Oscillatory pattern of arteriovenous anastomoses and skin blood flow within thermoneutral zone

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BACKGROUND

- Core temperature regulation is a key mechanism for homeostasis and within the thermoneutral zone, it is probably maintained stable with adjusting oscillations in acral skin blood flow. The acral skin contains arteriovenous anastomoses (AVA), which are shunts between arterial and venous circulation in hands and feet. The blood flow through AVAs is adjusted by sympathetic vasoconstrictor nerves. The AVAs constrict simultaneously in hands and feet.
- The vasoconstrictions appear at a frequency of 2 to 3 per minute (0.03-0.05 Hz) while the subject is thermoneutral [1]. By changing frequency of this vasomotor activity the AVAs may regulate body temperature within the thermoneutral zone at low energy expenditure.
- In this study we describe the AVA vasomotion from upper to lower thermoneutral zone in healthy subjects. We hypothesized that from 32°C to 18°C of ambient temperature, the oscillatory pattern shifts from higher to lower frequency.

METHODS

- Twelve young, healthy volunteers participated in an experimental protocol with changing ambient temperature [2]. In this study we reanalyze the data by wavelet analysis. The subject was supine in a climate chamber. Laser Doppler fluxes were obtained from pulp of the right and left third fingers as a measure of acral skin blood flow. The ambient temperature went from 32°C to 18°C with three plateaus; 32°C, 25°C and 18°C.
- The wavelet transform (WT) technique was used to analyze the acral blood flow oscillations. The time-frequency analysis tools employed in our study have been developed by the Department of Physics, Lancaster University, UK [3].
- The Morlet wavelet [4] was selected for the WT analysis of the acral skin blood flow at five distinct time intervals - of approx. 800 s each- including three plateaus and their corresponding transition zones. For each time interval and for both right and left fingertips signals, the time averaged wavelet spectral power were calculated and were divided to two frequency intervals of [0.02Hz - 0.05Hz] and [0.05Hz - 0.08Hz] respectively.
- For each of the aforementioned time intervals the integral under the curve of the wavelet spectral power at both frequent intervals was estimated along with the coherence and the phase lag of the two fingertip signals. The data are reported as Hodges-Lehmann estimates of median with 95% confidence interval [5].

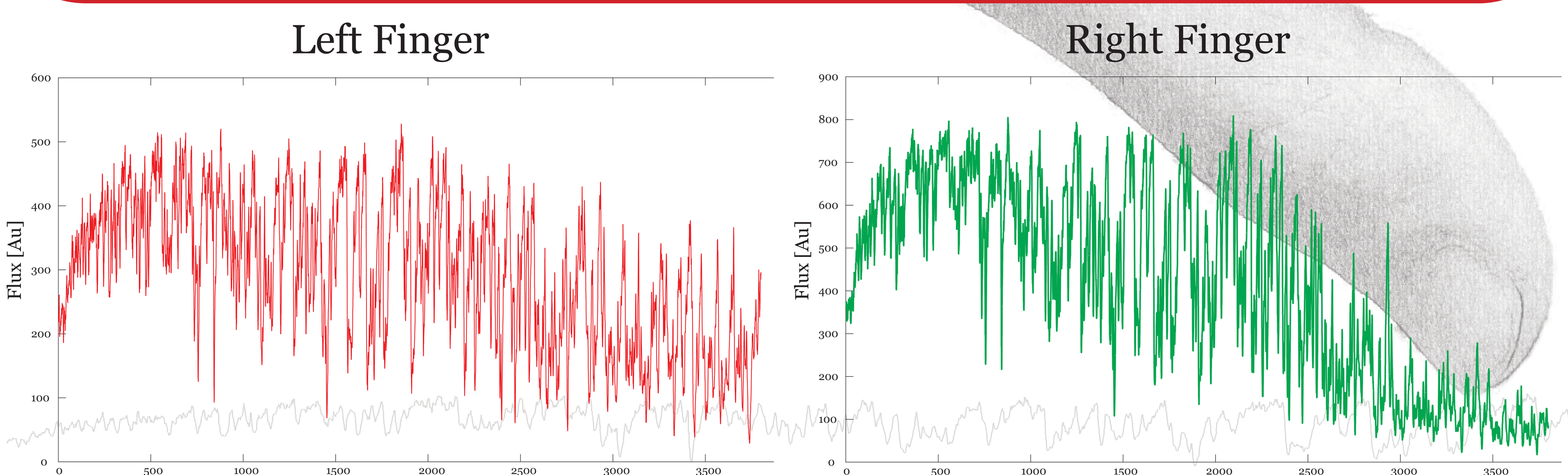

Figure 1: Simultaneous bilateral recordings from pulp of the third fingers (acralskin) in one subject during whole body surface cooling in a climate chamber from 32 °C to17 °C. The above two signal curves correspond to Laser Doppler flux left fingertip (red) and right fingertip (green).

