9th meeting of
European **S**tudy **G**roup on **C**ardiovascular **O**scillations

Wavelet phase coherence analysis of polyfrequency skin blood flow oscillations under normal conditions in human

- *Arina Tankanag, Andrey Grinevich, Tatiana Kirilina*, Gennady Krasnikov*, Galina Piskunova*, Nikolay Chemeris*
- Institute of Cell Biophysics, Russian Acad. Sci.,Pushchino, Russia
- * Tula State Lev Tolstoy Pedagogical University, Tula, Russia

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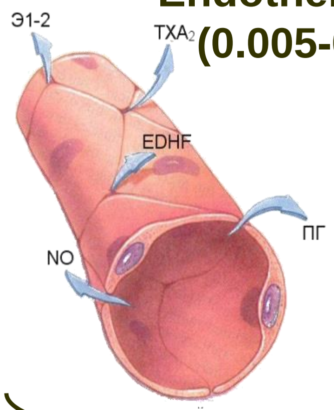
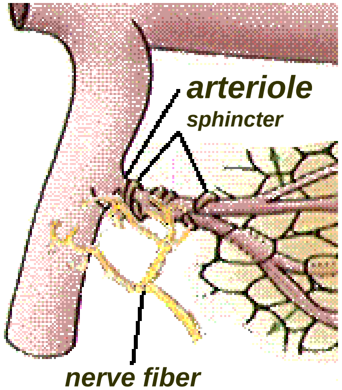
Central or local

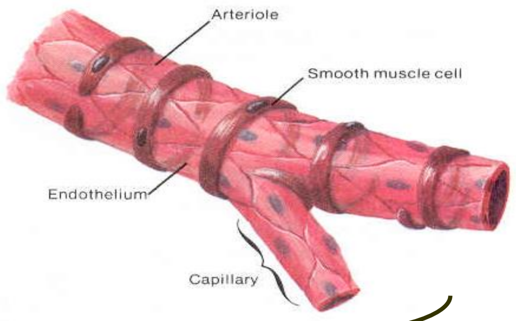
Neurogenic rhythm (0.052-0.145 Hz)

Endothelial rhythm (0.005-0.021 Hz)

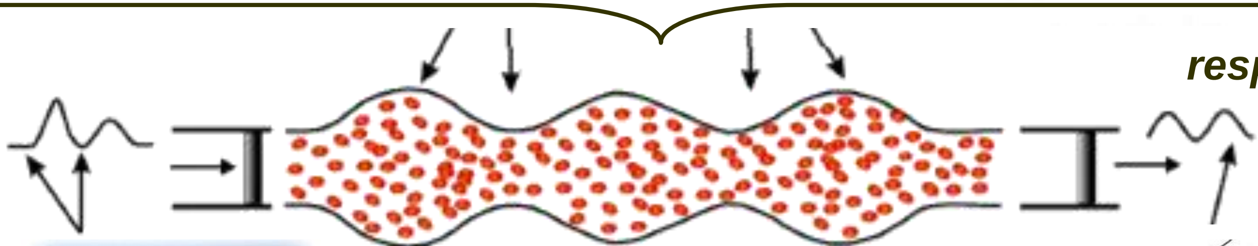




Myogenic rhythm (0.052-0.145 Hz)



