HRV and MEASUREMENT OF THE ARTERIAL BAROREFLEX

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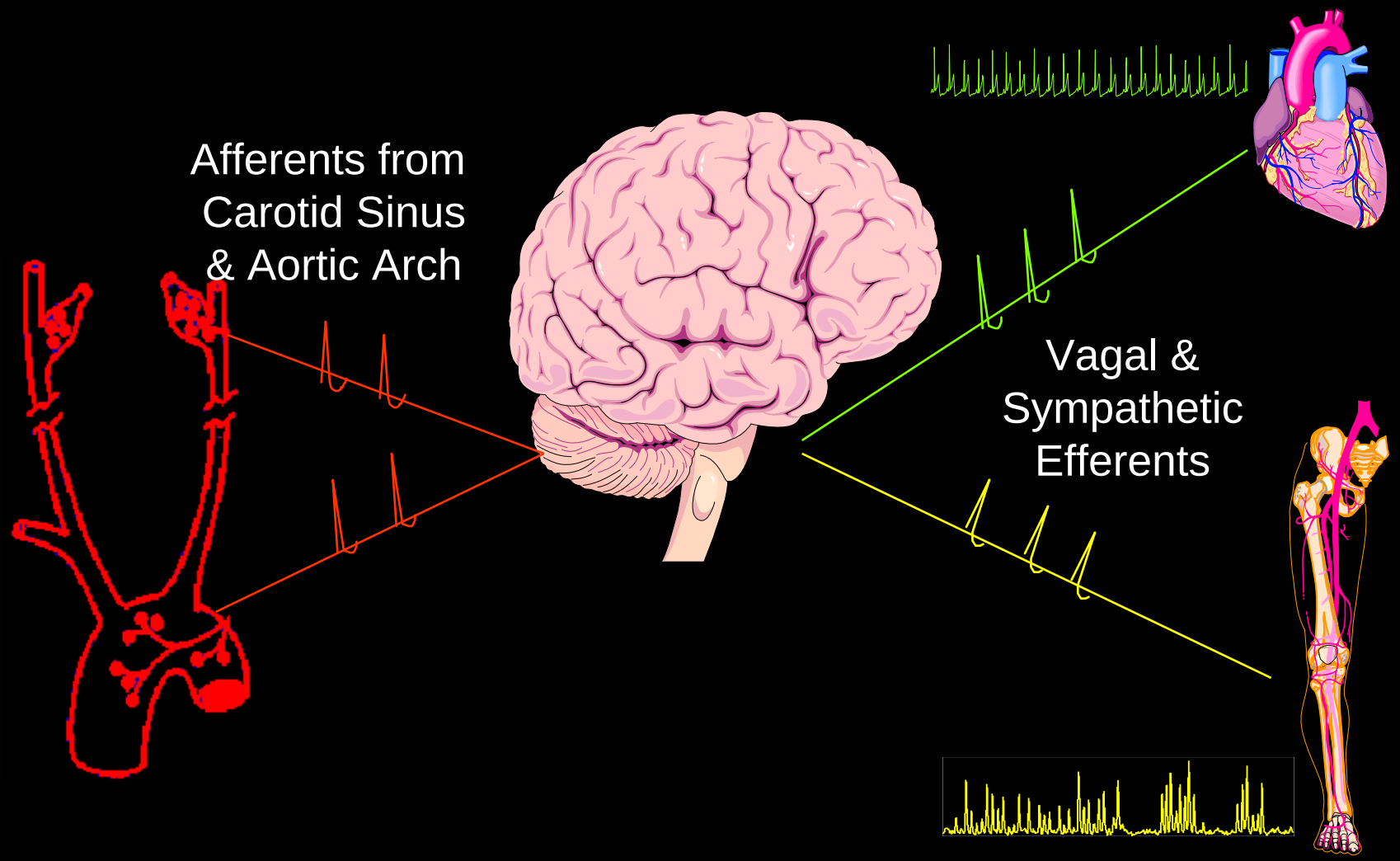
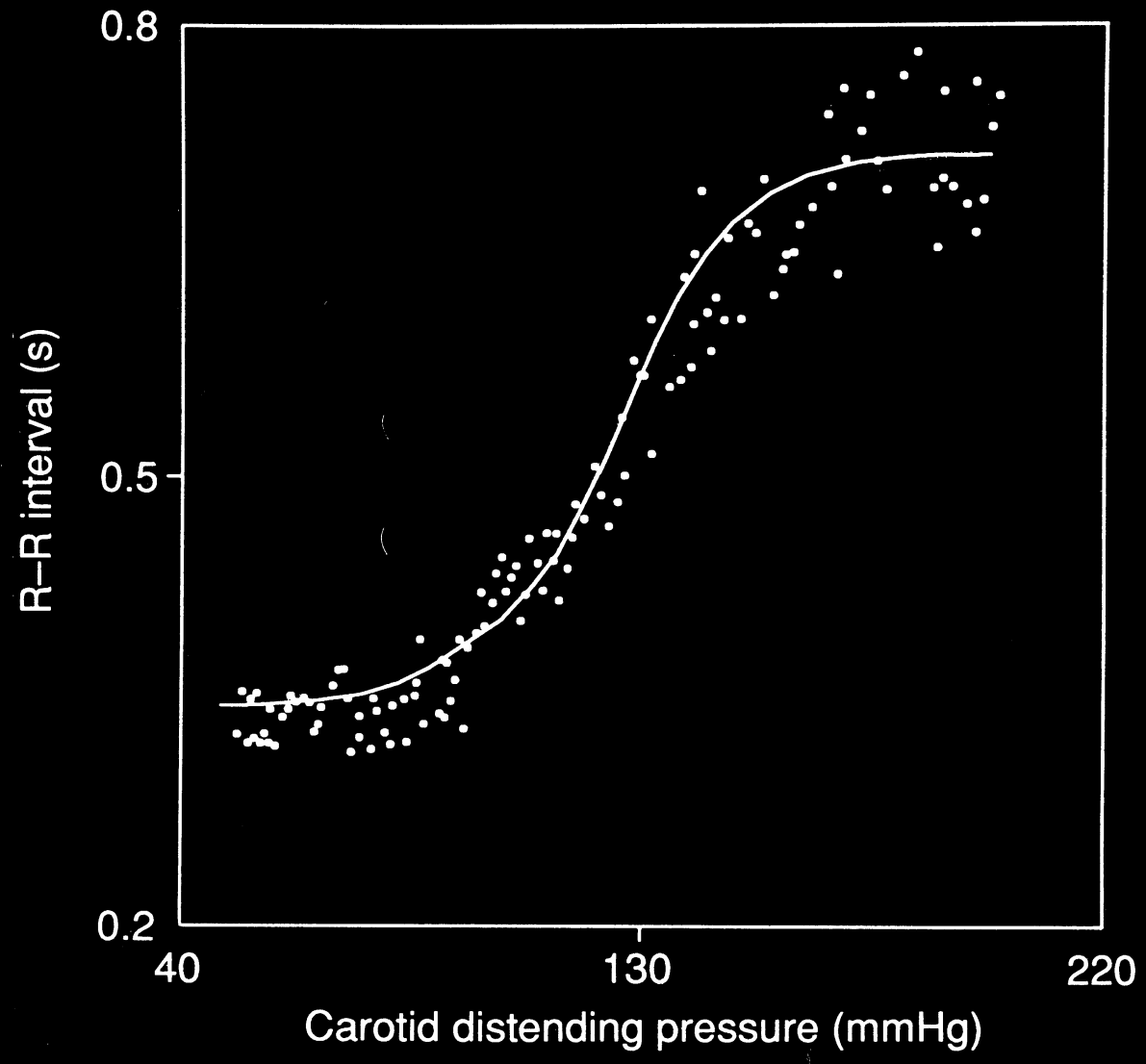
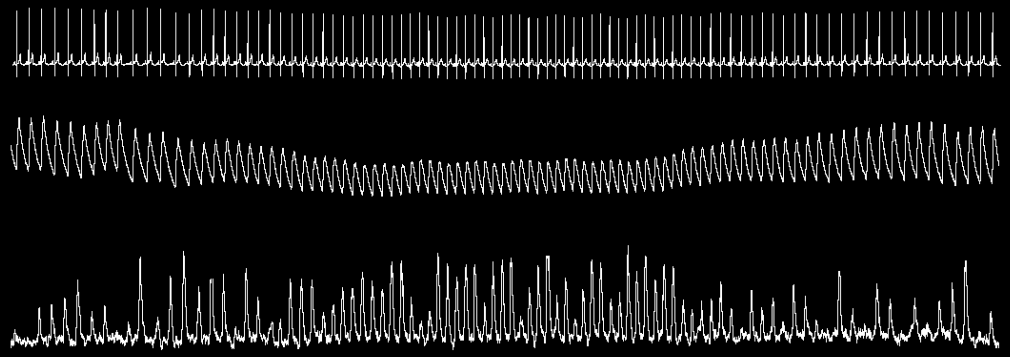
Arterial Baroreflex Control of Blood Pressure

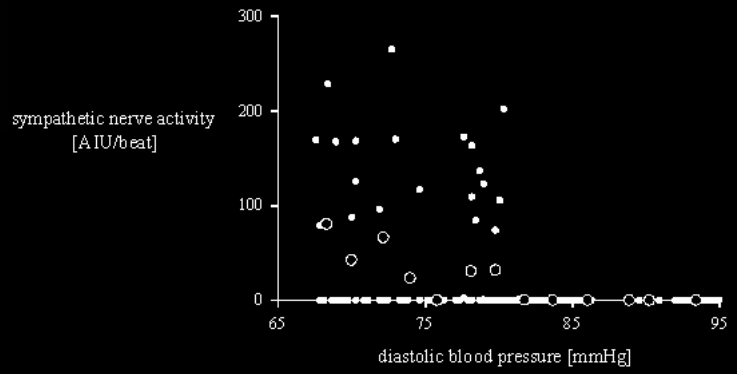


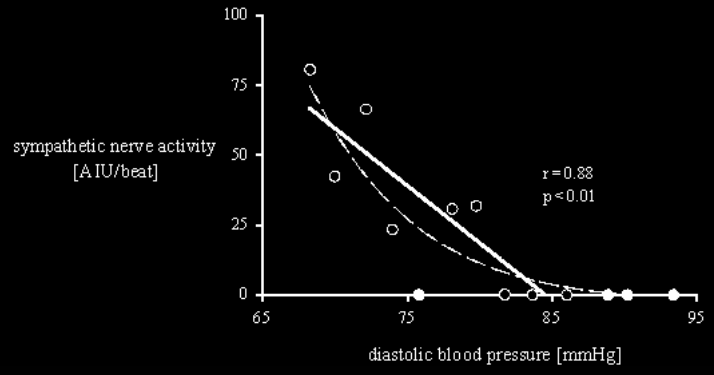
Koch's *Blutdruckcharacteristik*, 1931



Muscle Sympathetic Activity in Response to Pressure Changes in a Human, 2006







BAROREFLEX ASSESSMENTS IN HUMANS

Physical

Valsalva's Maneuver

Neck Suction

Pharmacologic

Steady-state Infusions

Oxford Phenylephrine Bolus

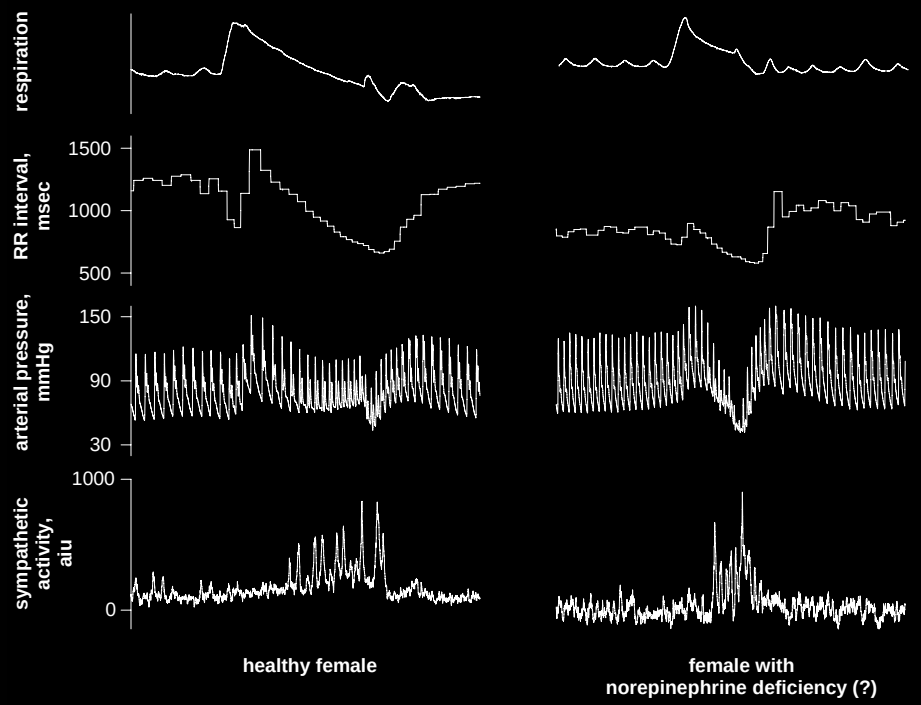
Modified Oxford Nitroprusside/Phenylephrine Boluses