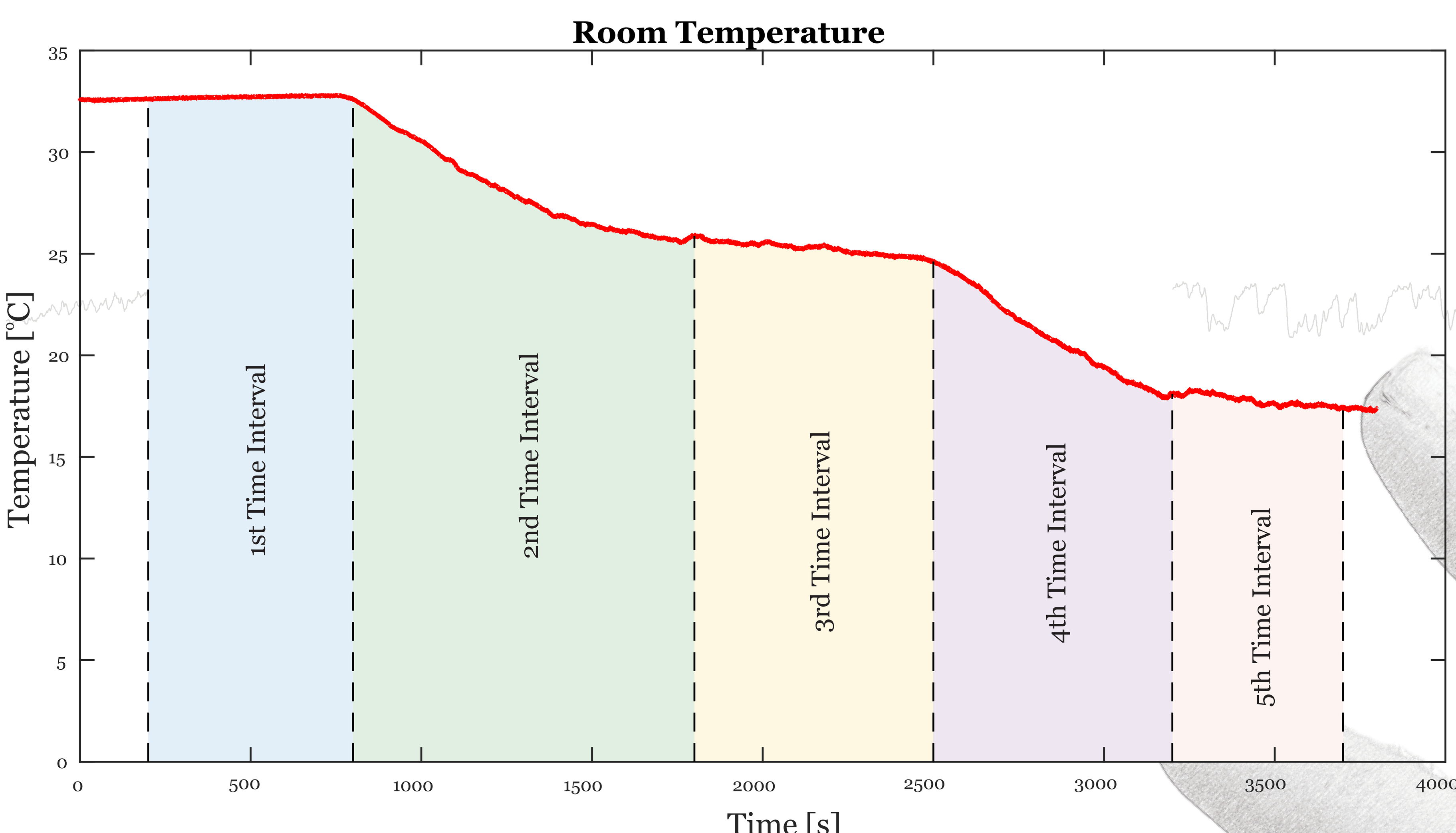

Figure 2: Measured ambient temperature inside the climate chamber. The10-min. plateau periods at 32 °C, 25 °C and18 °C correspond to the 1st, 3rd and 5th time interval.