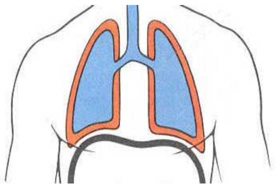
pulse wave



respiratory function

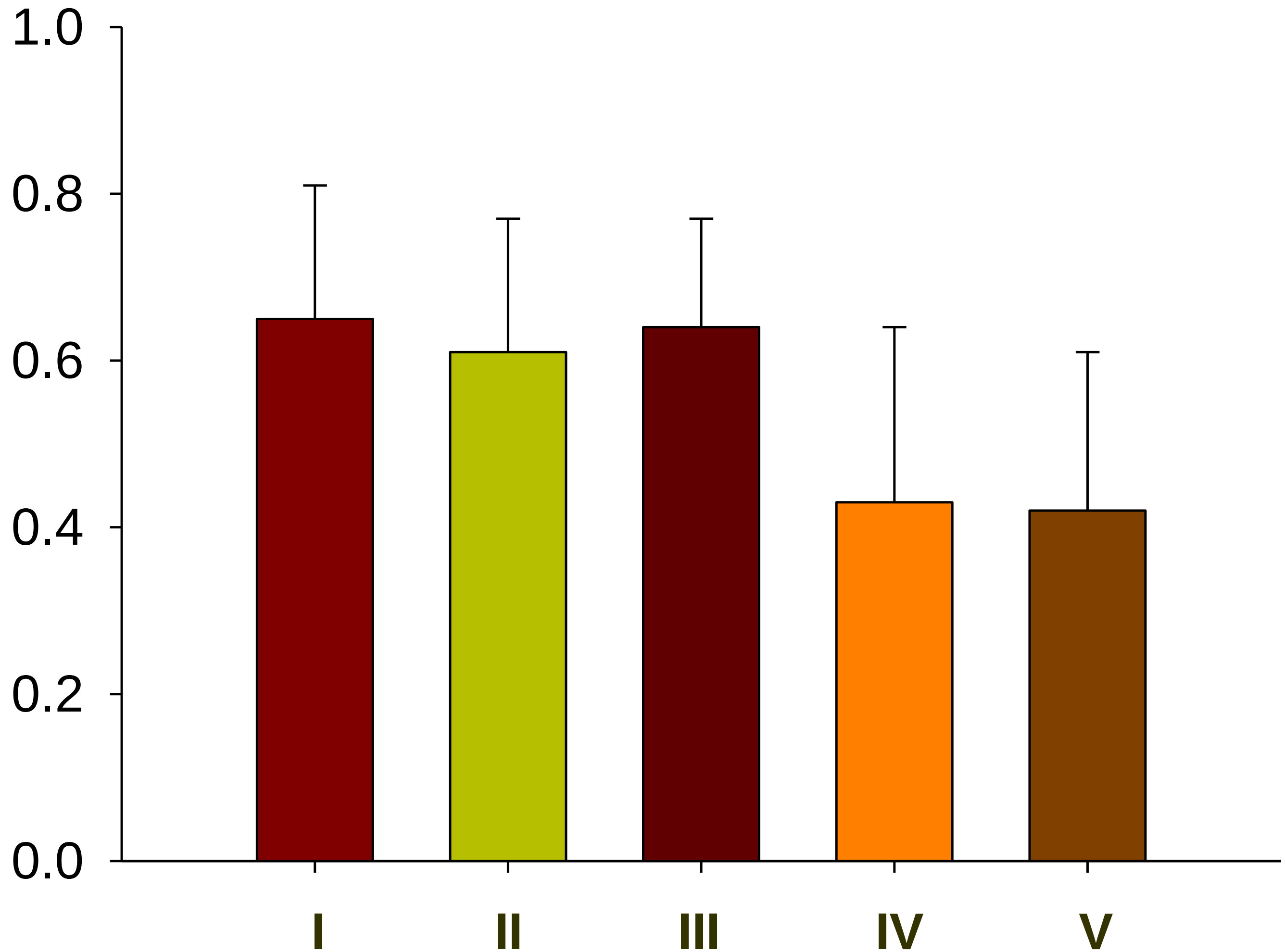
Cardio-rhythm (0.6-2 Hz)

Respiratory rhythm (0.145-0.6 Hz)



Cross-correlation function

I – endothelial rhythm
II – neurogenic rhythm
III – myogenic rhythm
IV – respiratory rhythm
V – cardio rhythm



Kirilina T.V. et al. Spatial synchronization of the blood flow oscillations in human skin microcirculation. Region. Blood Circ. Microcirc. #8, p. 32-36 [in Russian].

Aim of the study

The aim was to detect the frequency intervals for the peripheral blood flow oscillations in contralateral sites of forearm skin with high statistically reliable degree of wavelet phase coherence

Participants

20 healthy young women
aged from 18 to 22 years

Weight: 60 ± 11 kg
Height: 166 ± 5 cm
Arterial blood pressure: 119 ± 7/69 ± 7 mm Hg
Heart rate 73 ± 11 bpm

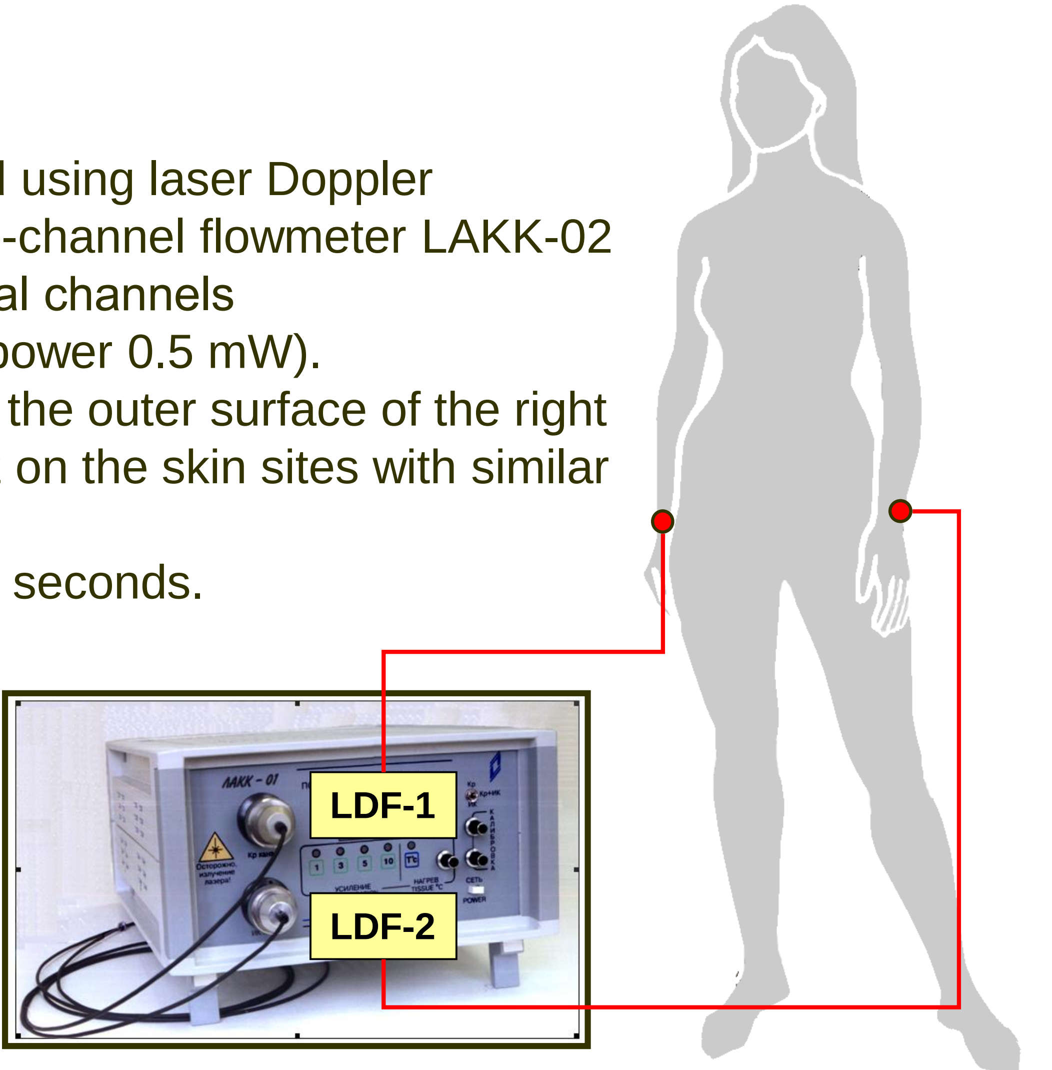
The exclusion criteria were previous history of any illnesses.
The study was approved by the local Committee for Human Biomedical Research Ethics and was carried out in accordance with the principles outlined in *Declaration of Helsinki*