Inferential

Spectral

Sequence

Studying Blood Pressure Control in Man: Valsalva's Maneuver



"If the glottis be closed after a deep inspiration, and a strenuous and prolonged expiratory effort be then made, such pressure can be exerted upon the heart and intrathoracic vessels that the movement and flow of the blood are temporarily arrested."
Antonio Maria Valsalva (1666-1723)

Studying Blood Pressure Control in Man: Neck Suction

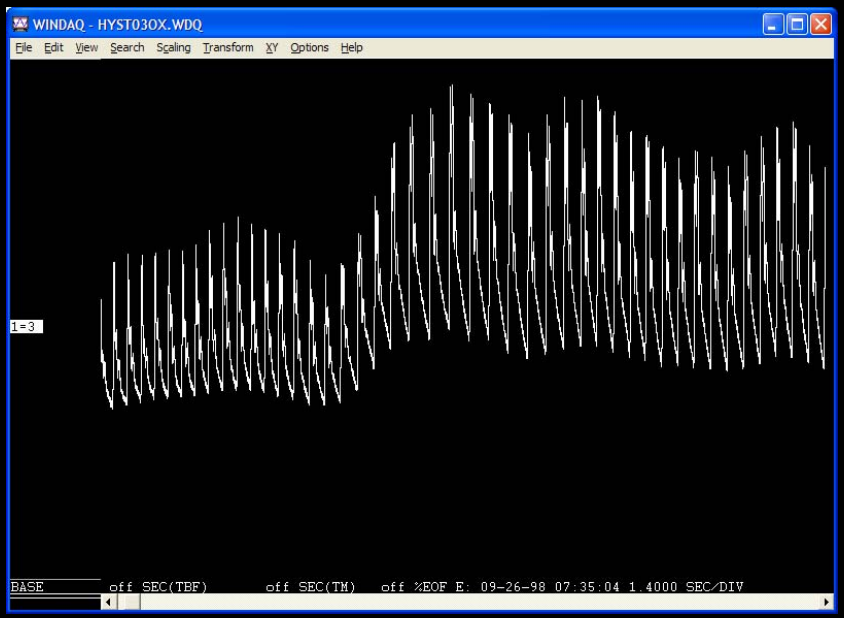
Some Observations on the Effects of Stimulating the Stretch Receptors in the Carotid Artery of Man.
Ernsting, Parry. *Journal of Physiology*, 1957

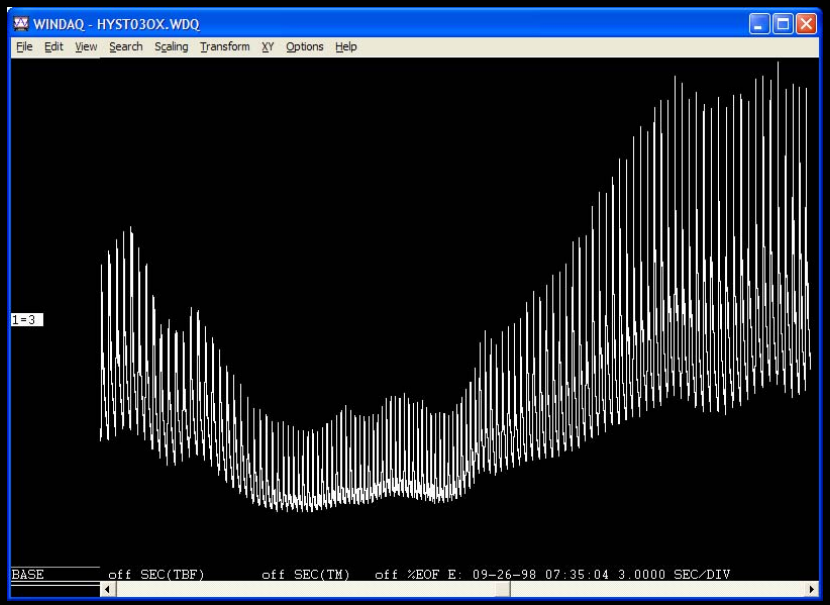
Spaceflight Alters Autonomic Regulation of Arterial Pressure in Humans.
Fritsch-Yelle et al. *Journal of Applied Physiology*, 1994

A Simplified Paired Neck Chamber for the Demonstration of Baroreflex Blood Pressure Regulation.
Raine, Cable. *Advances in Physiology Education*, 1999

Studying Blood Pressure Control in Man: Pharmacologic Approaches

Reflex Regulation of Arterial Pressure During Sleep in Man. A quantitative method of assessing baroreflex sensitivity. Smyth, Sleight, Pickering. *Circulation Research*, 1969

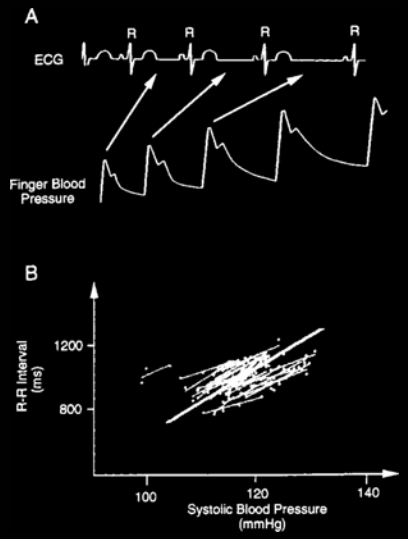




Inhibition of Sympathetic Neural Outflow During Thiopental Anesthesia in Humans. Ebert, Kanitz, Kampine. *Anesthesia and Analgesia*, 1990

Studying Blood Pressure Control in Man: ‘Spontaneous’ Baroreflex Indices

Spontaneous Cardiac Baroreflex in Humans. Comparison with Drug-Induced Responses.
Parlow, et al. *Hypertension*, 1995



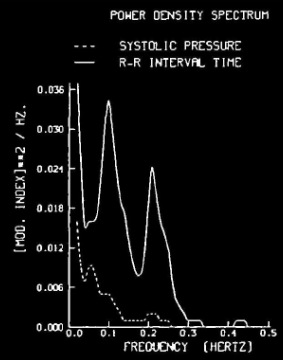


FIGURE 3. *Power density spectra of systolic blood pressure values and RR interval signals. Fluctuations are expressed as a fraction of the mean value, and the vertical scale is the squared modulation index × seconds.*

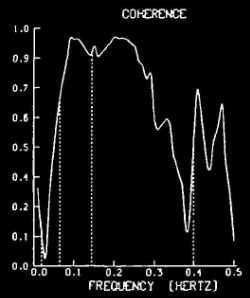


FIGURE 4. *Coherence function for the linear relation between systolic pressure and RR interval time. Vertical lines indicate the boundaries of the frequency bands as described in Subjects and Methods.*

Comparison Between Noninvasive Indices of Baroreceptor Sensitivity and the Phenylephrine Method in Post-Myocardial Infarction Patients.
Pitzalis, et al. *Circulation,* 1998

ADVANTAGES/DISADVANTAGES OF PHYSICAL ASSESSMENTS IN HUMANS

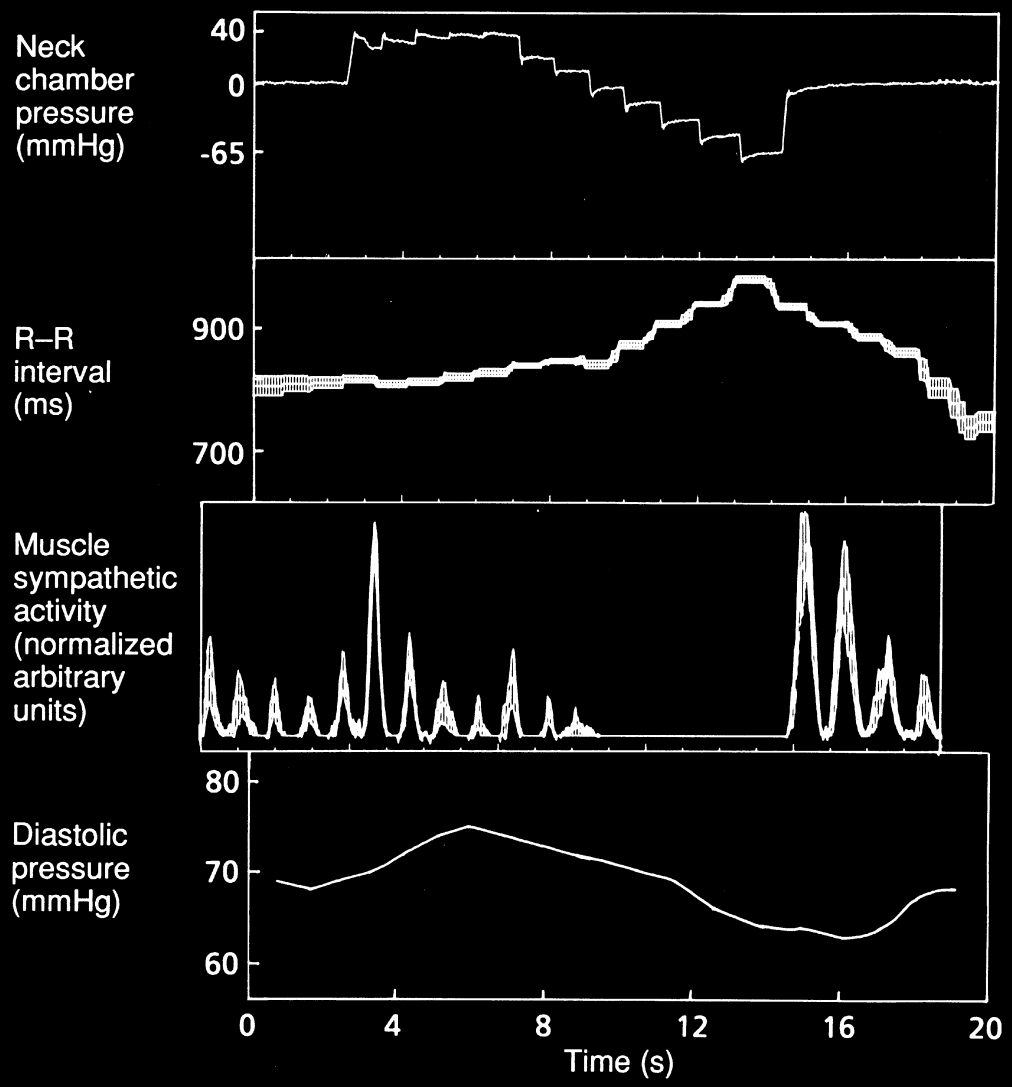
ADVANTAGES

- Noninvasive
- Ease of repeated trials
- Can generate full sigmoid relation (i.e., neck suction)

