512
beats
PSD
[msec² • 10³/Hz]
.2
0
.5
Hz
SAP
mmHg
150
50
PSD
[mmHg²/Hz]
50
RESP
a.u.
2
-2
PSD
[a.u.]
10

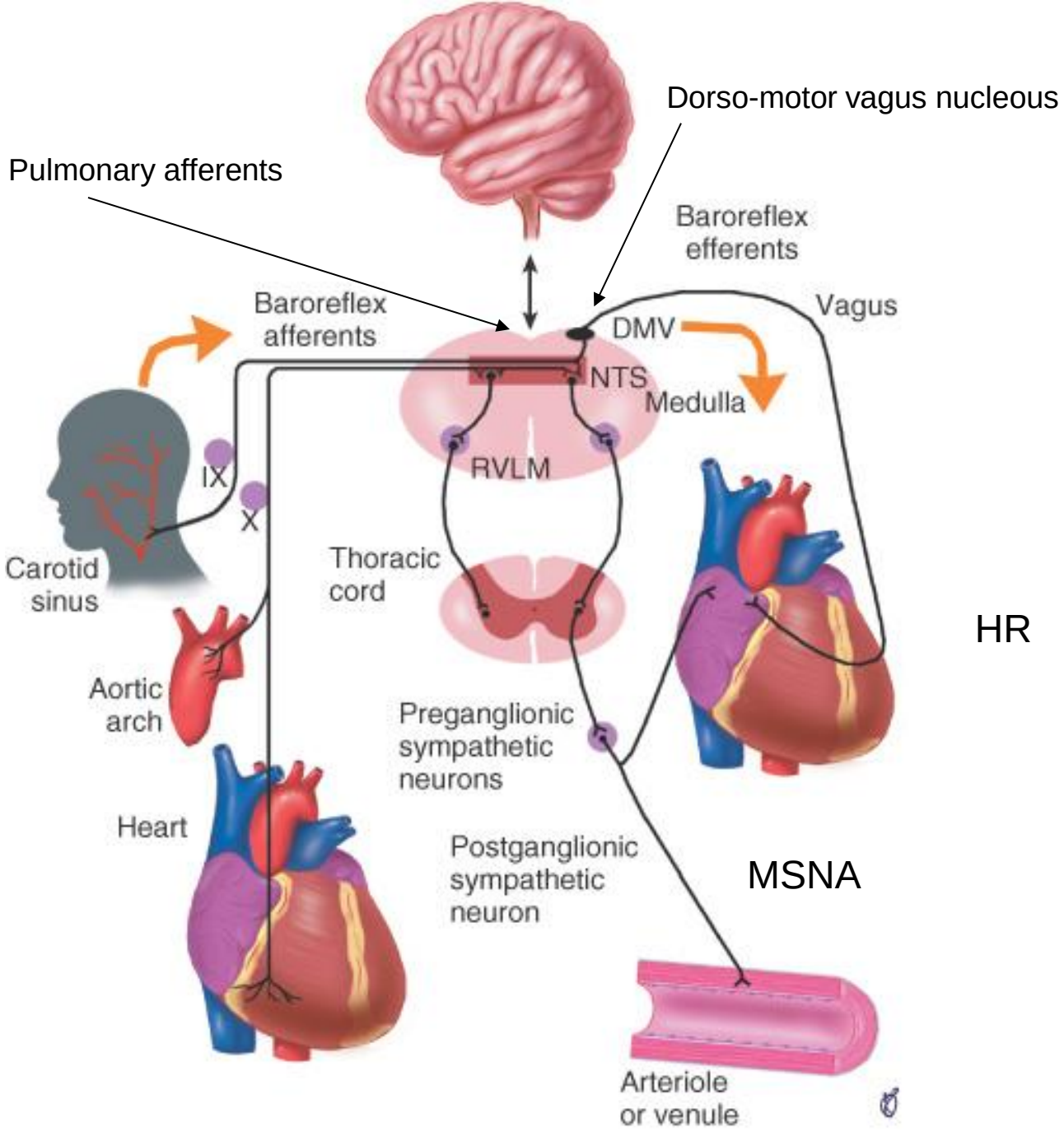
Summary

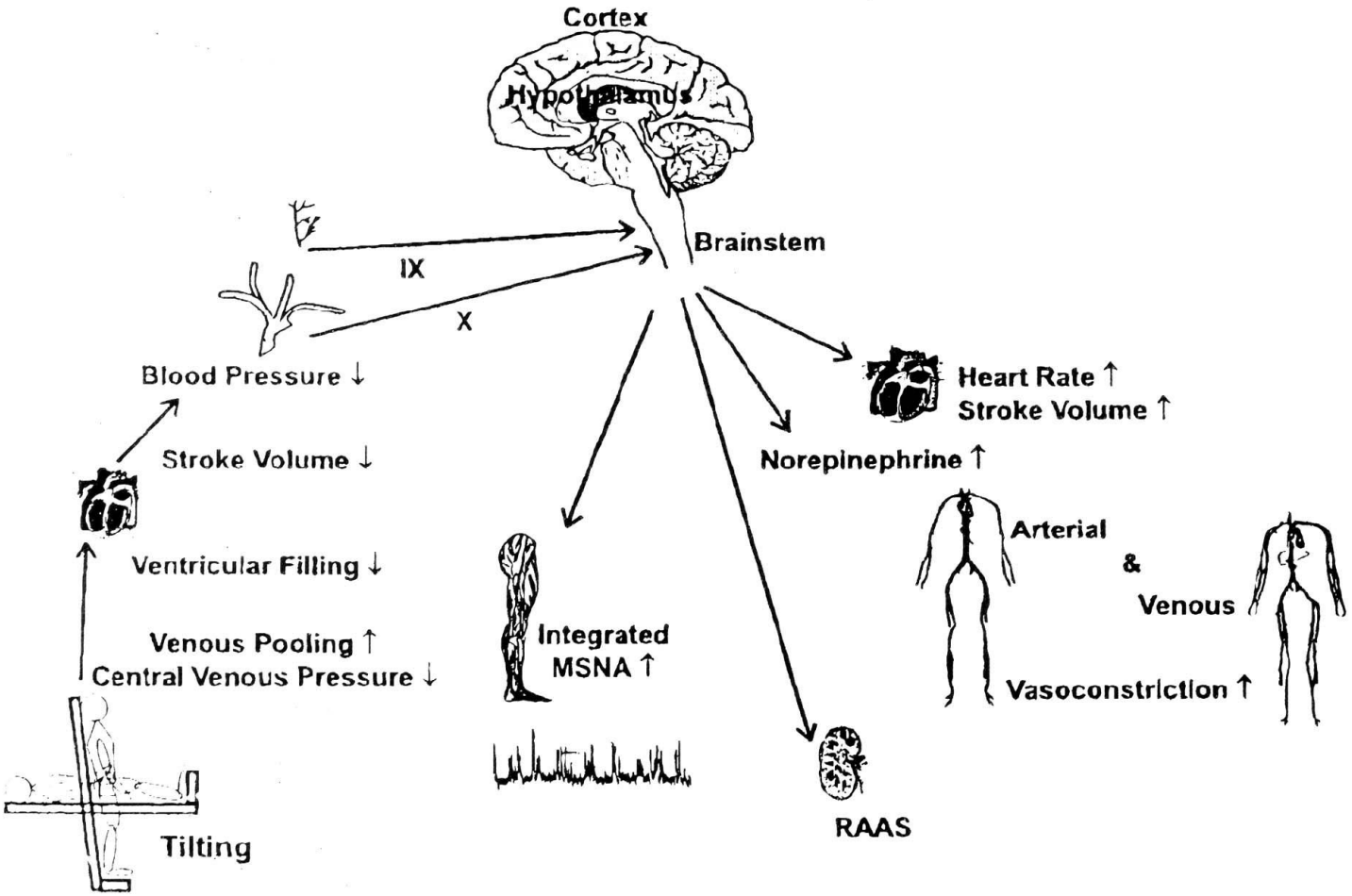
- Conditions characterized by an increased sympathetic activity are associated with an increase in the LF component of both RR and SAP variability

- An intact sympathetic innervation is essential to the genesis of the LF component