Measurement procedure

Skin blood perfusion was recorded using laser Doppler flowmetry (LDF) technique by dual-channel flowmeter LAKK-02 (‘LAZMA’, Russia) with two identical channels (wavelength 0.63 mkm, emission power 0.5 mW).

The LDF probes were fixed above the outer surface of the right and left forearms close to the wrist on the skin sites with similar blood flow levels.

The duration of recording was 750 seconds.



Wavelet phase coherence

For each signal a complex spectral function $X(\omega_k, t_n) = a_{k,n} + ib_{k,n}$ was determined.
The phase differential for a pair of signals $x_1(t)$ and $x_2(t)$ at any time point t_n and frequency ω_k was calculated, and the coefficients were determined

$$\cos(\Delta\phi_{k,n}) = \frac{a_{1k,n}a_{2k,n} + b_{1k,n}b_{2k,n}}{\sqrt{a_{1k,n}^2 + b_{1k,n}^2}\sqrt{a_{2k,n}^2 + b_{2k,n}^2}} \qquad \sin(\Delta\phi_{k,n}) = \frac{b_{1k,n}a_{2k,n} - a_{1k,n}b_{2k,n}}{\sqrt{a_{1k,n}^2 + b_{1k,n}^2}\sqrt{a_{2k,n}^2 + b_{2k,n}^2}}$$

The coefficients were determined and averaged over the whole time of registration N

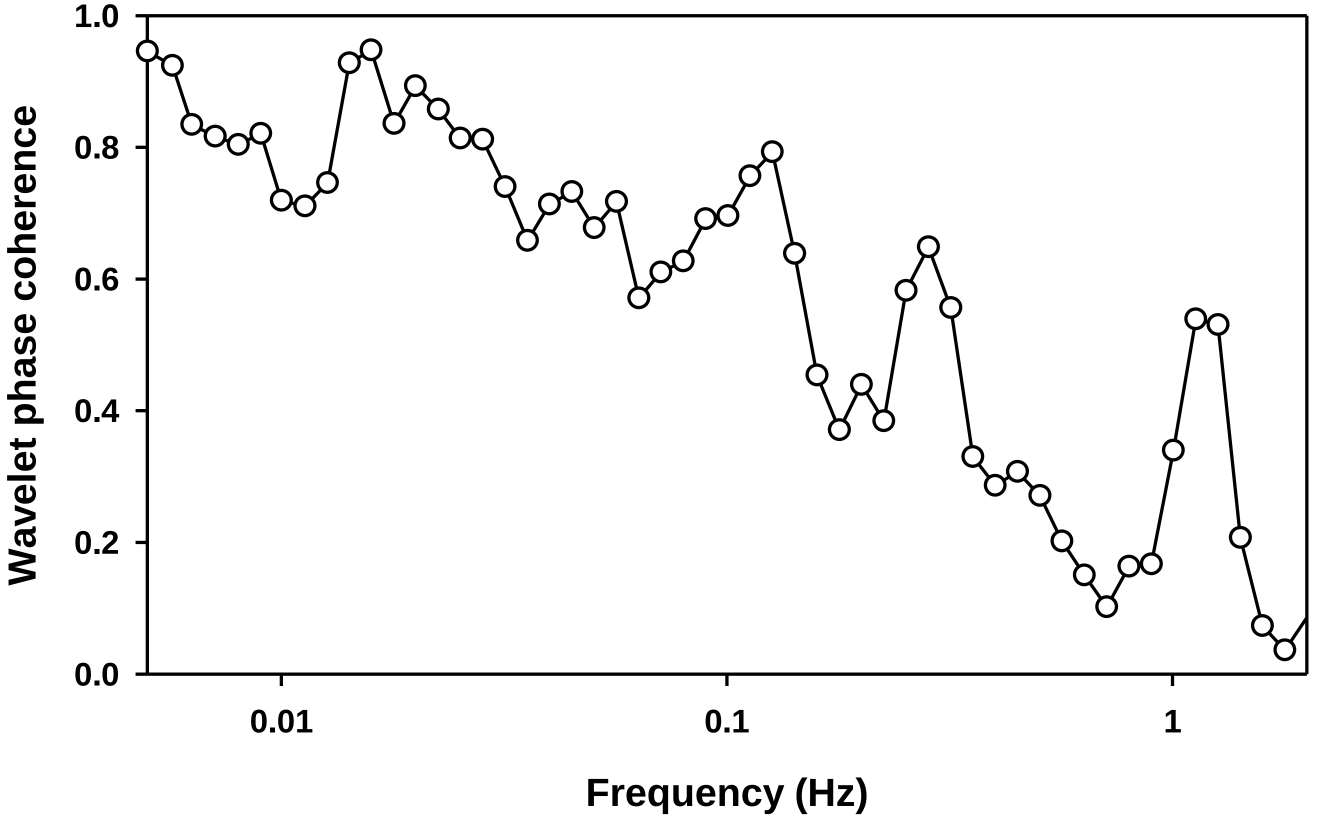
$$\langle \cos(\Delta\phi_{k,n}) \rangle = \frac{1}{N}\sum_{n=1}^{N}\cos(\Delta\phi_{k,n}) \qquad \langle \sin(\Delta\phi_{k,n}) \rangle = \frac{1}{N}\sum_{n=1}^{N}\sin(\Delta\phi_{k,n}).$$