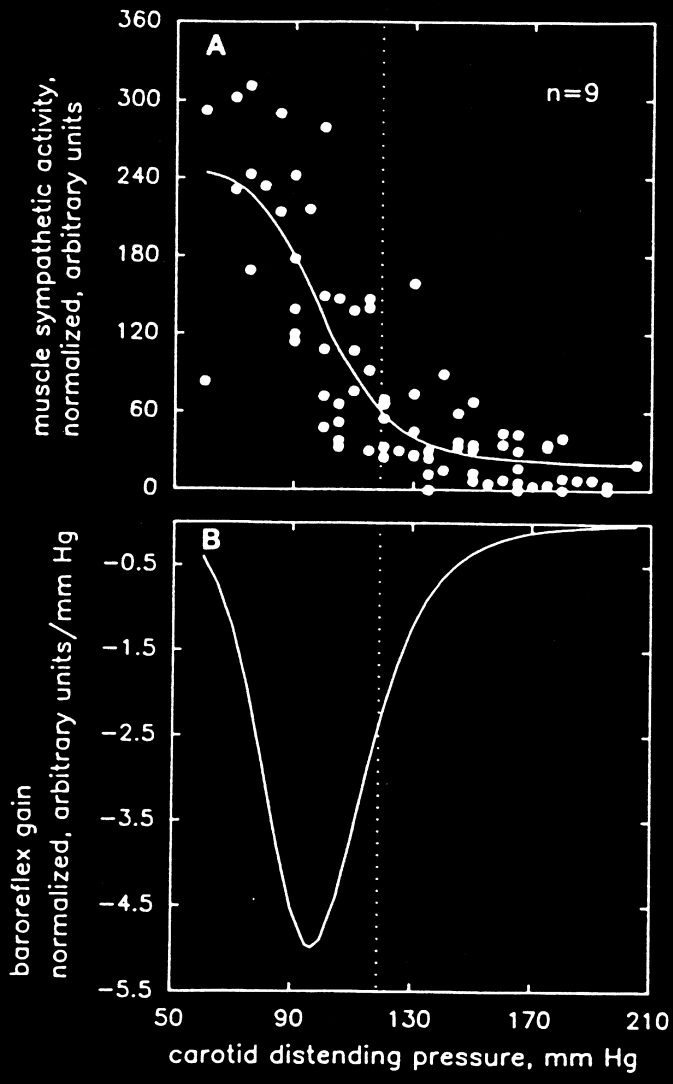
DISADVANTAGES

- Obtrusive
- Few data points
- Difficult to assess vascular sympathetic limb

SYMPATHETIC RESPONSES TO NECK SUCTION



from Fritsch et al., Am. J. Physiol. 1991



from Rea & Eckberg, Am. J. Physiol. 1987

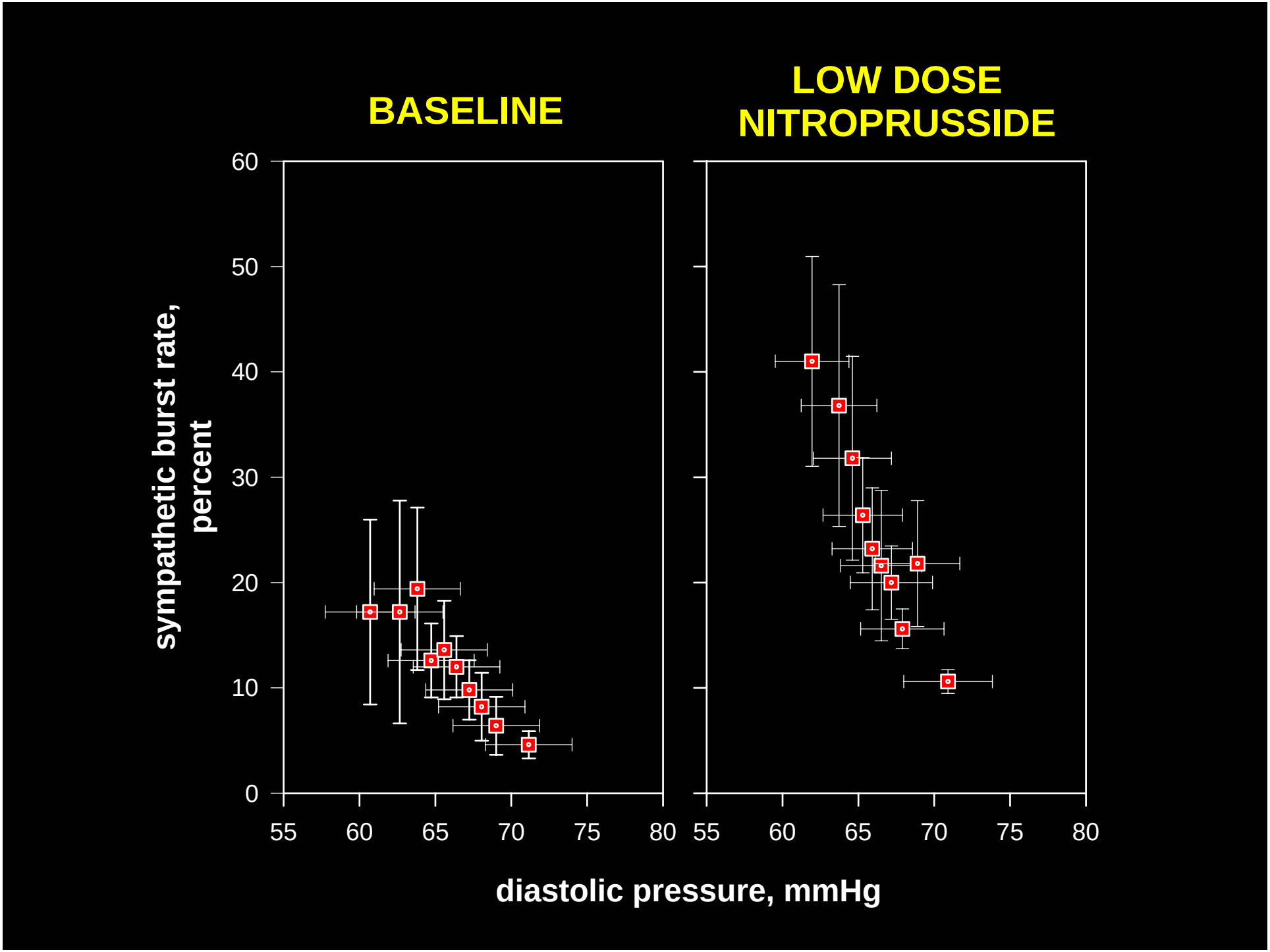
ADVANTAGES/DISADVANTAGES OF PHARMACOLOGIC ASSESSMENTS

ADVANTAGES

- Driving pressure to generate response
- Can produce wide range of pressure input
- Drugs are widely available & accepted for use

DISADVANTAGES

- Invasive
- Possible extra-vascular effects
- Adaptation to stimulus (e.g., steady-state infusion)


BASELINE
LOW DOSE
NITROPRUSSIDE
sympathetic burst rate,
percent
0
10
20
30
40
50
60
55
60
65
70
75
80
55
60
65
70
75
80
diastolic pressure, mmHg