Outline

- Role of arterial baroceptors in physiology



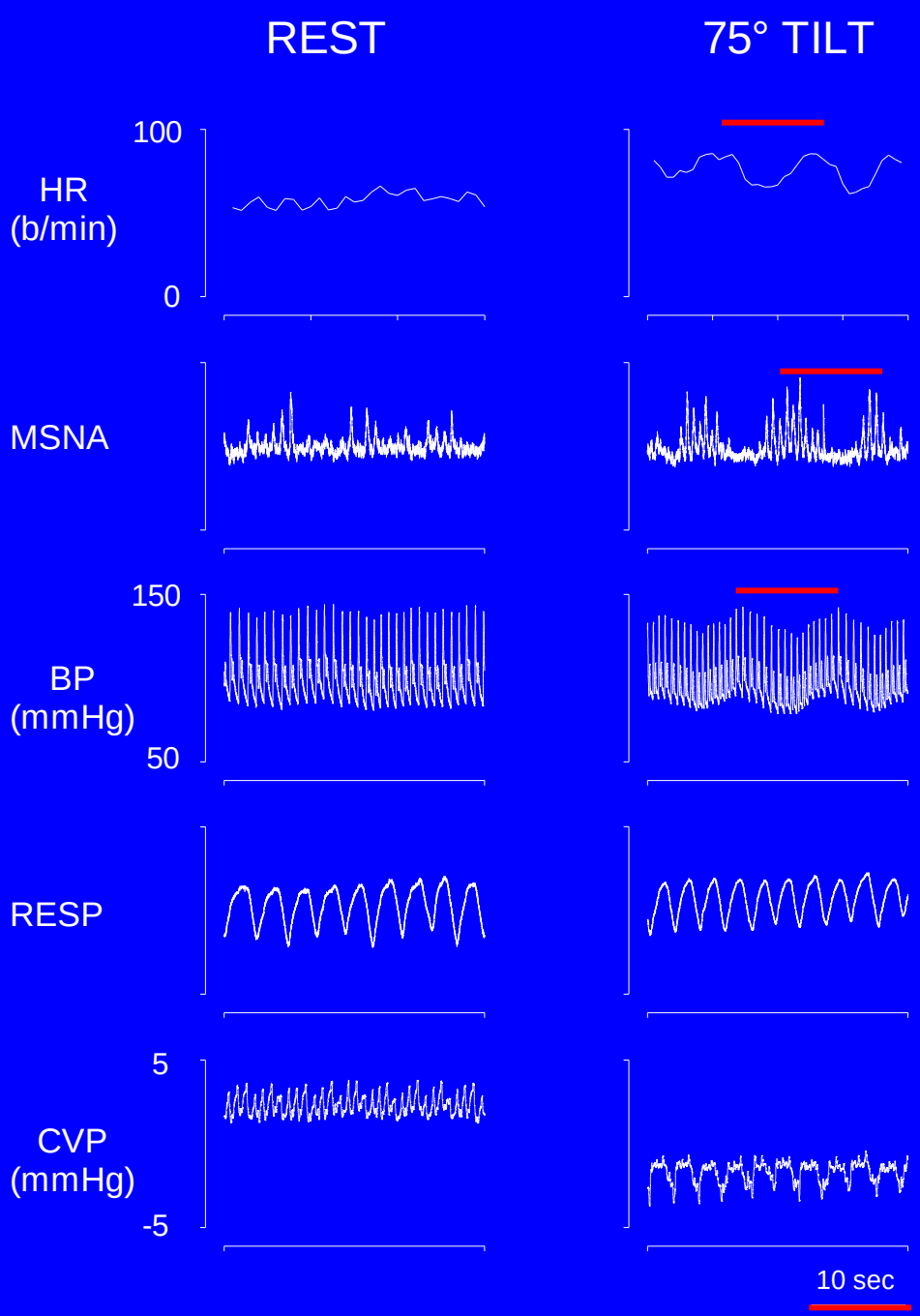


Mosqueda-Garcia et al. Circulation. 2000;102:2898

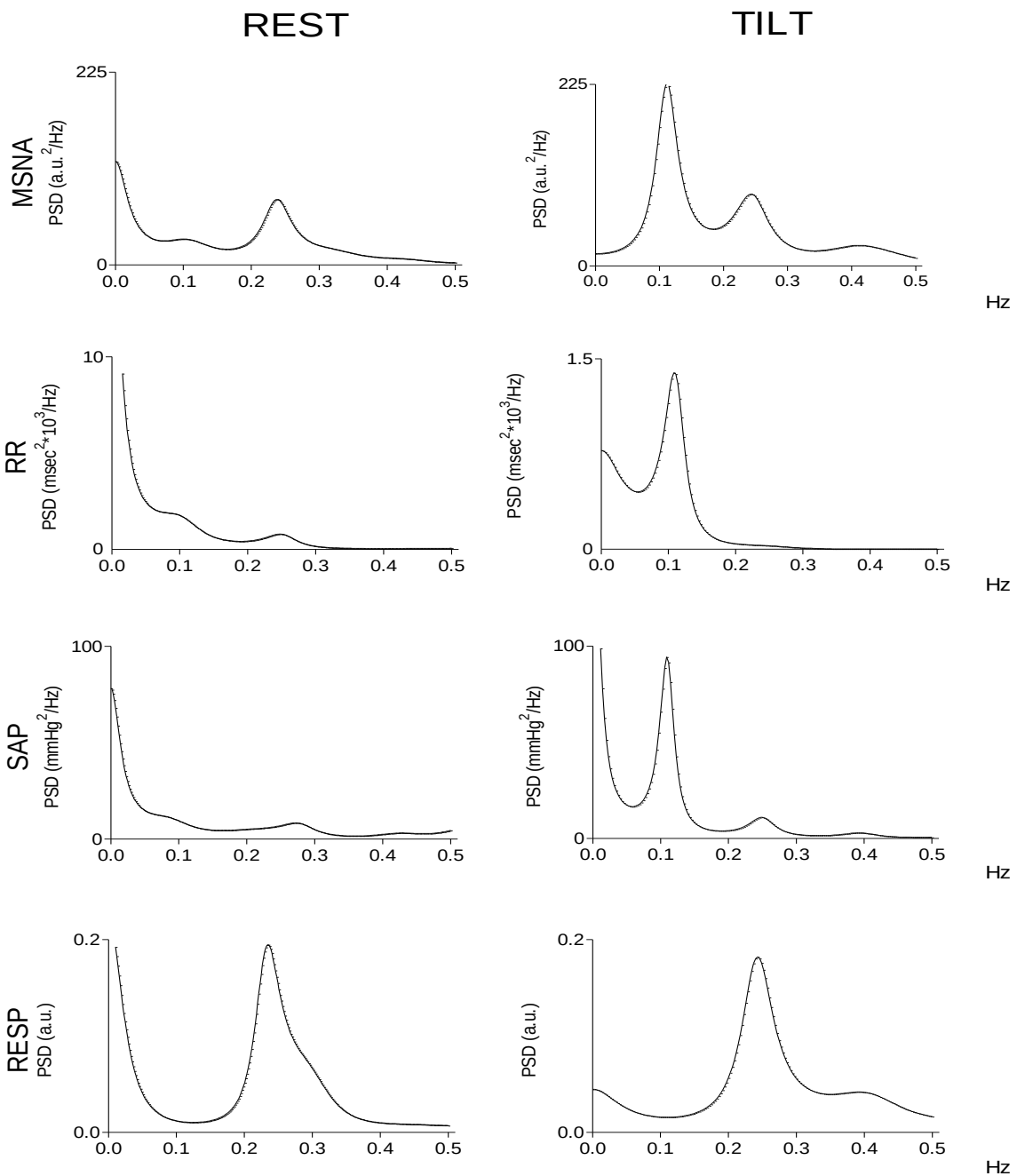
During the up-right position, a proper baroreceptor function is crucial for:

- *increasing HR, MSNA and maintaining BP*

- synchronizing the spontaneous fluctuations at 0.1 Hz (LF) of the sympathetic activity to the vessels (MSNA) and the controlled cardiovascular variables (HR and SAP)



Furlan et al, Circulation 2000; 101: 886



Furlan et al, Circulation 2000; 101: 886

Summary

- In the presence of synchronous LF oscillations in RR interval, SAP and MSNA variability during the up-right position (*increase in coherence index*), healthy subjects are characterized by a proper orthostatic tolerance.