The degree of correlation between the phases of the analyzed signals was estimated from the value of the wavelet phase coherence for each analyzed frequency ω_k

$$C_\phi(\omega_k) = \sqrt{\langle \cos(\Delta\phi_{k,n}) \rangle^2 + \langle \sin(\Delta\phi_{k,n}) \rangle^2}$$

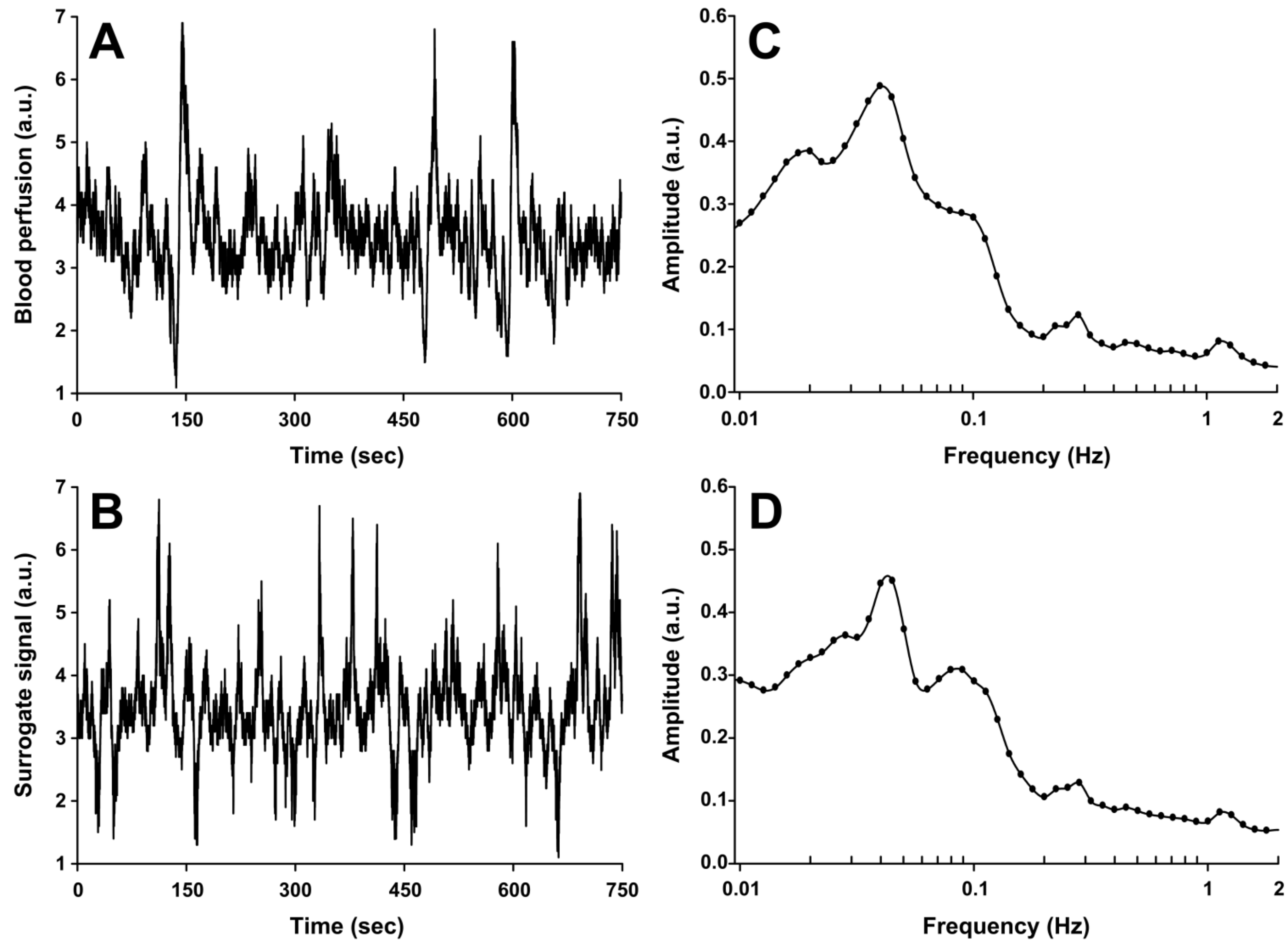
The $C\phi(\omega_k)$ function takes the values from 0 to 1.
We assume that $C\phi(\omega)$ for the local mechanisms of blood flow regulation might be proximal to 0, being closer to 1 for the central mechanisms.