ADVANTAGES/DISADVANTAGES OF INFERENTIAL ASSESSMENTS IN HUMANS

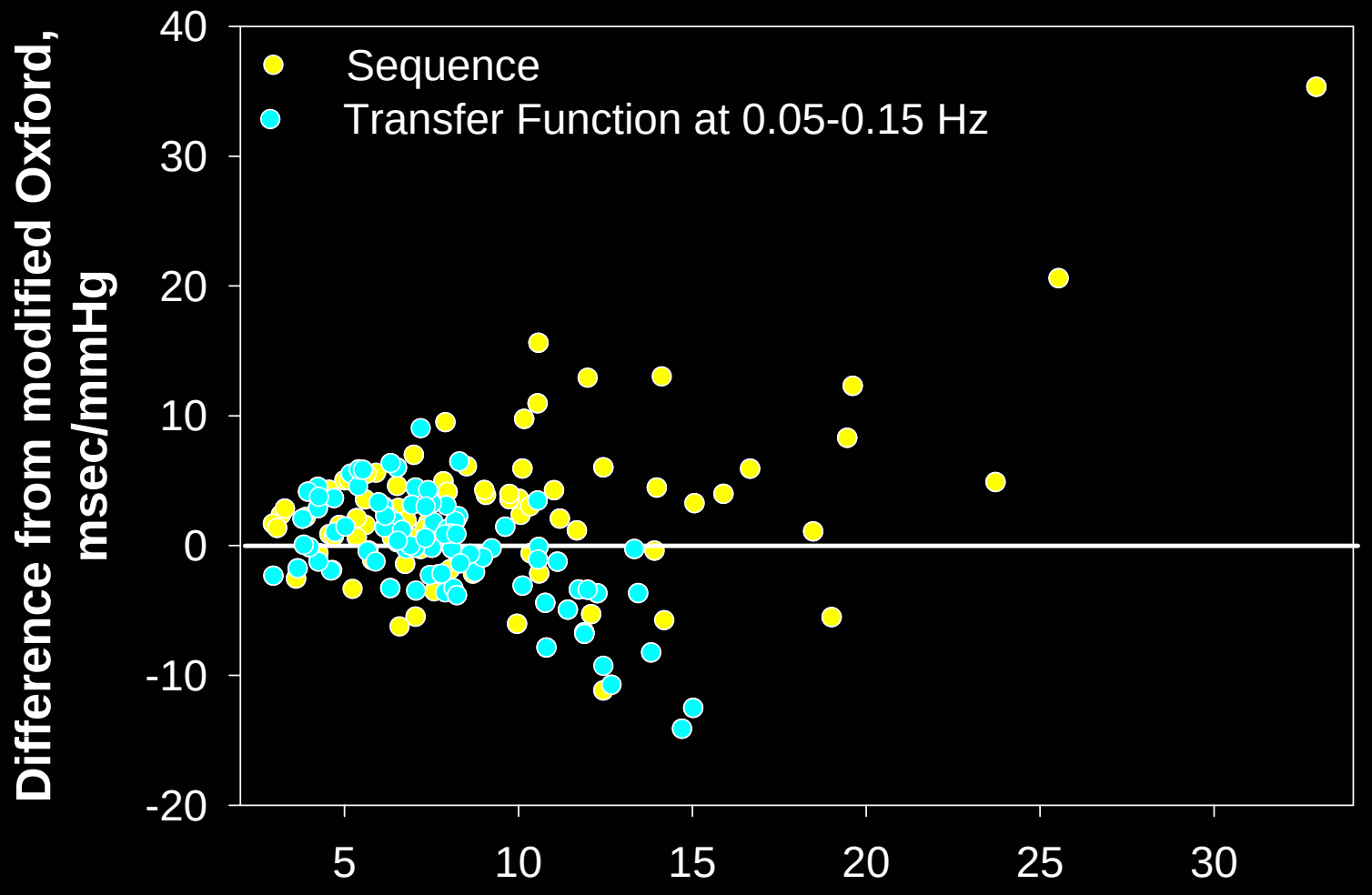
ADVANTAGES

- Noninvasive
- Unobtrusive
- Convenient

DISADVANTAGES

- Small input range
- Observational
- Baroreflex role unclear

BLAND-ALTMAN COMPARISON



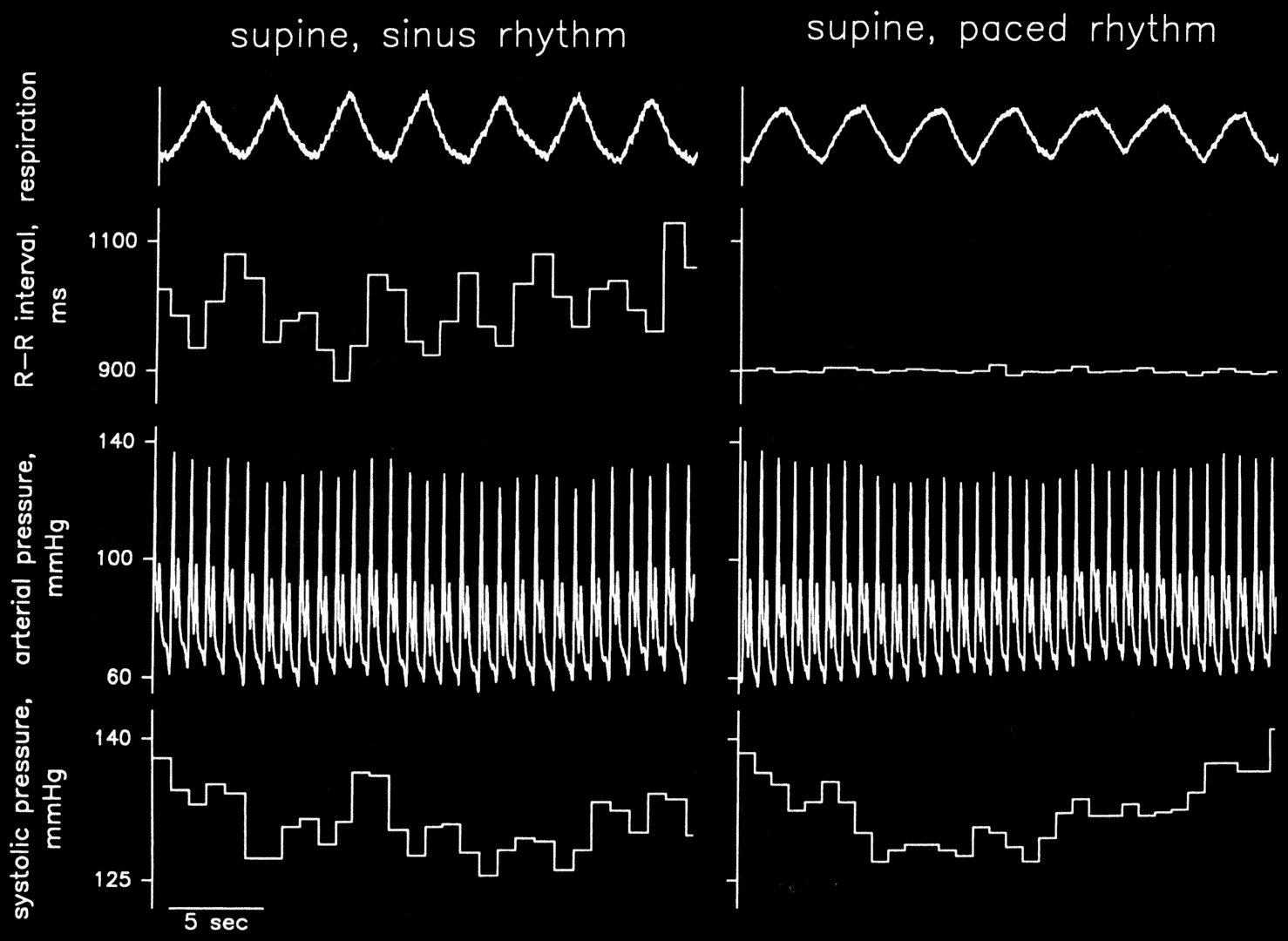
Testing the Link Between Pressure and Heart Rate Oscillations

The role of the heart in buffering blood pressure fluctuations

Taylor, Eckberg.
Circulation, 1996

Hamner, Morin, Rudolph, Taylor.
Journal of Applied Physiology, 2001

FUNDAMENTAL RELATIONS BETWEEN SHORT-TERM R-R INTERVAL AND ARTERIAL PRESSURE OSCILLATIONS IN HUMANS.
Taylor, Eckberg. *Circulation*, 1996



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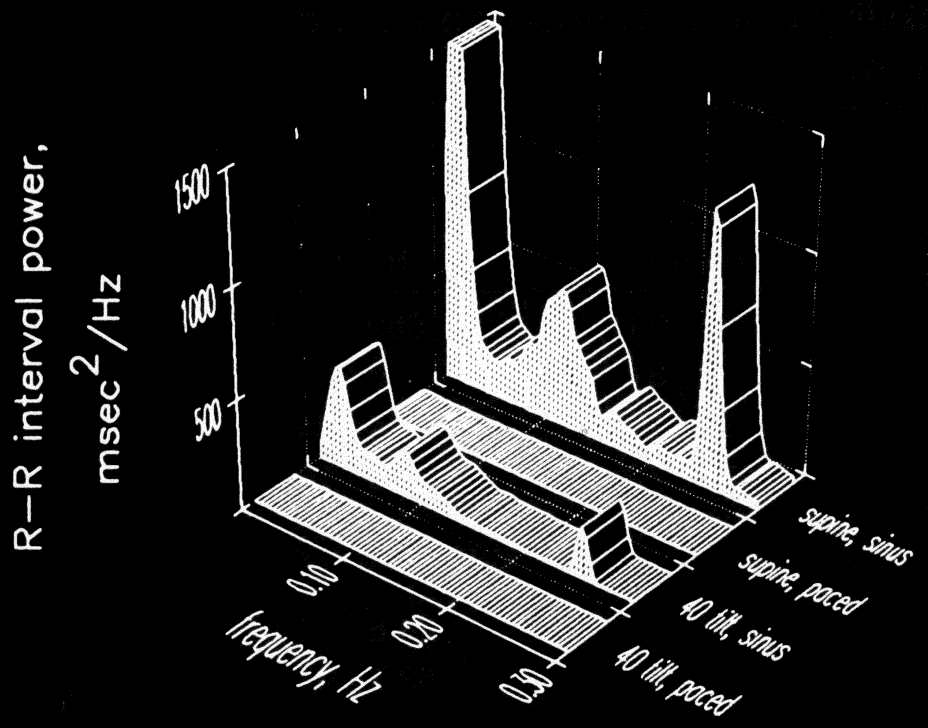
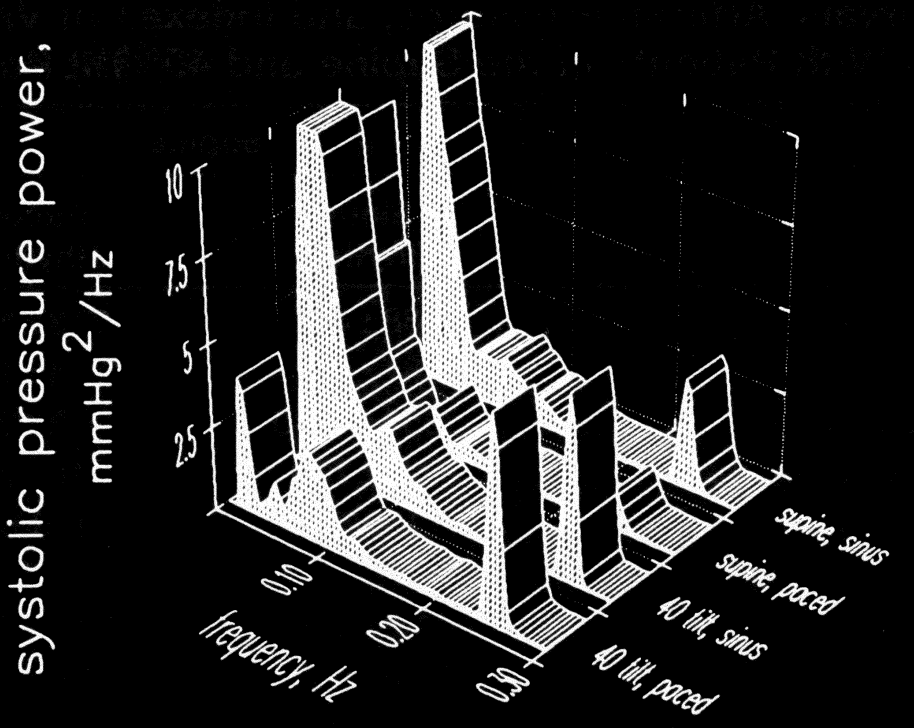
Taylor, Eckberg. *Circulation*, 1996





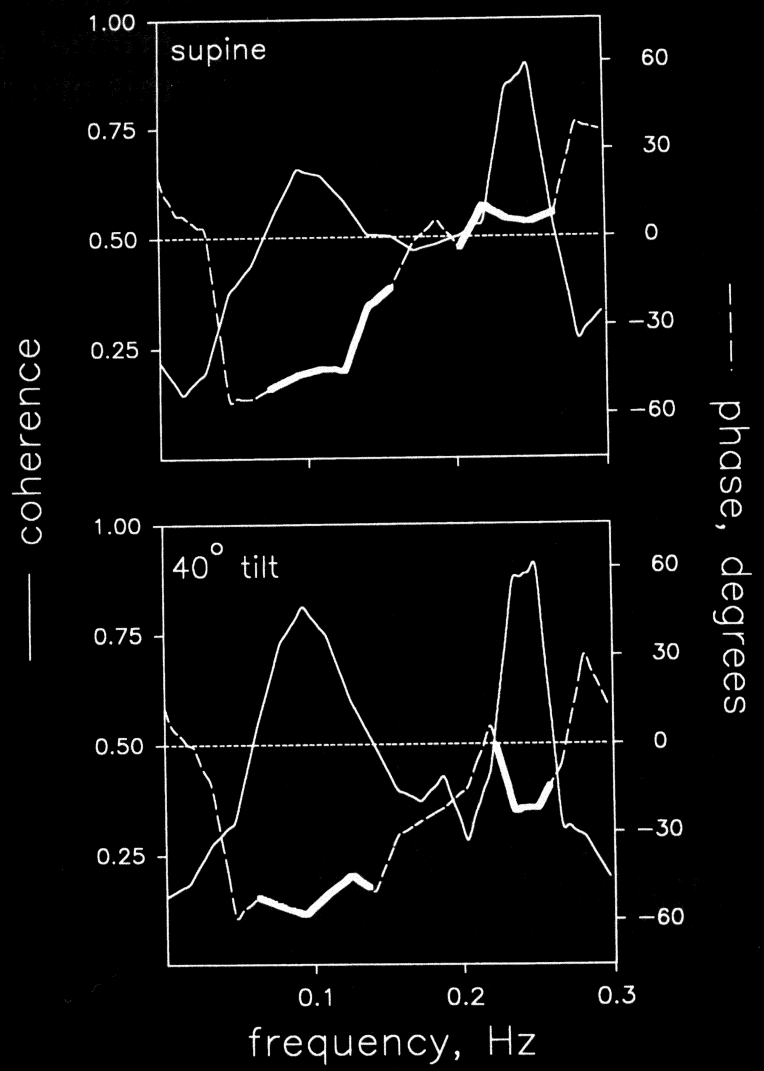
FUNDAMENTAL RELATIONS BETWEEN SHORT-TERM R-R INTERVAL AND ARTERIAL PRESSURE OSCILLATIONS IN HUMANS.
Taylor, Eckberg. *Circulation*, 1996

Average RR Intervals, Arterial Pressures, and Indexes of Variability During Sinus and Paced Cardiac Rhythm With Patients in the Supine and 40° Tilt Positions

	Supine		40° Tilt	
	Sinus Rhythm	Paced Rhythm	Sinus Rhythm	Paced Rhythm
RR interval, ms	988±42	772±34*	813±34†	659±22*†
SD, ms	67±5	4±1*	39±3†	6±2*
Low-frequency power, ms^2	3853±1210	8±2*	1190±157†	44±26*
Respiratory-frequency power, ms^2	2995±726	10±2*	422±72†	30±18*
Arterial pressure, mm Hg	139/66	139/68	127/68	131/73
Low-frequency power, mm Hg^2				
Systolic pressure	11.3±3.0	10.5±2.1	19.4±3.0†	24.6±5.2†
Diastolic pressure	21.0±5.2	21.6±4.2	29.9±4.3†	58.7±9.1*†
Respiratory-frequency power, mm Hg^2				
Systolic pressure	6.8±1.8	2.9±0.6*	8.0±1.8	10.8±2.6*†
Diastolic pressure	3.0±0.4	2.3±0.4*	3.9±1.0	8.0±1.8*†

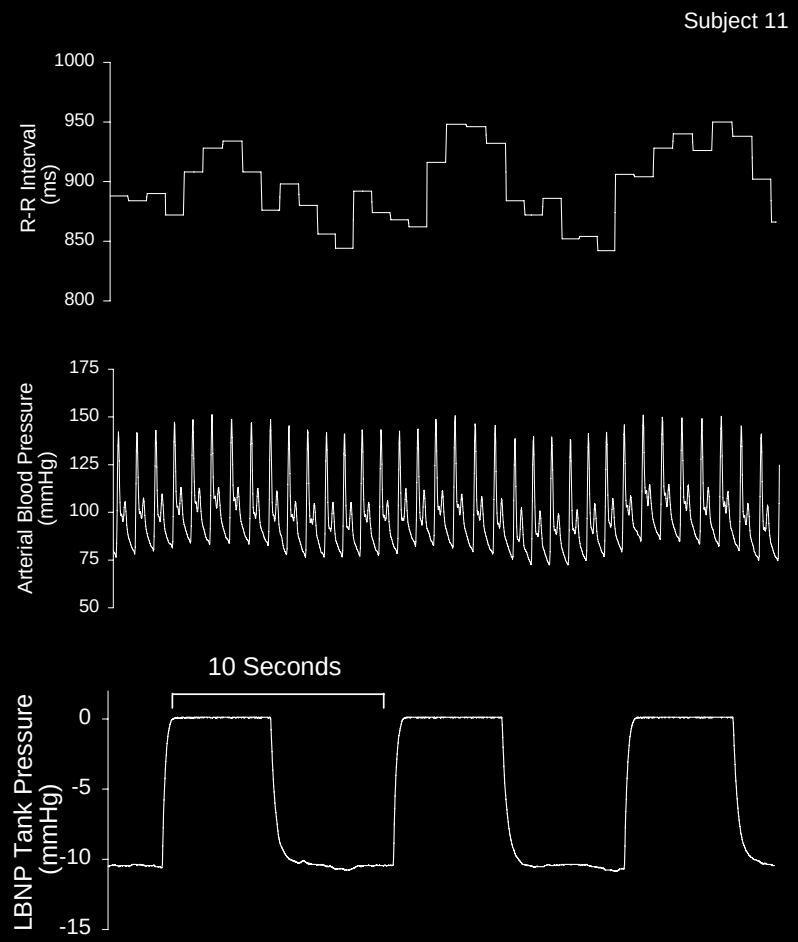
*$P<.05$ vs sinus rhythm.
†$P<.05$ vs supine position.