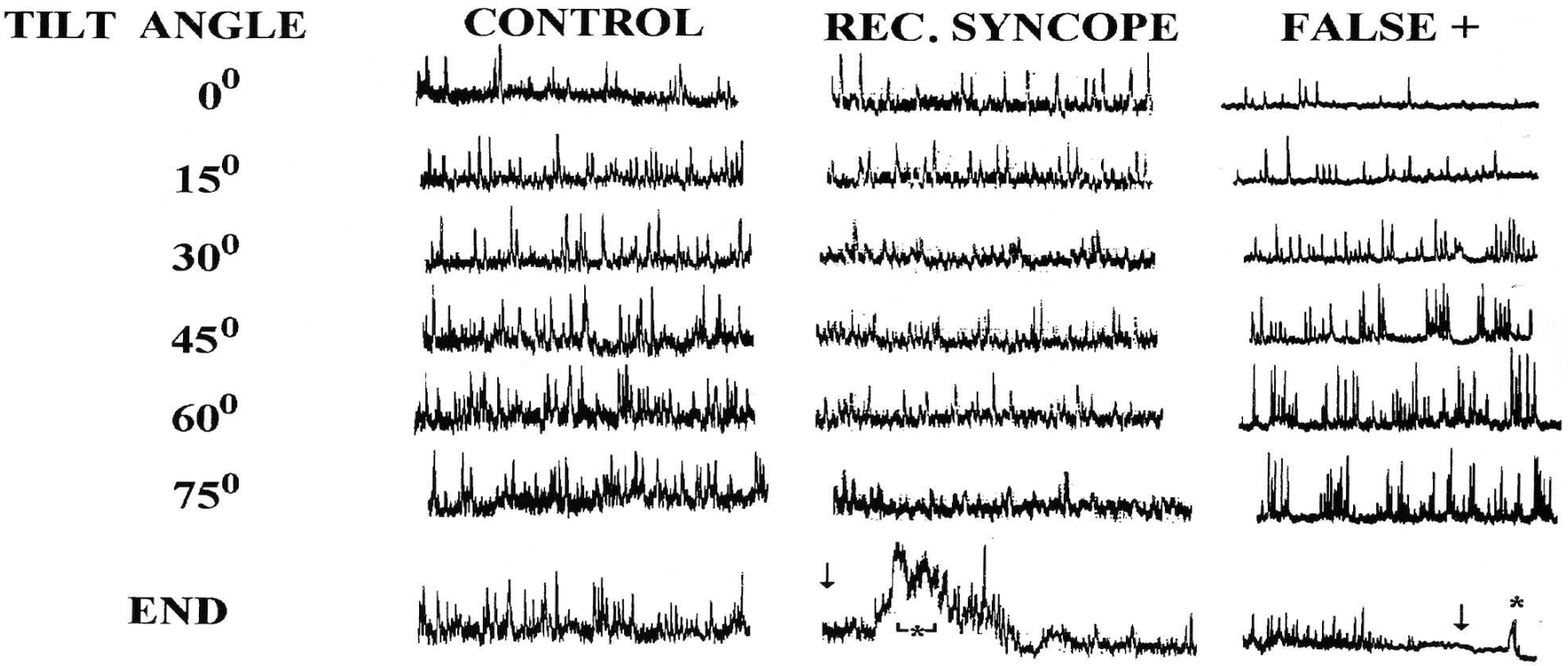
- Baroreceptor mechanisms play a crucial role in adapting heart rate, SAP and MSNA mean values to the up-right position and also in synchronizing the LF spontaneous fluctuations of these parameters

Outline

- Role of arterial baroceptors in pathophysiology (vasovagal syncope)

BACKGROUND

During orthostatic vasovagal syncope, the neural sympathetic vasomotor control (MSNA) is silenced.



Mosqueda-Garcia et al.
J Clin Invest.
1997;99:2736

What about Pre-syncope?

Hypothesis

• *Pre-syncope* might be characterized by impaired cardiac and vascular sympathetic baroreflex control

• resulting in a persistence of MSNA in the presence of an *uncoupling* between the neural sympathetic discharge activity and the BP fluctuations at ~0.1 Hz.

• that in turn promotes orthostatic intolerance with pre-syncope symptoms and signs

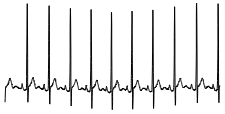
Population:

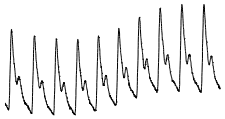
ESA project AO-06-BR-18

N = 10, male
Age = 31 1 years
BMI = 23,4 ± 0,2 Kg/m^2

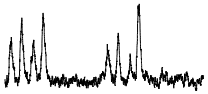
European Space Agency

Variables:

ECG 

BP 

RESP 

MSNA 

N=8

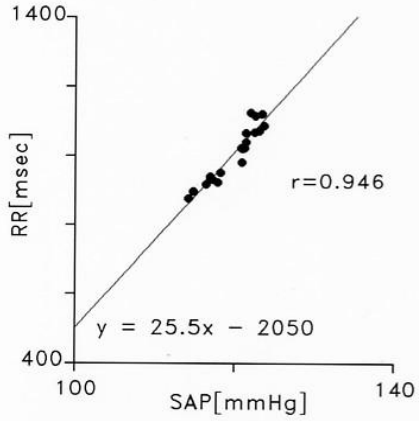
Protocol: Rest (15'), Tilt (15', 80° head-up) + LBNP (-10 mmHg step wise increase) till pre-syncope