Wavelet phase coherence



Method of surrogates

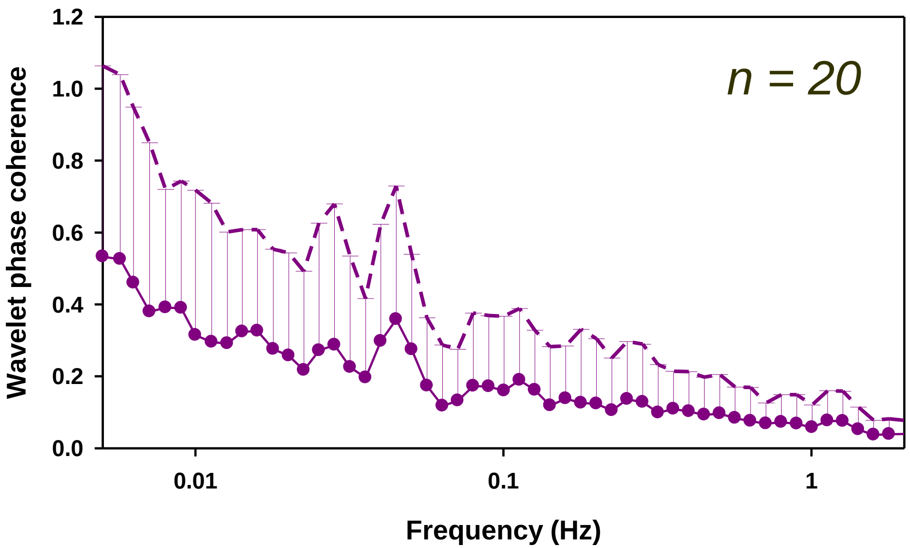
The original LDF signal (A), one of its surrogates (B) and their amplitude-frequency spectra (C and D, respectively)



The frequency axis in panels C and D is in logarithmic scale

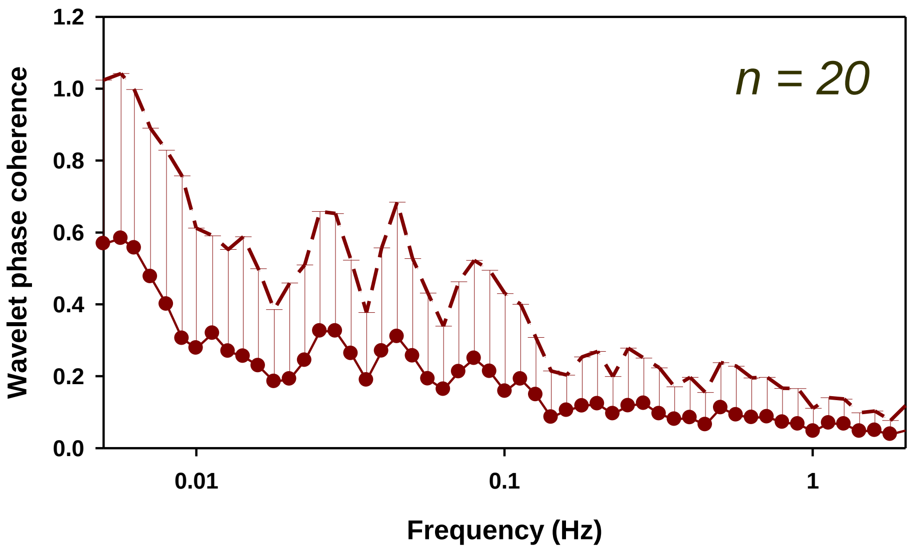
Significance of wavelet phase coherence

left forearm



$$\mathrm{Th}_{left}(\omega_k) = \overline{C}_{sur\_left}(\omega_k) + 2{*}\sigma_{sur\_left}(\omega_k)$$

right forearm



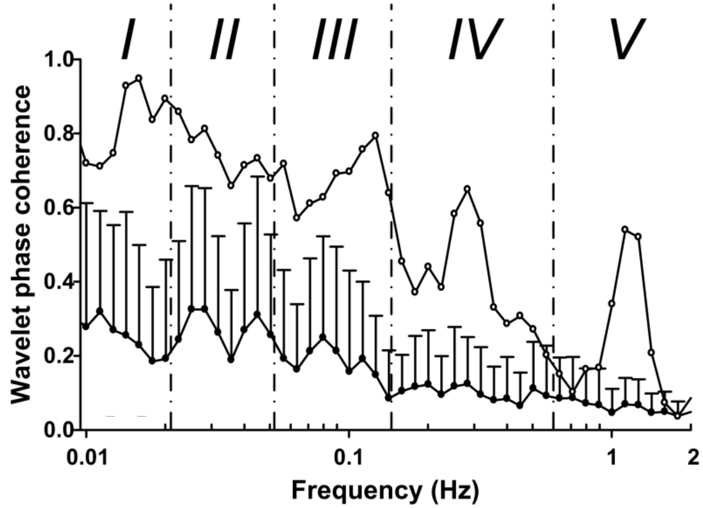
$$\mathrm{Th}_{right}(\omega_k) = \overline{C}_{sur\_right}(\omega_k) + 2{*}\sigma_{sur\_right}(\omega_k)$$

The wavelet phase coherence value $C(\omega_k)$ at frequency ω_k was considered ***significant***, when ***both*** conditions $C(\omega_k) > \mathrm{Th}_{left}(\omega_k)$ and $C(\omega_k) > \mathrm{Th}_{right}(\omega_k)$ were satisfied.