FUNDAMENTAL RELATIONS BETWEEN SHORT-TERM R-R INTERVAL AND ARTERIAL PRESSURE OSCILLATIONS IN HUMANS.
Taylor, Eckberg. *Circulation*, 1996



INCONSISTENT LINK BETWEEN BETWEEN LOW FREQUENCY OSCILLATIONS: R-R INTERVAL RESPONSES TO AUGMENTED MAYER WAVES.

Hamner, et al. *Journal of Applied Physiology*, 2001



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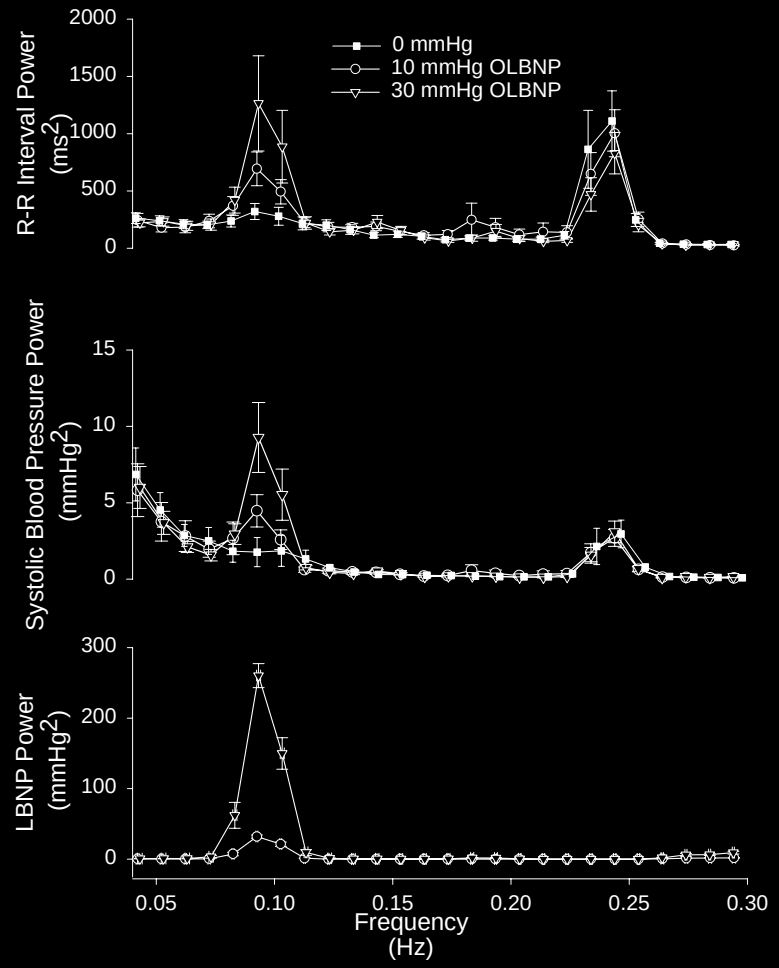

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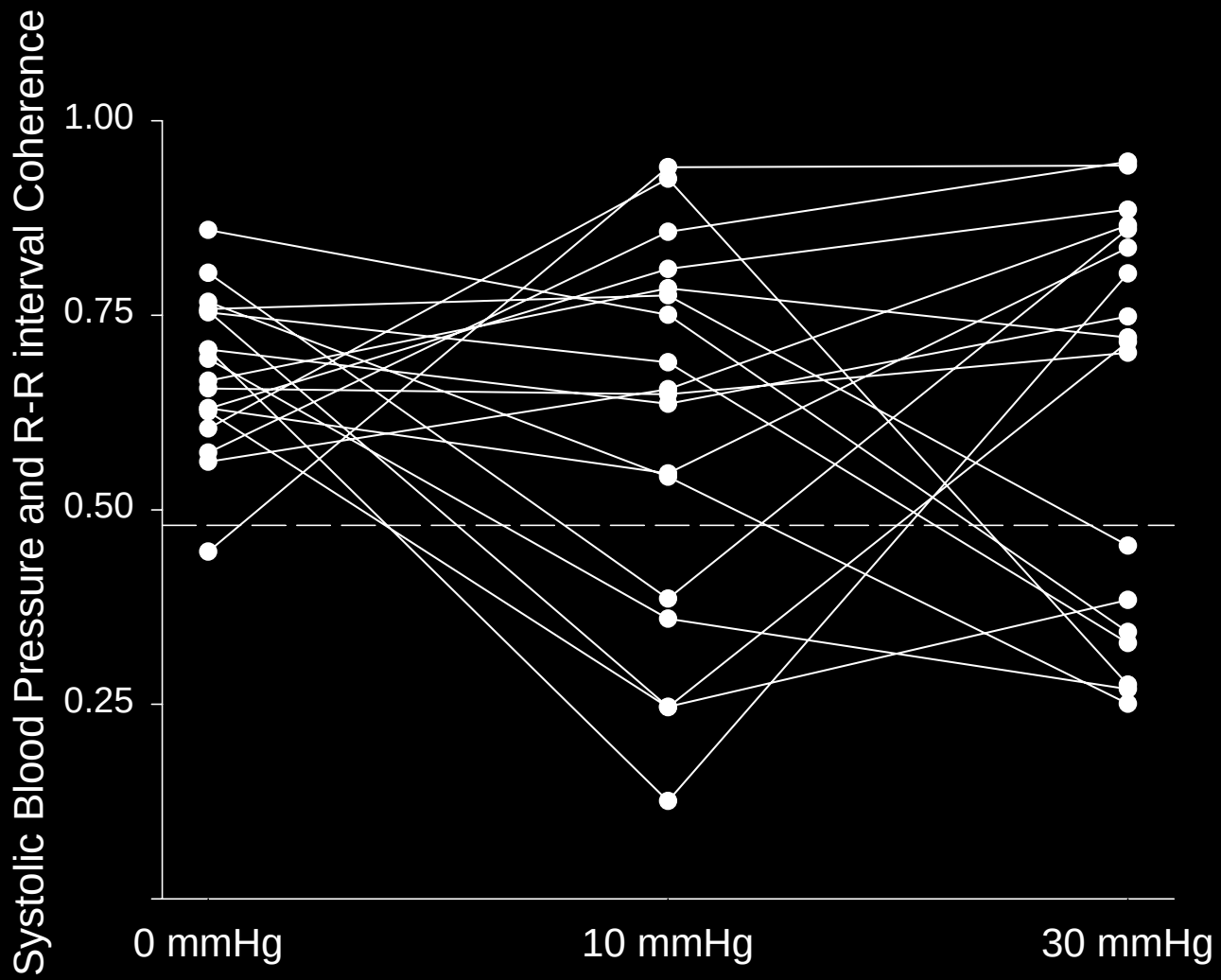

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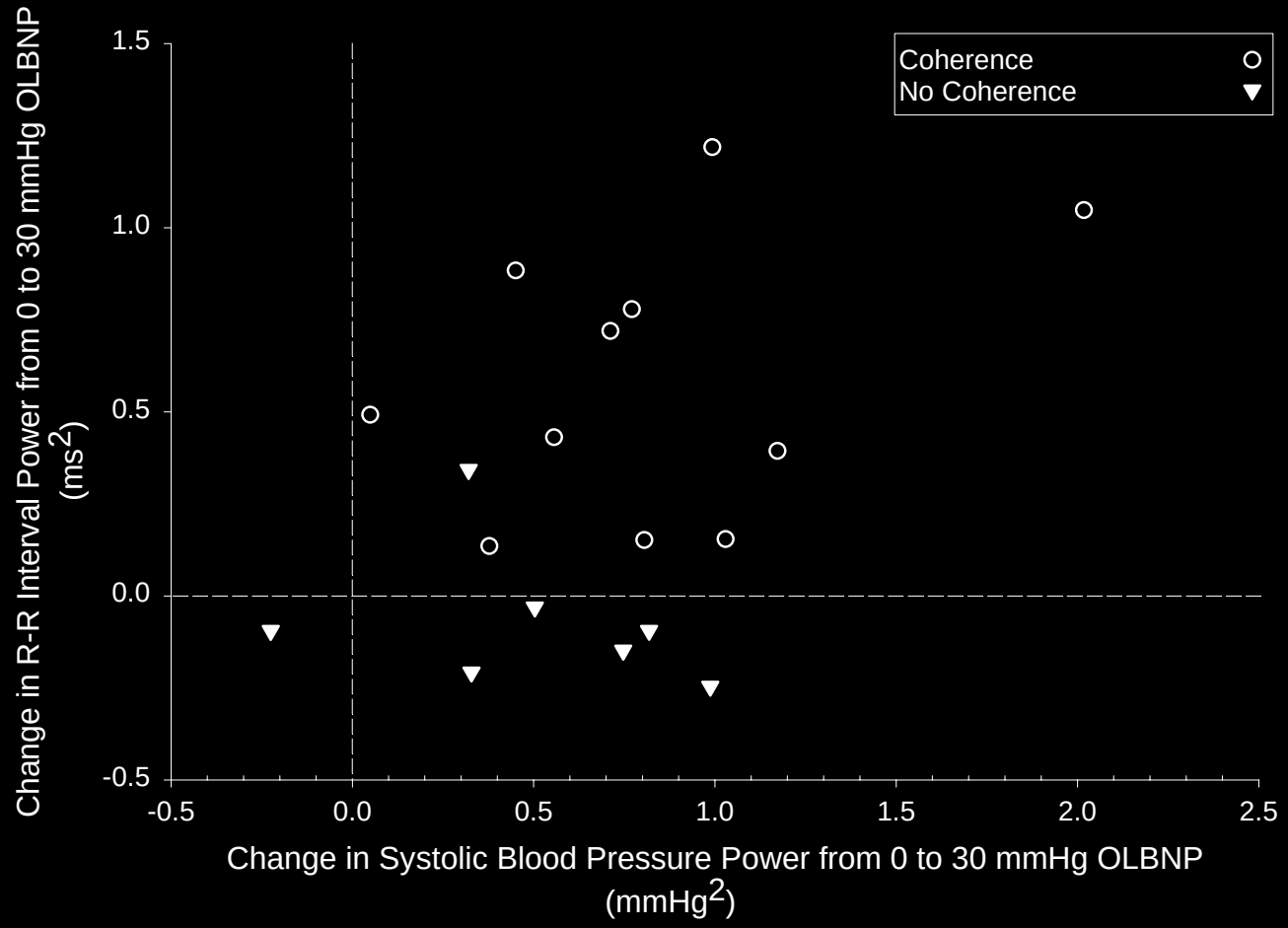