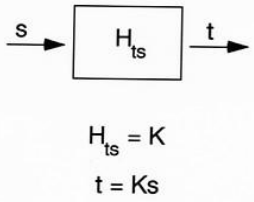
Analysis:

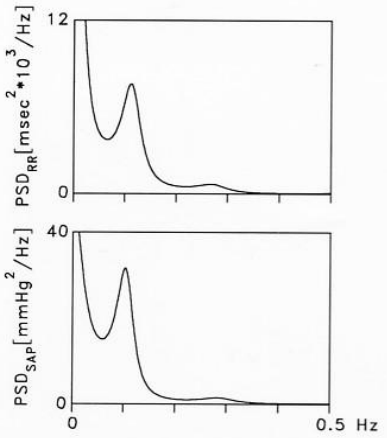
Rest (5')	Tilt1 (asymptomatic 3')	Tilt2 (pre syncope 1')

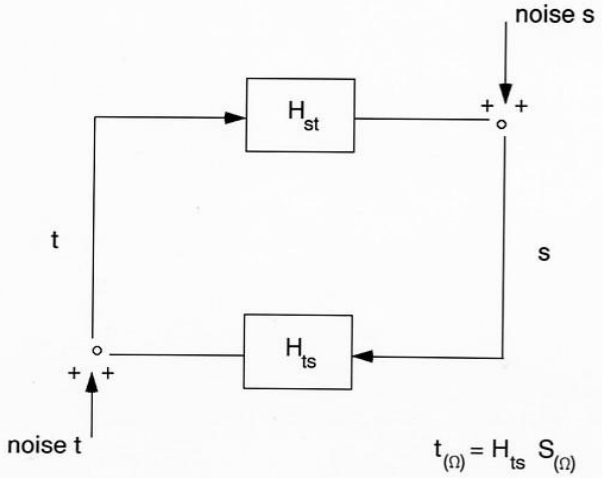
Methodology:

Autoregressive spectrum and cross-spectrum analysis techniques assessed RR, SAP and MSNA variability and their linear coupling.