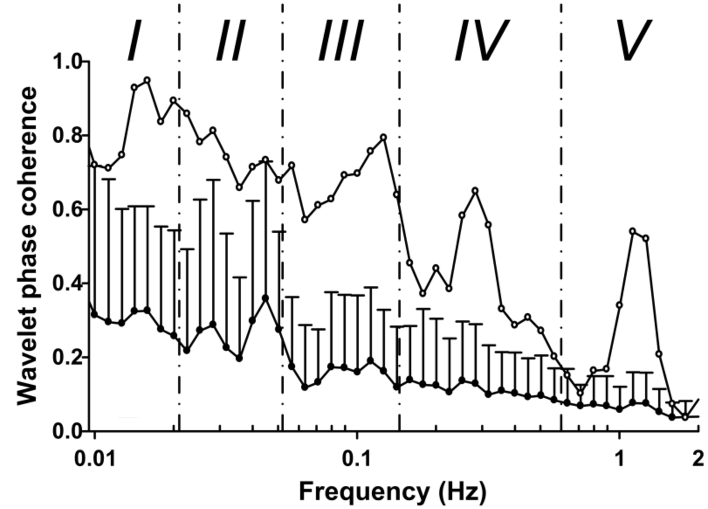
Wavelet phase coherence

Subject 1

left forearm

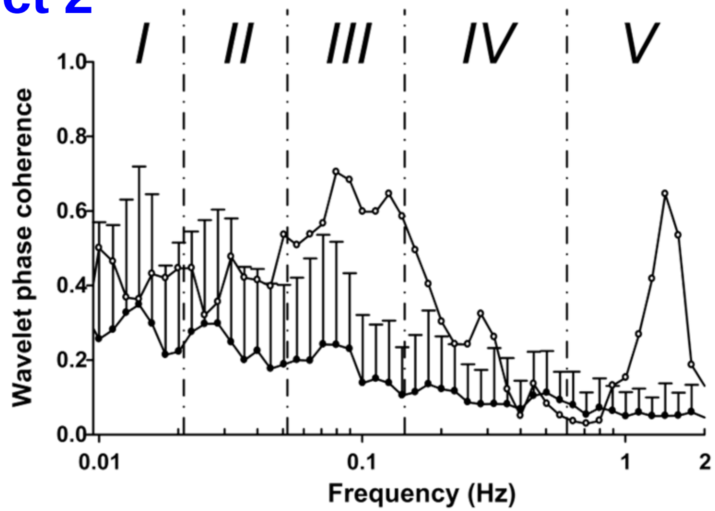


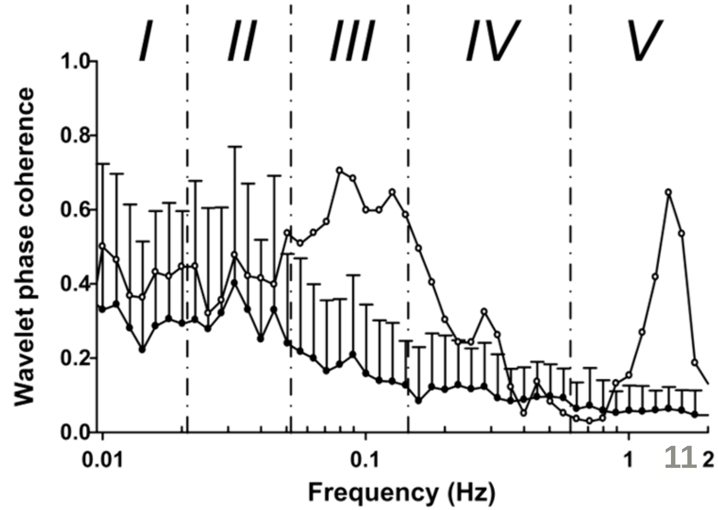
right forearm



I– endothelial rhythm
II – neurogenic rhythm
III – myogenic rhythm
IV – respiratory rhythm
V – cardio rhythm