Validating ‘Spontaneous’ Baroreflex Estimates

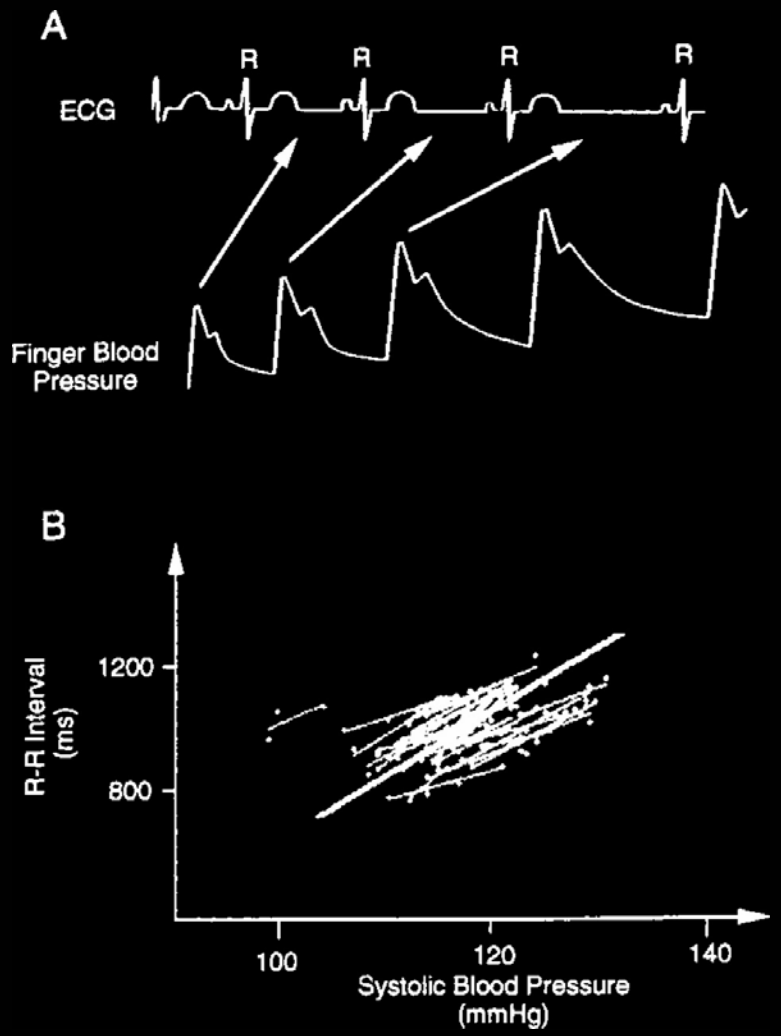
The relationship of ‘spontaneous’ indices to directly measured gain and carotid vascular distensibility

Lipman, Salisbury, Taylor.
Hypertension, 2003

SPONTANEOUS CARDIAC BAROREFLEX IN HUMANS COMPARISON WITH DRUG-INDUCED RESPONSES.

Parlow, et al. *Hypertension*, 1995

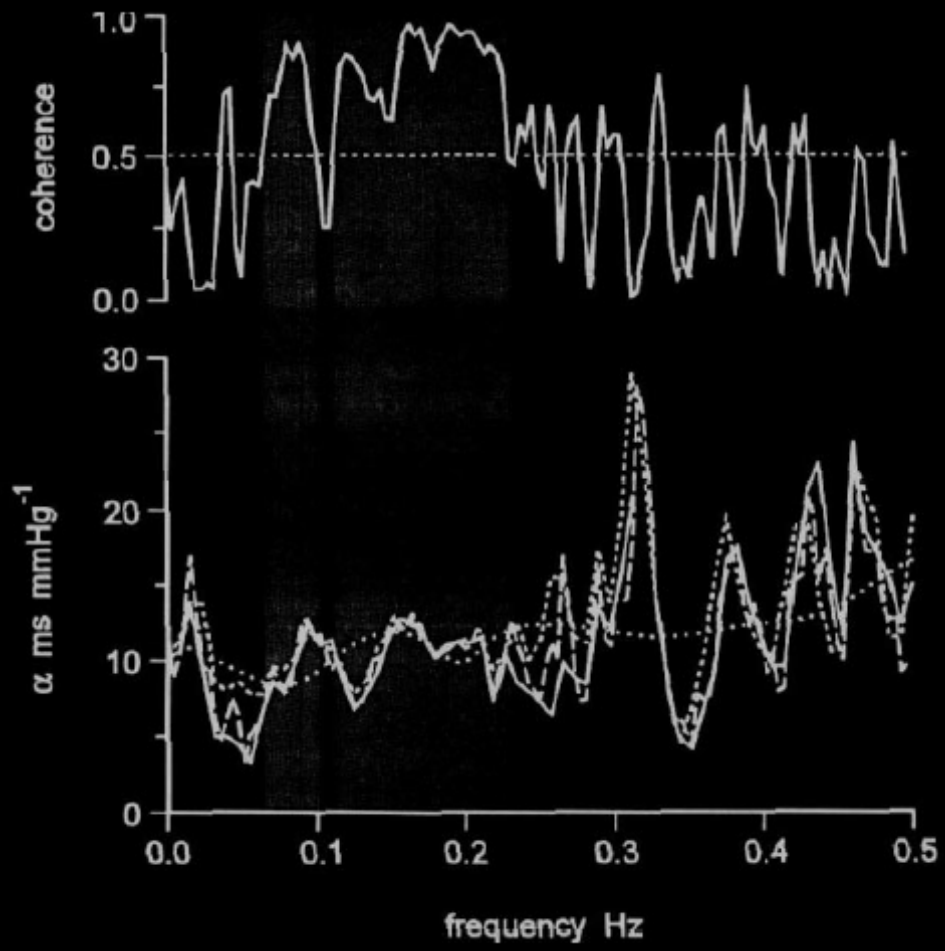
A linear regression was applied to all sequences of three or more successive heart beats in which there were concordant increases or decreases in systolic BP and RR interval, and an average regression slope was calculated for the sequences detected during each recording period.



MEASUREMENT OF BAROREFLEX GAIN FROM HEART RATE AND BLOOD PRESSURE SPECTRA: A COMPARISON OF SPECTRAL ESTIMATION TECHNIQUES

Clayton, et al. Physiol. Meas. 1995

Transfer function gain alpha was calculated from the ratio of RR interval and blood pressure amplitude spectra. Estimates of alpha at frequencies for which the coherence function of RR interval and blood pressure evaluated either from the FFT or from the zero-padded FFT spectra was less than 0.5 were excluded from further analysis.



COMPARISON BETWEEN NONINVASIVE INDICES OF BARORECEPTOR SENSITIVITY AND THE PHENYLEPHRINE METHOD IN POST-MYOCARDIAL INFARCTION PATIENTS.

Pitzalis, et al. *Circulation,* 1998

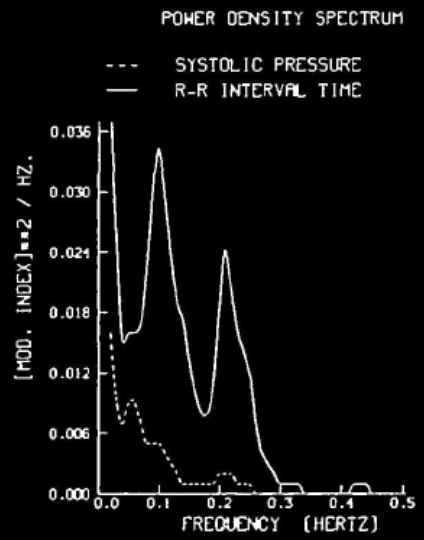


FIGURE 3. *Power density spectra of systolic blood pressure values and RR interval signals. Fluctuations are expressed as a fraction of the mean value, and the vertical scale is the squared modulation index × seconds.*

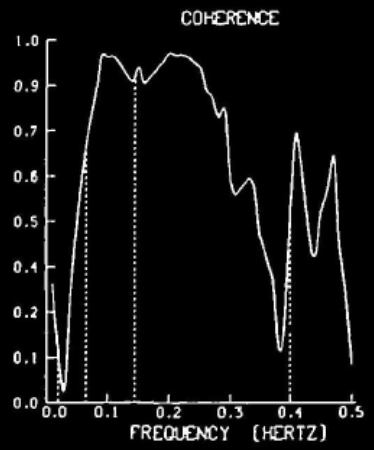
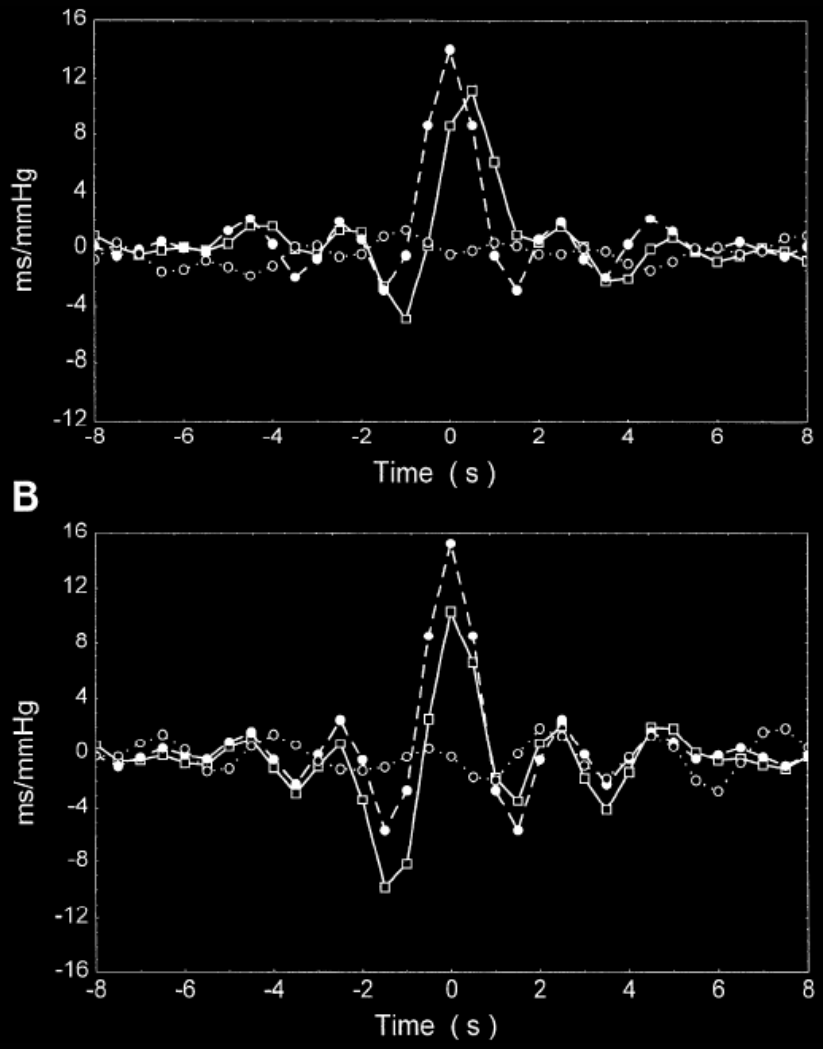


FIGURE 4. *Coherence function for the linear relation between systolic pressure and RR interval time. Vertical lines indicate the boundaries of the frequency bands as described in Subjects and Methods.*