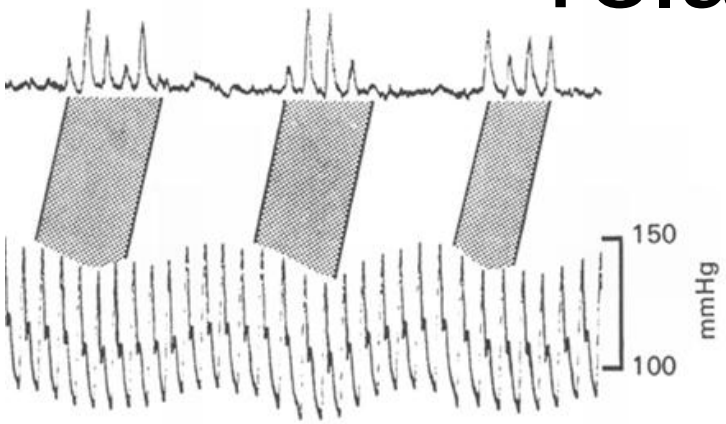




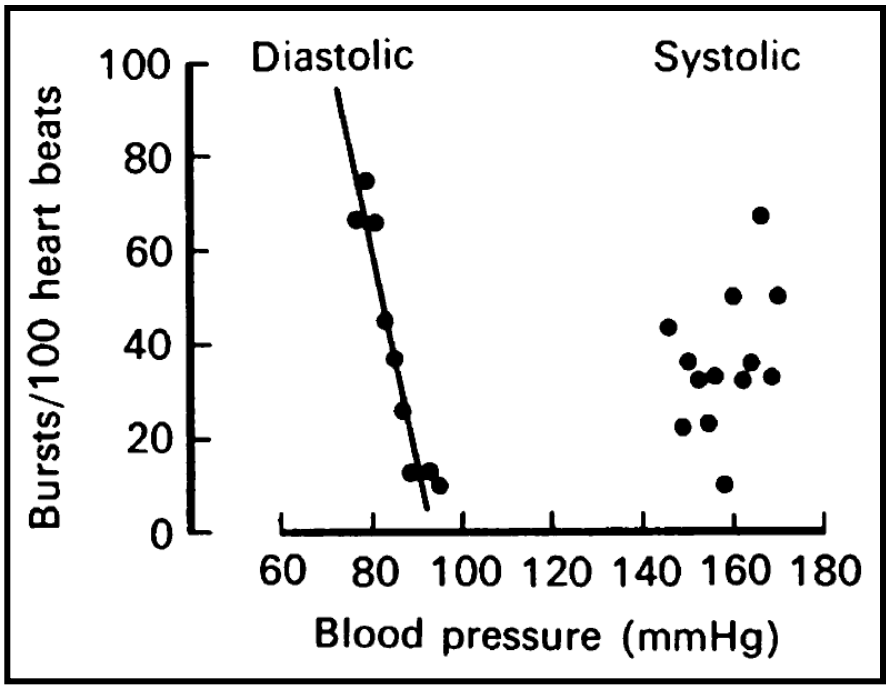


$$\alpha = [P_t\ (f)/\ P_s\ (f)]^{1/2}$$

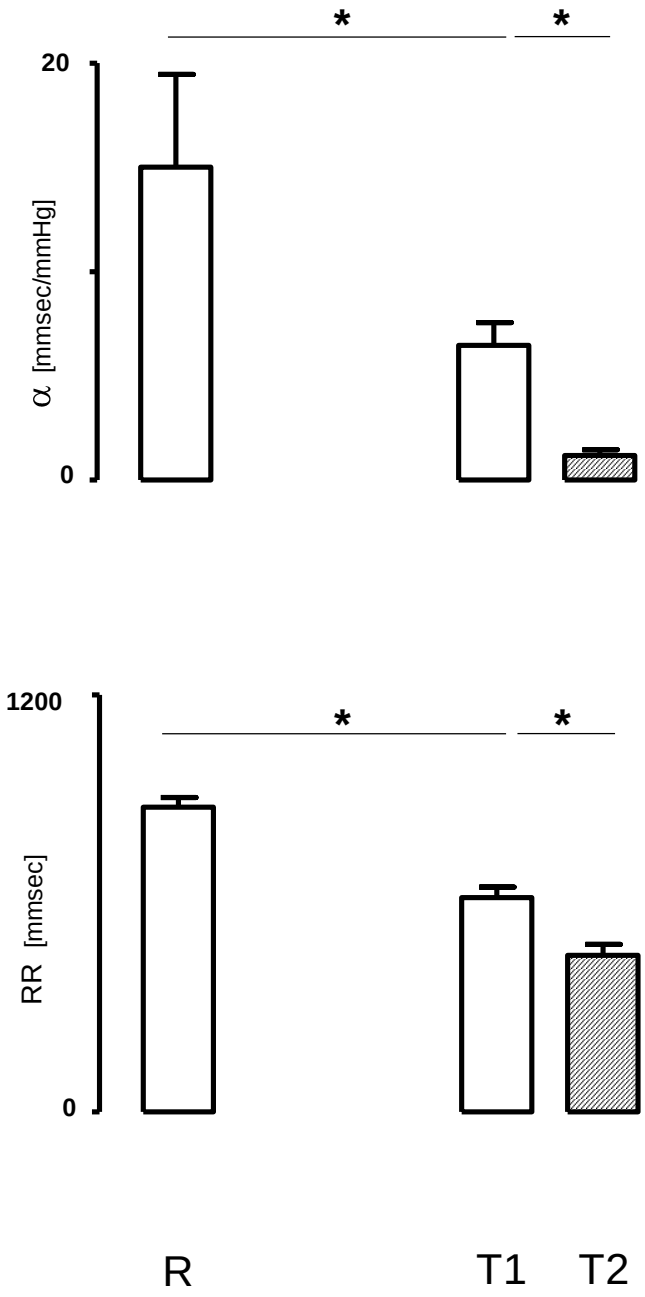
sBRS: BP and MSNA relationship

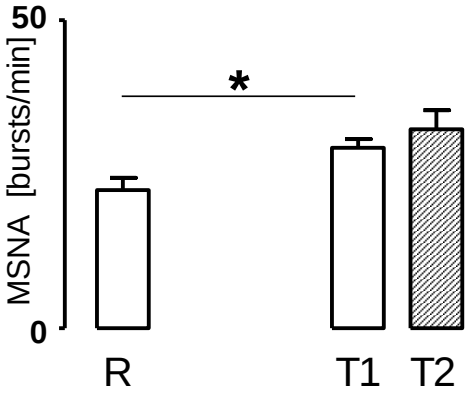


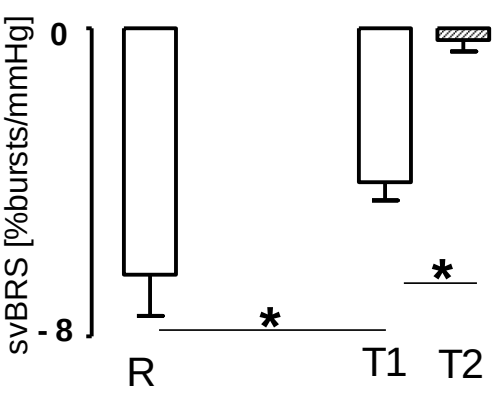