Subject 2

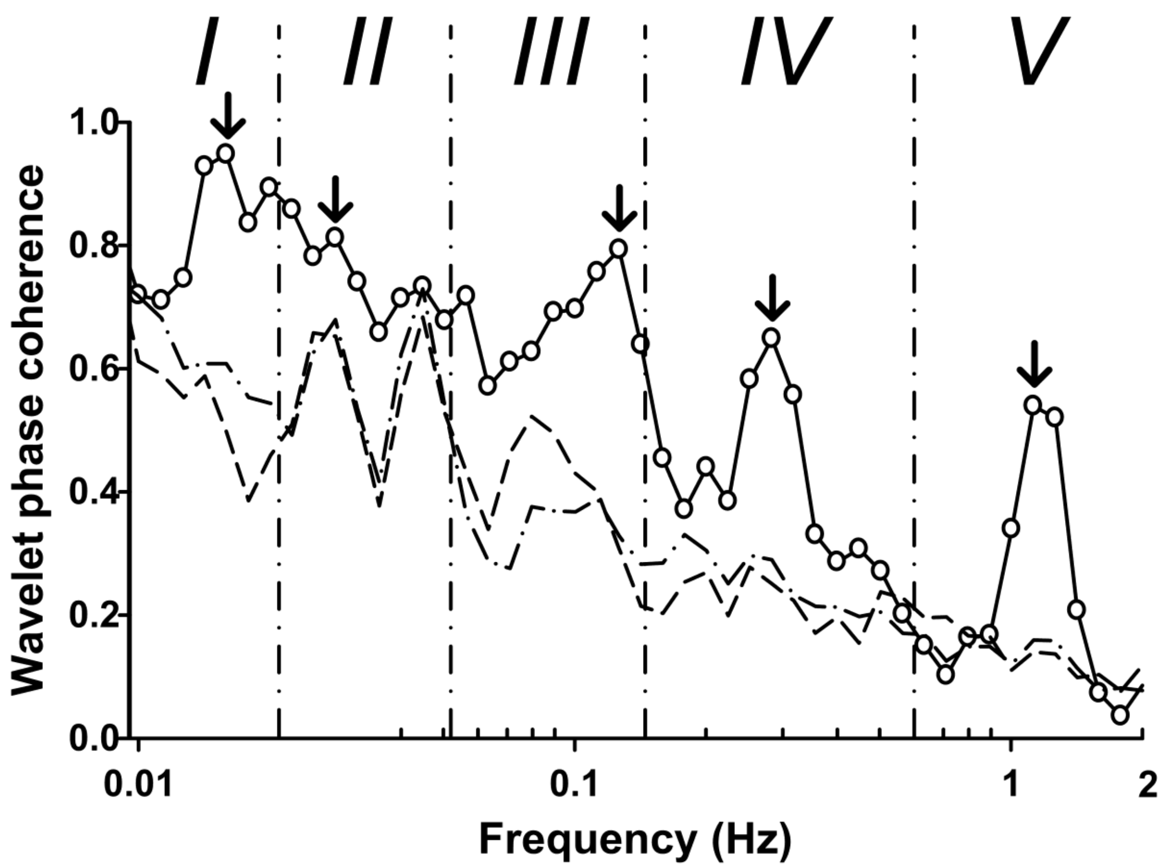




Wavelet phase coherence

Wavelet phase coherence between the blood flow oscillations of the left and right forearms (-O-), and the thresholds (mean + 2σ) for the surrogates of the left (dashed line) and right (dash-dotted line) forearms. Arrows indicate the C(ω) function values accounted in the statistical analysis.

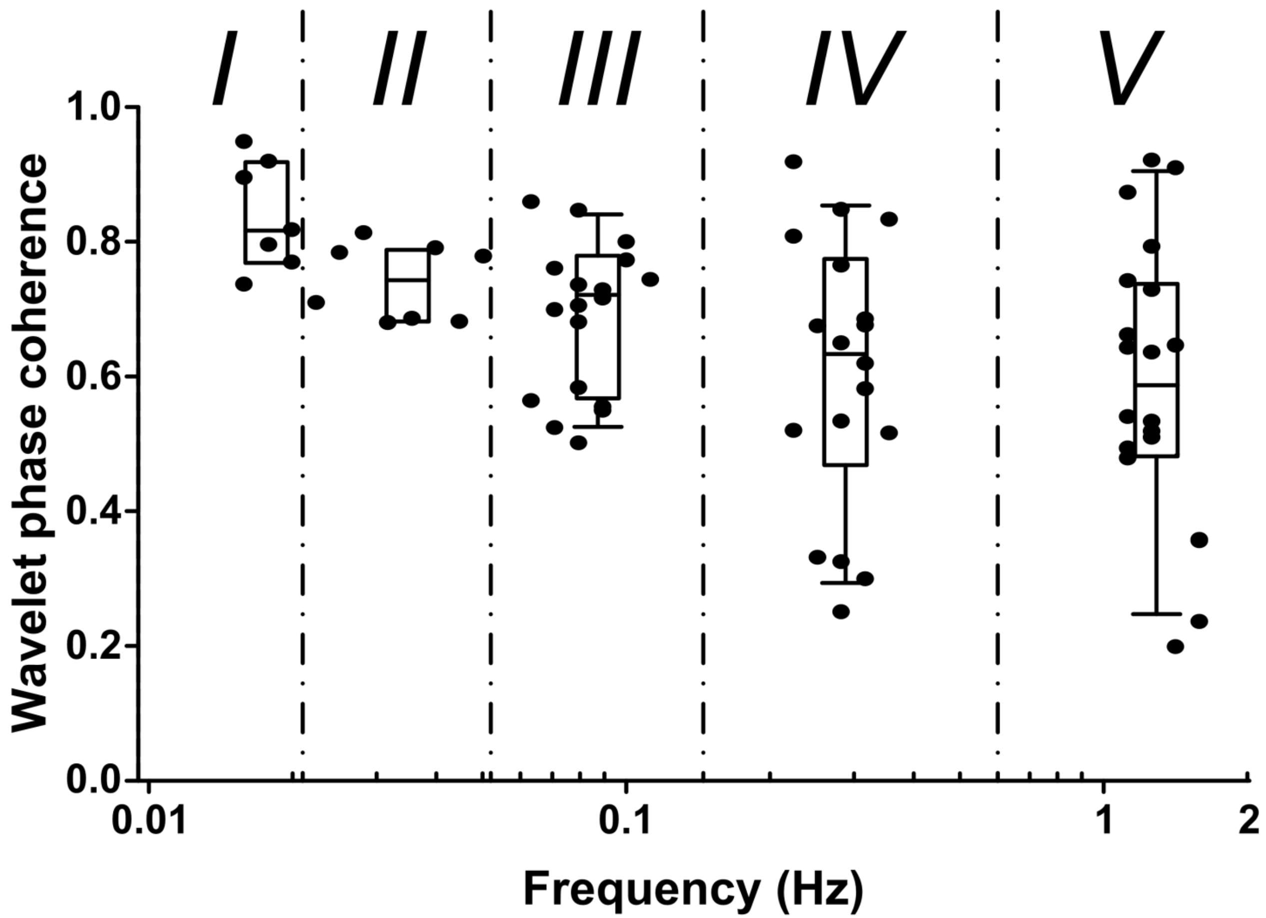
I– endothelial rhythm
II – neurogenic rhythm
III – myogenic rhythm
IV – respiratory rhythm
V – cardio rhythm