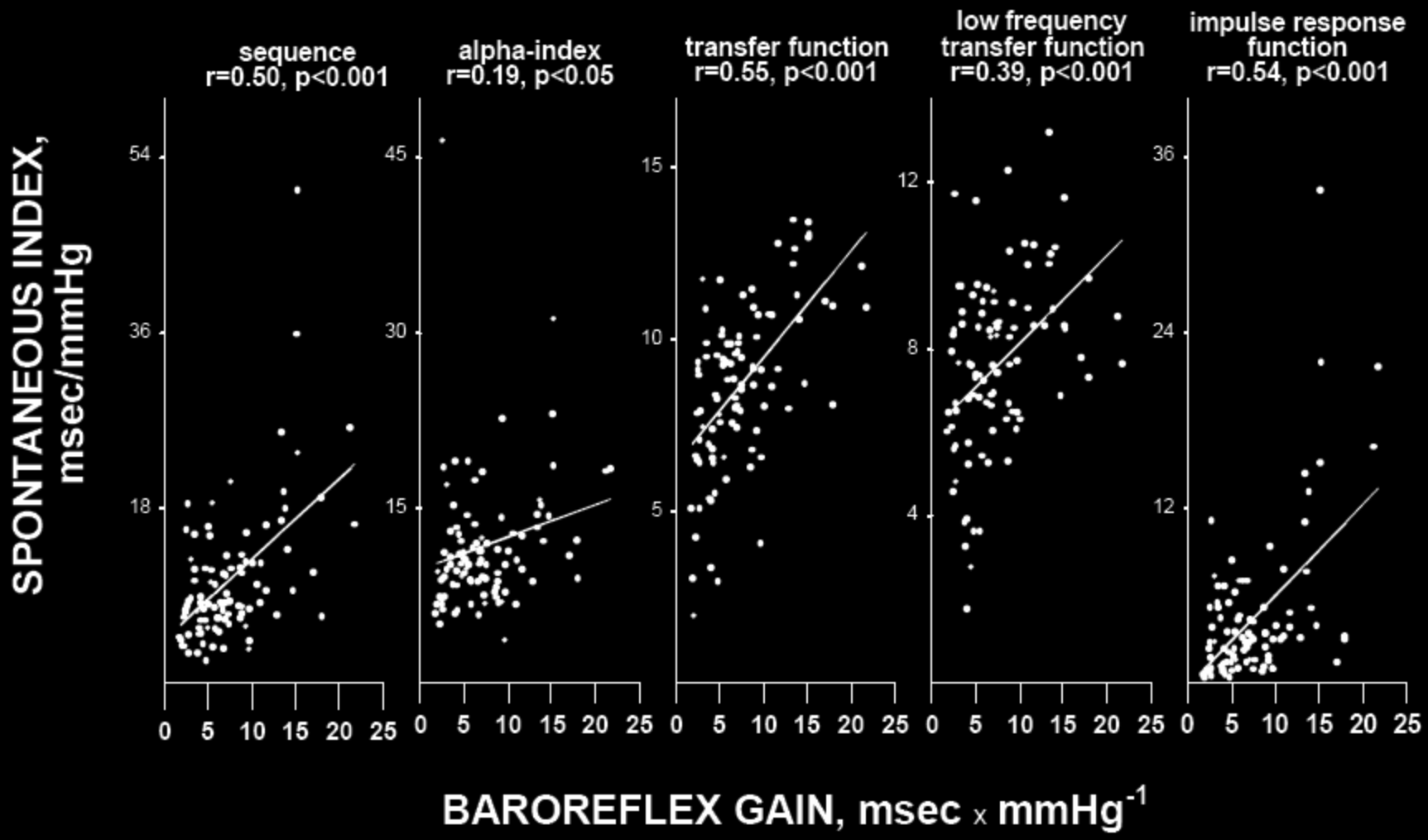
The modulus, or gain, function specifies the ratio between changes in RR interval time and changes in systolic blood pressure (msec/mm Hg) in a specified frequency band. Therefore the modulus function in the frequency domain is comparable to the regression coefficient in the time domain. The modulus in the mid frequency band (0.07-0.14 Hz) between systolic blood pressure and RR interval time gives equivalent results to those obtained using the phenylephrine method.

IMPULSE RESPONSE ANALYSIS OF BARORECEPTOR SENSITIVITY.
Panerai, et al. *American Journal of Physiology*, 1997

The Impulse Response Function was obtained with the inverse FFT. The peak value and its smoothed version were shown to be significantly correlated to BRS. We suggest that IRF might be the ideal method to assess BRS.



SPONTANEOUS INDICES ARE INCONSISTENT WITH ARTERIAL BAROREFLEX GAIN.
Lipman, et al. *Hypertension*, 2003



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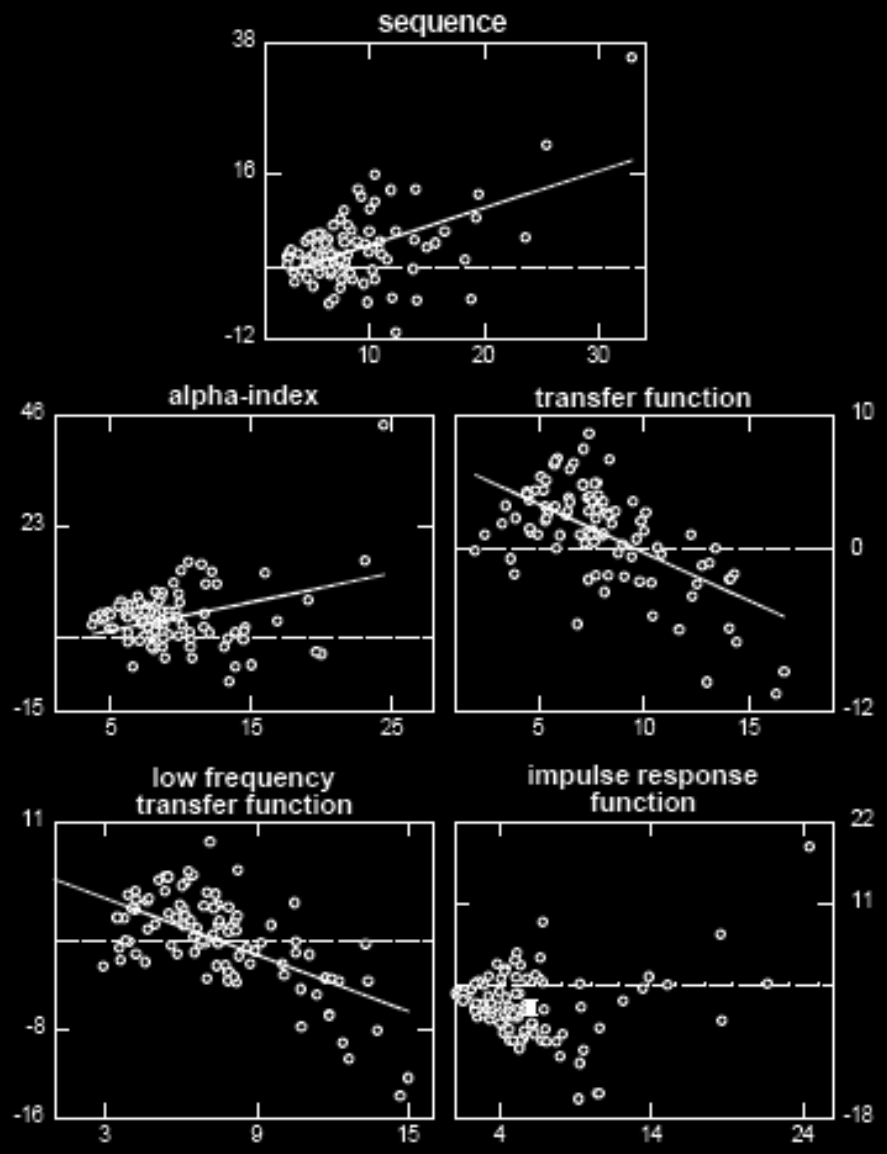
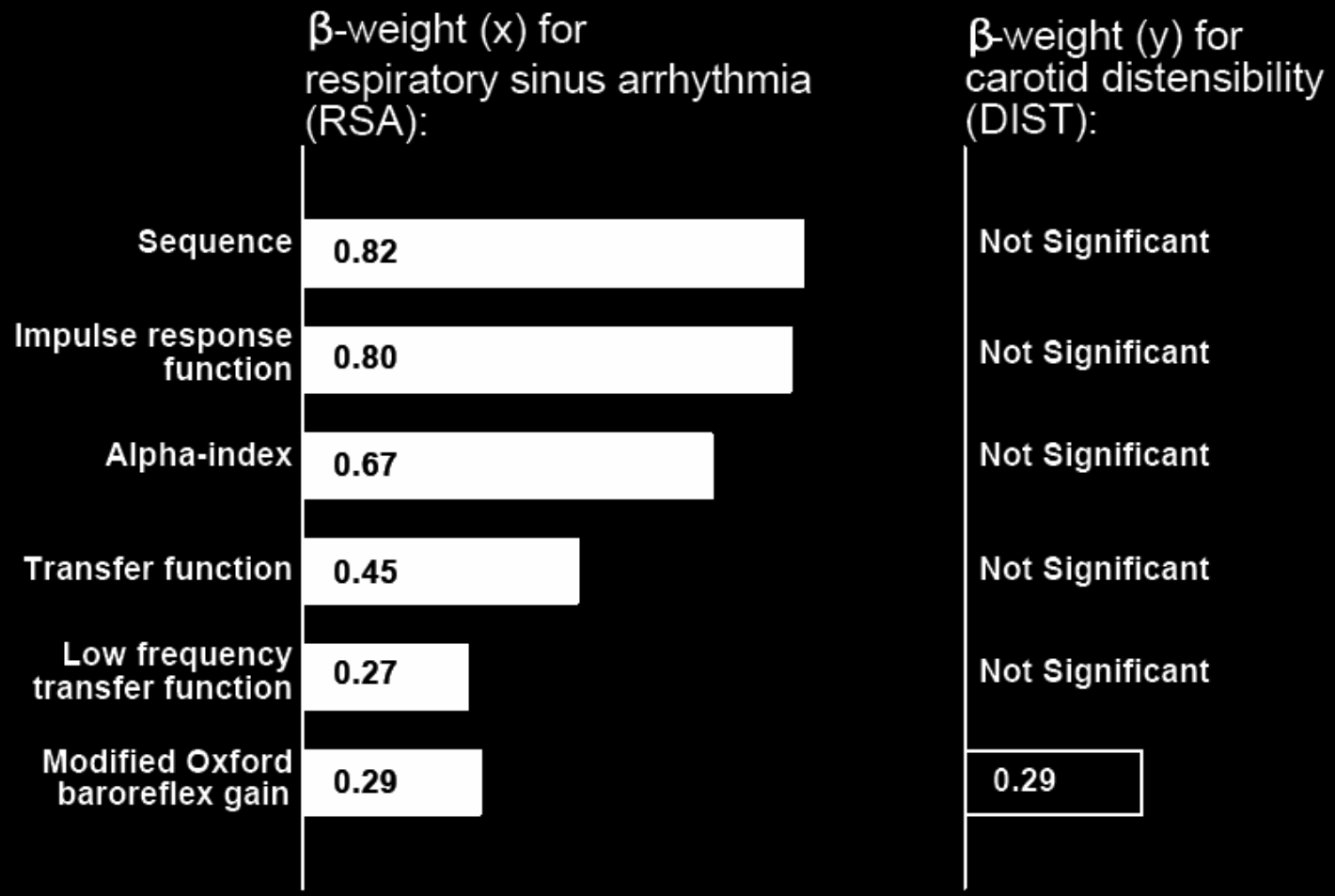


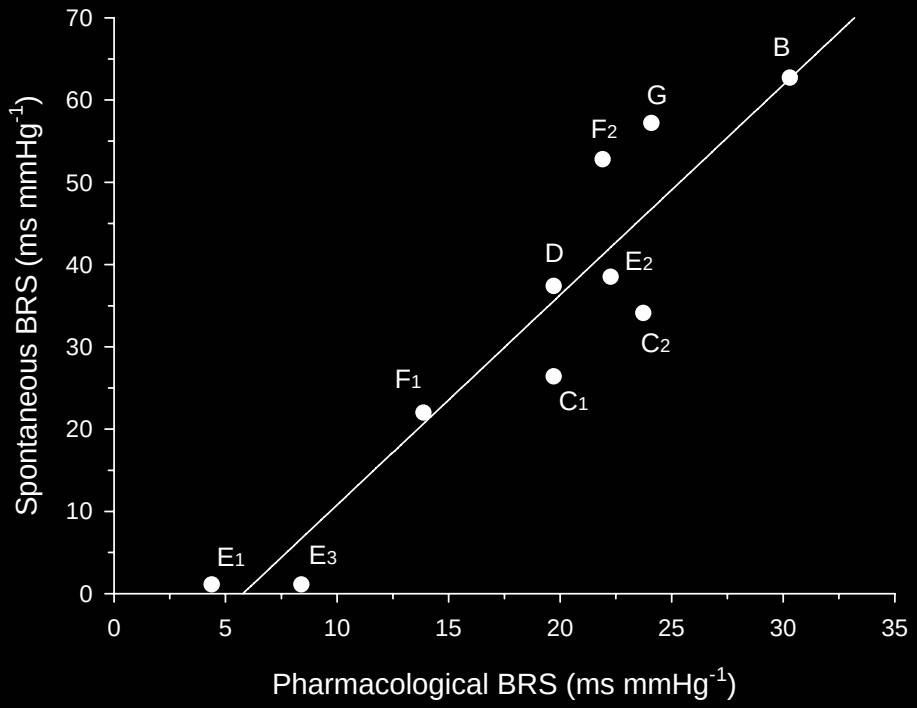
SPONTANEOUS INDICES ARE INCONSISTENT WITH ARTERIAL BAROREFLEX GAIN.