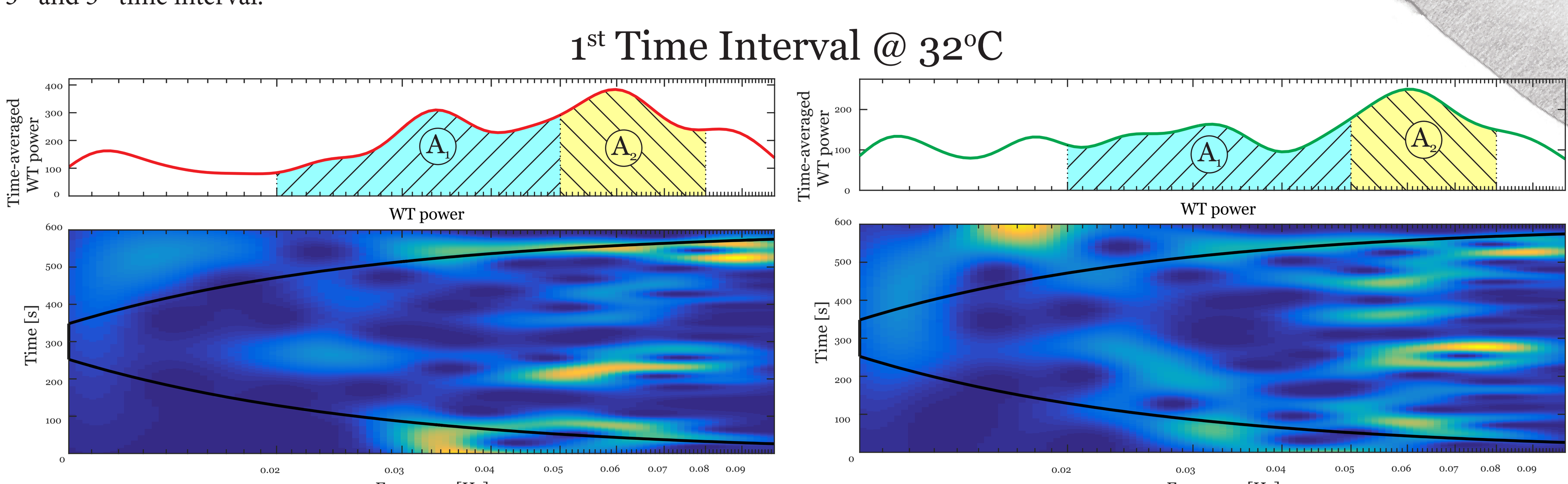

Figure 3: WT contour plot along with the time-averaged WT power for the left (red) and right (green) fingertip. The A_1 area under each curve corresponds to the 1st frequency interval [0.02Hz - 0.05Hz] and the A_2 area to the 2nd frequency interval [0.05Hz - 0.08Hz].

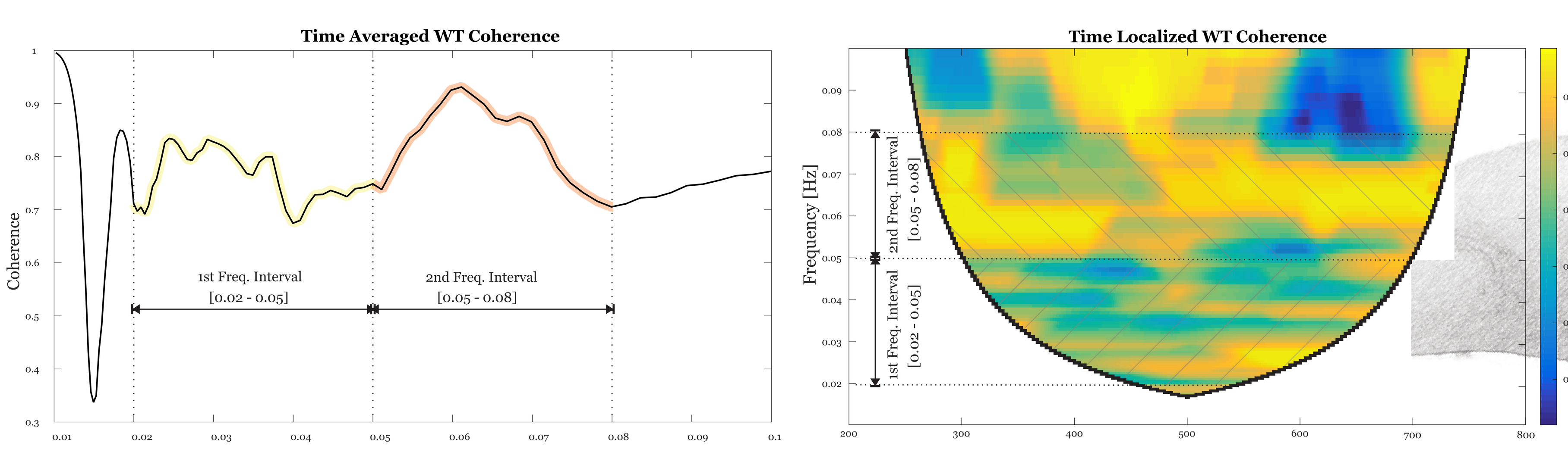

Figure 4: The time-averaged WT coherence (left) and the time-localized WT coherence (right) of the analyzed blood flow signals measured at the two fingertips at the 1st time interval @ 32°C.