Wavelet phase coherence

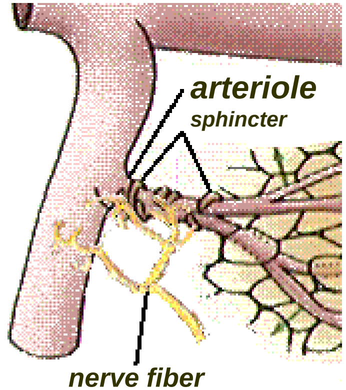
Reliable values of the $C_l(\omega)$ function (dots), the group median and boxplots of the coherence calculated within frequency intervals.

I– endothelial rhythm
II – neurogenic rhythm
III – myogenic rhythm
IV – respiratory rhythm
V – cardio rhythm

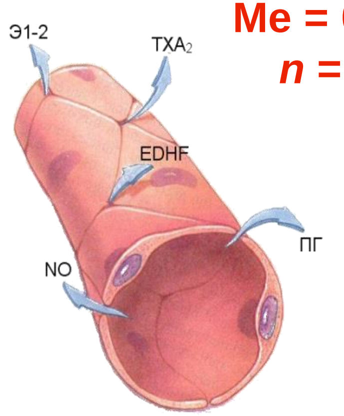


Central or local

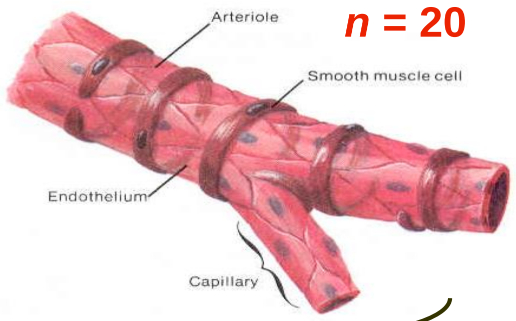
Neurogenic rhythm
Me = 0.74
n = 8



Endothelial rhythm
Me = 0.82
n = 7

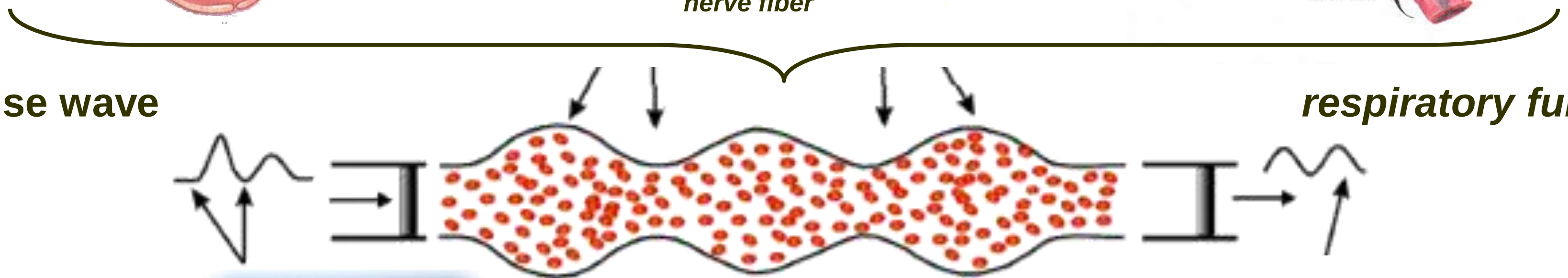


Myogenic rhythm
Me = 0.72
n = 20



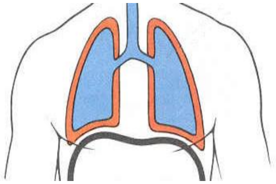
pulse wave

respiratory function



Cardio-rhythm
Me = 0.59
n = 20

Respiratory rhythm
Me = 0.63
n = 18



Conclusions

The results obtained suggest that the microvascular blood flow possesses not only the local mechanisms of generating low-frequency blood flow oscillations, but also a central mechanism, which is likely to synchronize low-frequency oscillations throughout the whole cardiovascular system

Probable mechanisms

- myogenic response
- autonomic nervous control
- central neurogenic and/or humoral regulation
- ???

A. V. Tankanag et al., Wavelet phase coherence analysis of the skin blood flow oscillations in human. Microvascular Research, 2014, v. 95.

Thank you for attention!