An acute decrease in BP causes an increase of MSNA burst rate, while an increase of BP leads to the reverse situation

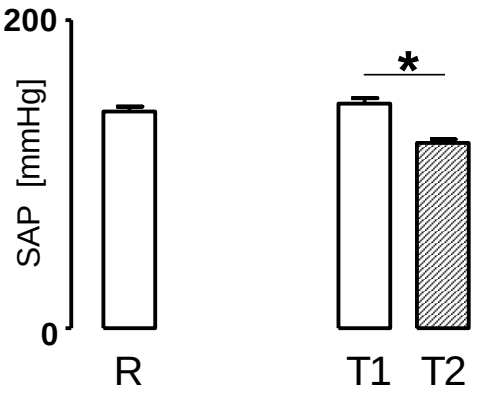


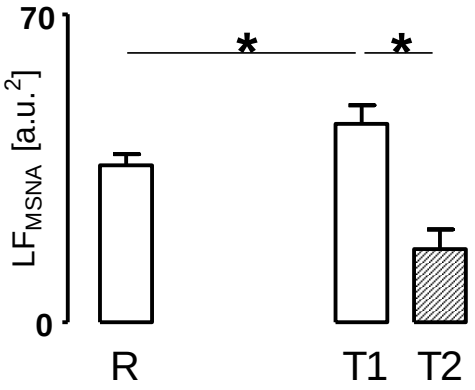
G. Sundlof and B. G. Wallin, J. Physiol., 274:621-637, 1978