Lipman, Salisbury, Taylor,
Hypertension, 2003

Forward stepwise linear regression
= constant + (x RSA) + (y DIST)



EVALUATION OF SPONTANEOUS BAROREFLEX SENSITIVITY IN CONSCIOUS DOGS.
Frankle, et al. *Journal of Physiology*, 1993

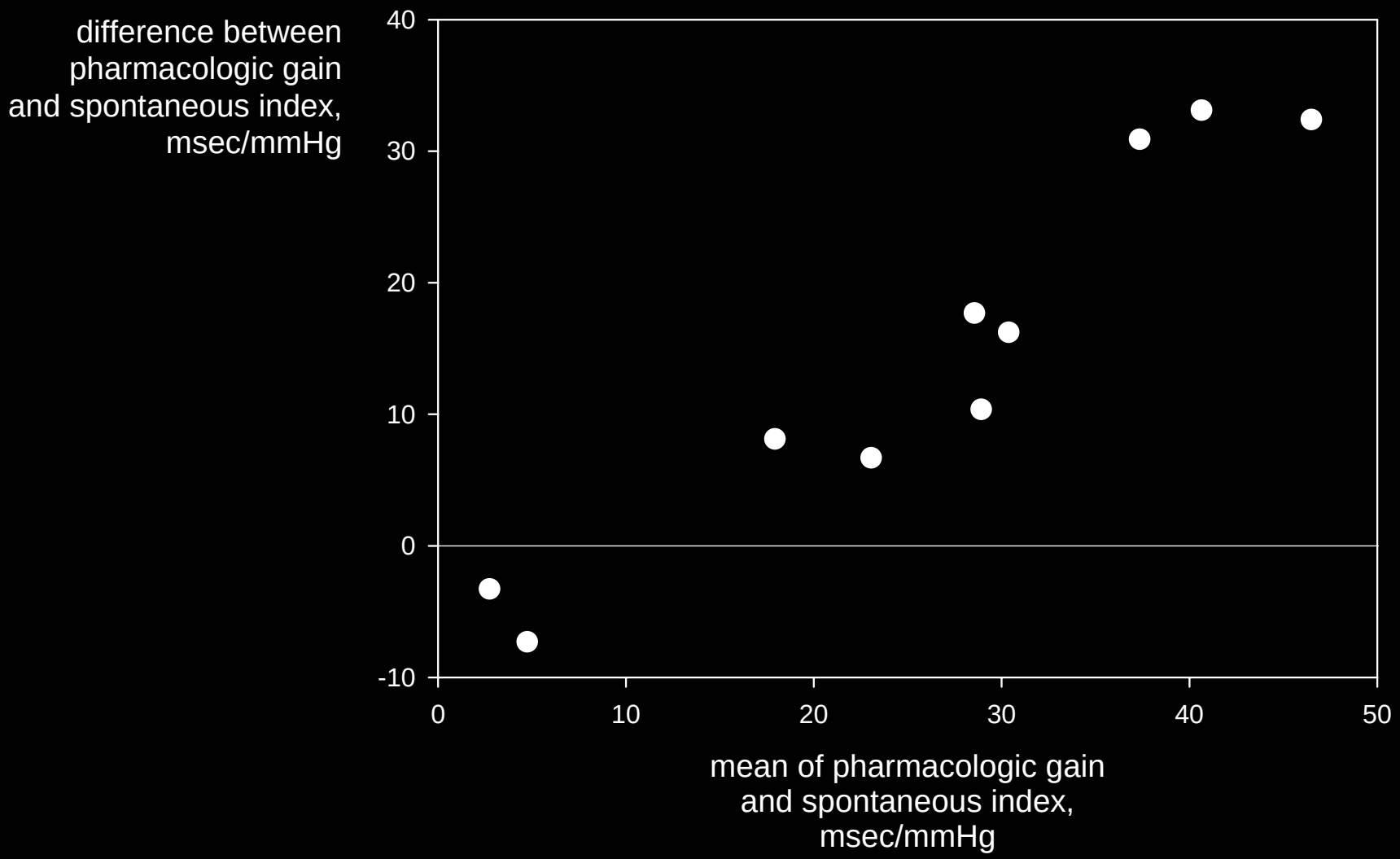


"We conclude that the spontaneous BRS is a useful quantitative indicator of baroreflex function in conscious resting dogs."

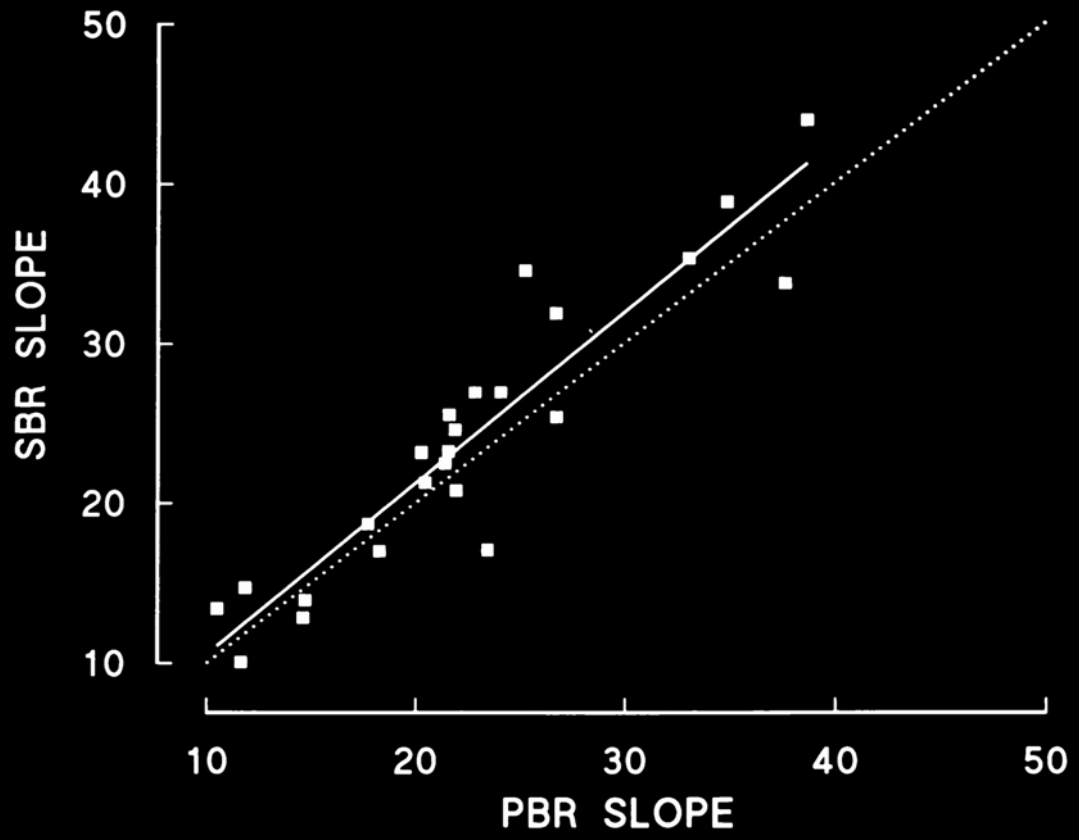
ADAPTED FROM:

EVALUATION OF SPONTANEOUS BAROREFLEX SENSITIVITY IN CONSCIOUS DOGS.

Frankle, et al. *Journal of Physiology*, 1993



SPONTANEOUS CARDIAC BAROREFLEX IN HUMANS
COMPARISON WITH DRUG-INDUCED RESPONSES.
Parlow, et al. *Hypertension,* 1995



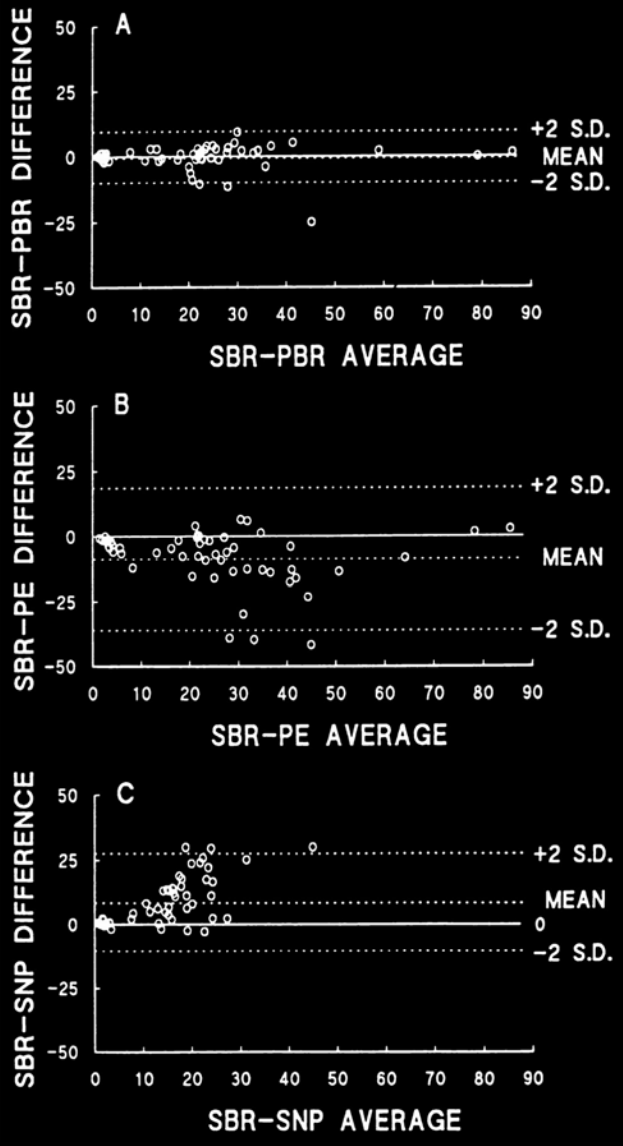
correlation of spontaneous baroreflex (SBR) slopes with the pharmacologic gain derived from the tangent to the mean preinjection systolic pressure on a sigmoid curve fitted to data forced to pass through the average preinjection values (r=.96, P<.001)

SPONTANEOUS CARDIAC BAROREFLEX IN HUMANS COMPARISON WITH DRUG-INDUCED RESPONSES.

Parlow, et al. *Hypertension,* 1995

Comparison of the SBR and drug-induced tangent methods shows negligible bias and very narrow dispersion about the mean difference.

By contrast, the SBR slopes yielded a negative bias with respect to the phenylephrine slopes and a positive bias with respect to the nitroprusside slopes; in these two comparisons, there is much wider dispersion about the mean difference.



Limitations in ‘Spontaneous’ Baroreflex Indices Explaining Lack of Correspondence to Direct Measures

- fluctuations in RR interval are not intimately and always linked to those in pressure via the baroreflex

- arterial baroreflex responses are greatest and most apparent with rapidly changing pressures, as opposed to stationary or minimally changing pressures

- the gain of a closed loop system can be assessed without opening the loop only if the system encompasses feedback relations alone, fluctuations are sufficiently large, and the gain is linear across all ranges

- spectral analyses cannot explicitly discriminate between feedback and feedforward gain

- sequence analysis cannot discriminate between patterns deriving from a deterministic baroreflex relationship and those deriving from simple correlations in two sinusoidally oscillating variables

The time has come to jump off what might be called the ‘baroreflex bandwagon’
unless some more precise measurement has been made of some component of the reflex path. . .
I suggest that further measurements of BRS (baroreflex sensitivity), by themselves, can contribute nothing to (our) understanding.

Dickinson, *Journal of Hypertension*, 2001