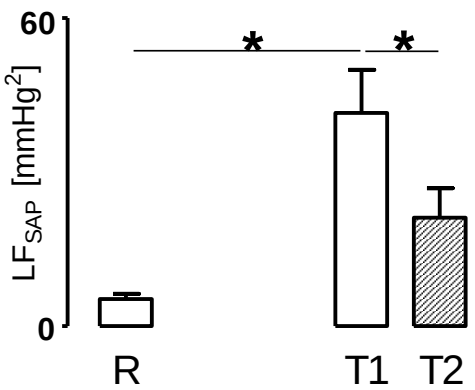

*
*
20
α [mmsec/mmHg]
0
1200
*
*
RR [mmsec]
0
R
T1
T2

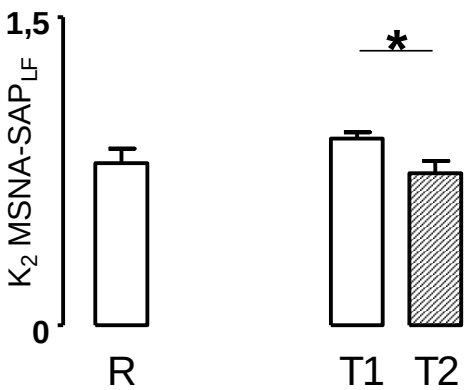

50
MSNA [bursts/min]
0
*
R
T1
T2

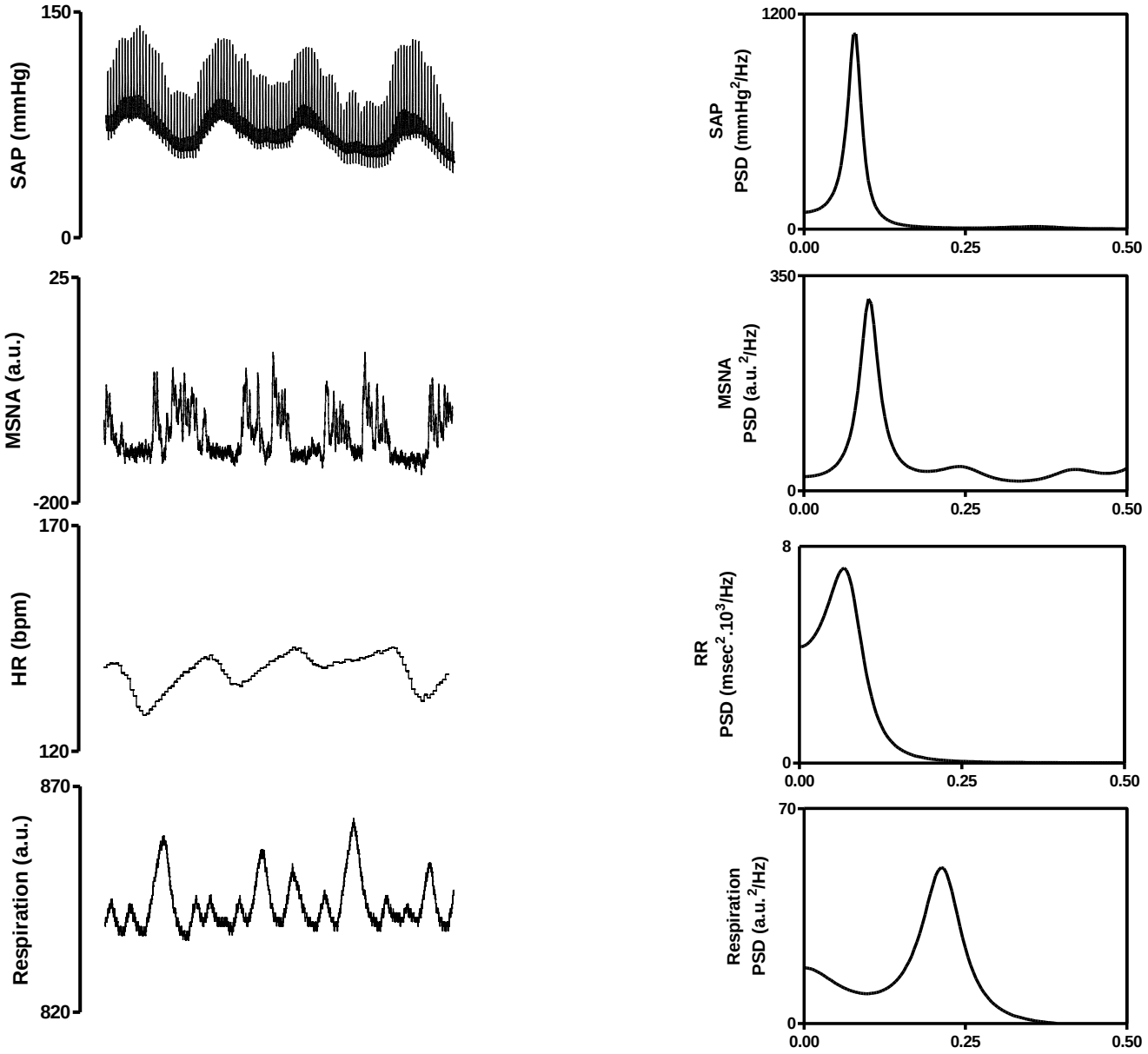

0
svBRS [%bursts/mmHg]
- 8
*
*
R
T1
T2


200
SAP [mmHg]
0
*
R
T1
T2

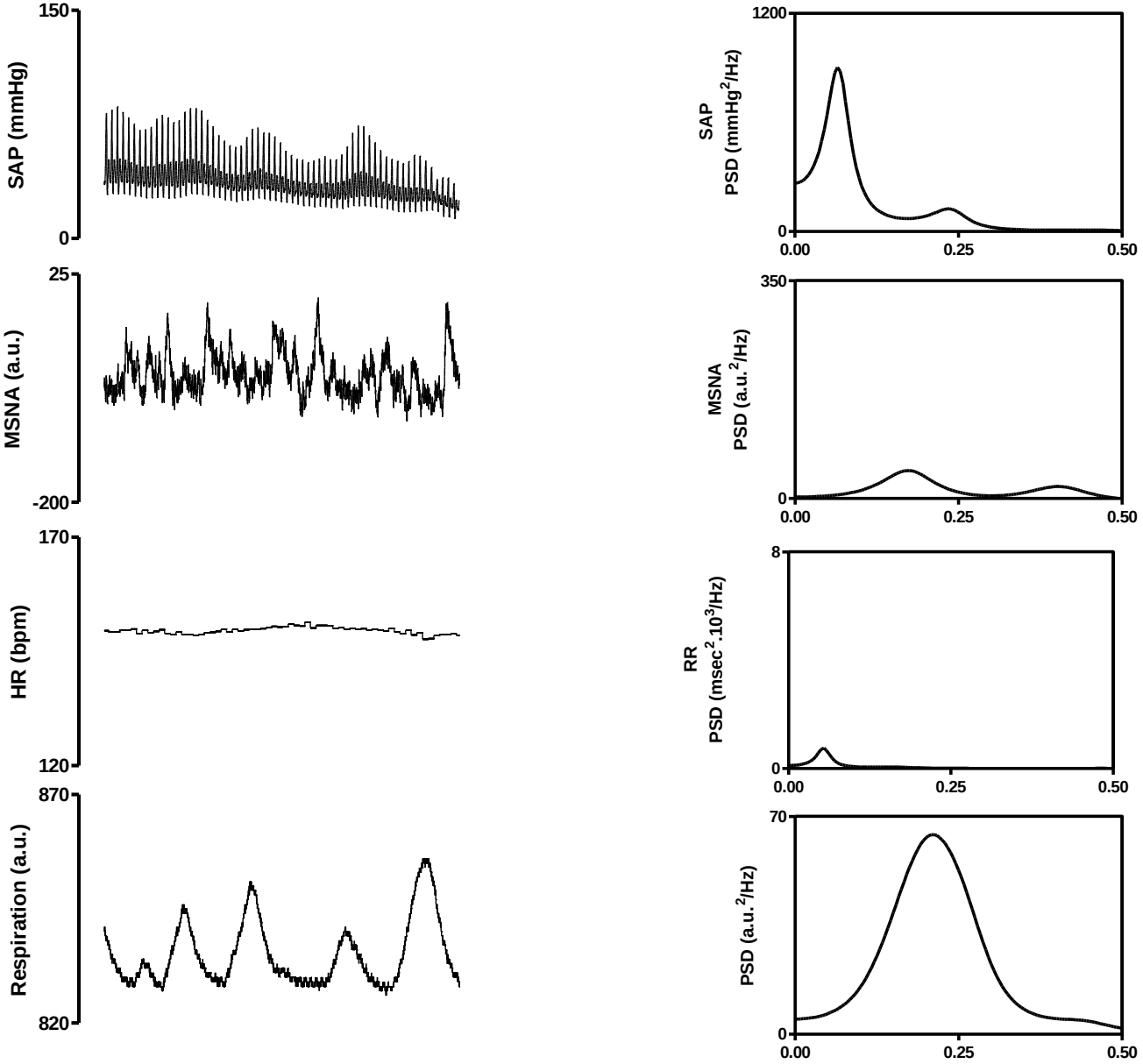

70
LF$_{MSNA}$ [a.u.^{2}]
0
*
*
R
T1
T2


60
LF$_{SAP}$ [mmHg^2]
0
*
*
R
T1
T2


1,5
K$_2$ MSNA-SAP$_{LF}$
0
*
R
T1
T2



Furlan et al Cardiovascular Rhythms in vasovagal syncope
Chapt 8, Vasovagal Syncope .Alboni and Furlan Eds. Springer 2015



Furlan et al Cardiovascular Rhythms in vasovagal syncope
Chapt 8, Vasovagal Syncope .Alboni and Furlan Eds. Springer 2015

SUMMARY

1. pre-syncope (T2) seems to be characterized by:
- reduced gain of cardiac (alpha index ↓) and vascular (svBRS) baroreceptor control
- reduced RR interval
- persistently high MSNA bursts/min (tonic)
- reduced SAP

2. During pre-syncope there is a loss of linear coupling between sympathetic vasomotor control (phasic) and the target organ (arterial vessels) response
- LF_{sap} ↓
- LF_{msna} ↓
- K_2 $LF_{MSNA\text{-}SAP}$ ↓

CONCLUSIONS

- A common oscillatory pattern at about 0.1 Hz can be detected from the variability of the sympathetic outflow and the cardiovascular target functions (vessels and heart) in healthy subjects with preserved orthostatic tolerance
- A baroreflex mediated high linear coupling among spontaneous fluctuations in HR, SAP and post-ganglionic neural sympathetic discharge activity, organized after a 0.1 Hz rhythm, characterizes a proper orthostatic tolerance
- A baroreceptor mediated reduced coupling at 0.1 Hz in the MSNA and SAP variability is associated with the onset of pre-syncope