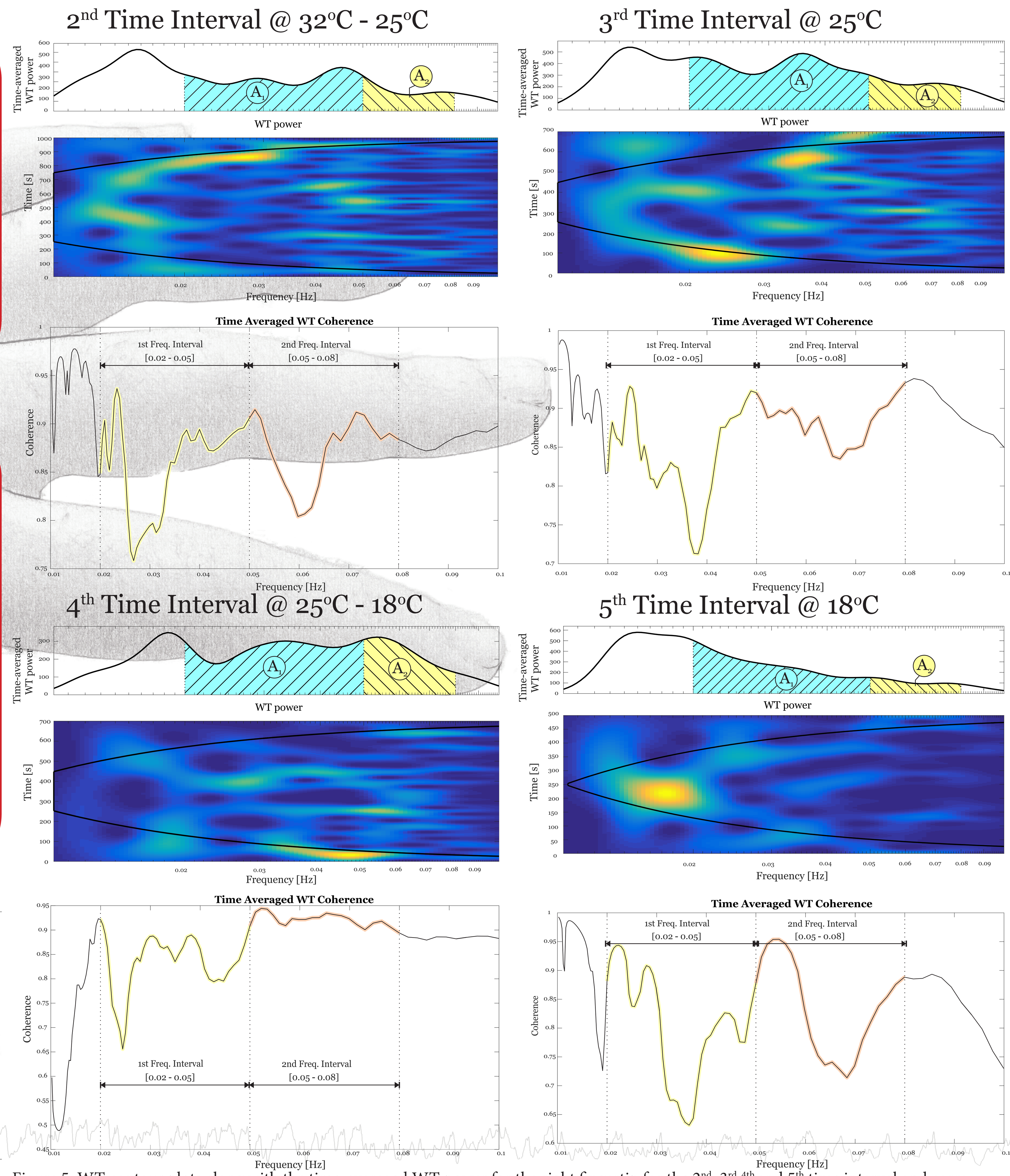

Figure 5: WT contour plots along with the time-averaged WT power for the right fingertip for the 2nd, 3rd, 4th and 5th time interval and corresponding temperatures (see Figure 2). The A_1 area under each curve corresponds to the 1st frequency interval [0.02Hz - 0.05Hz] and the A_2 area to the 2nd frequency interval [0.05Hz - 0.08Hz]. Below each WT contour plot, the curve of the time-averaged WT coherence between the analyzed signals from the left and right fingertip is also depicted.

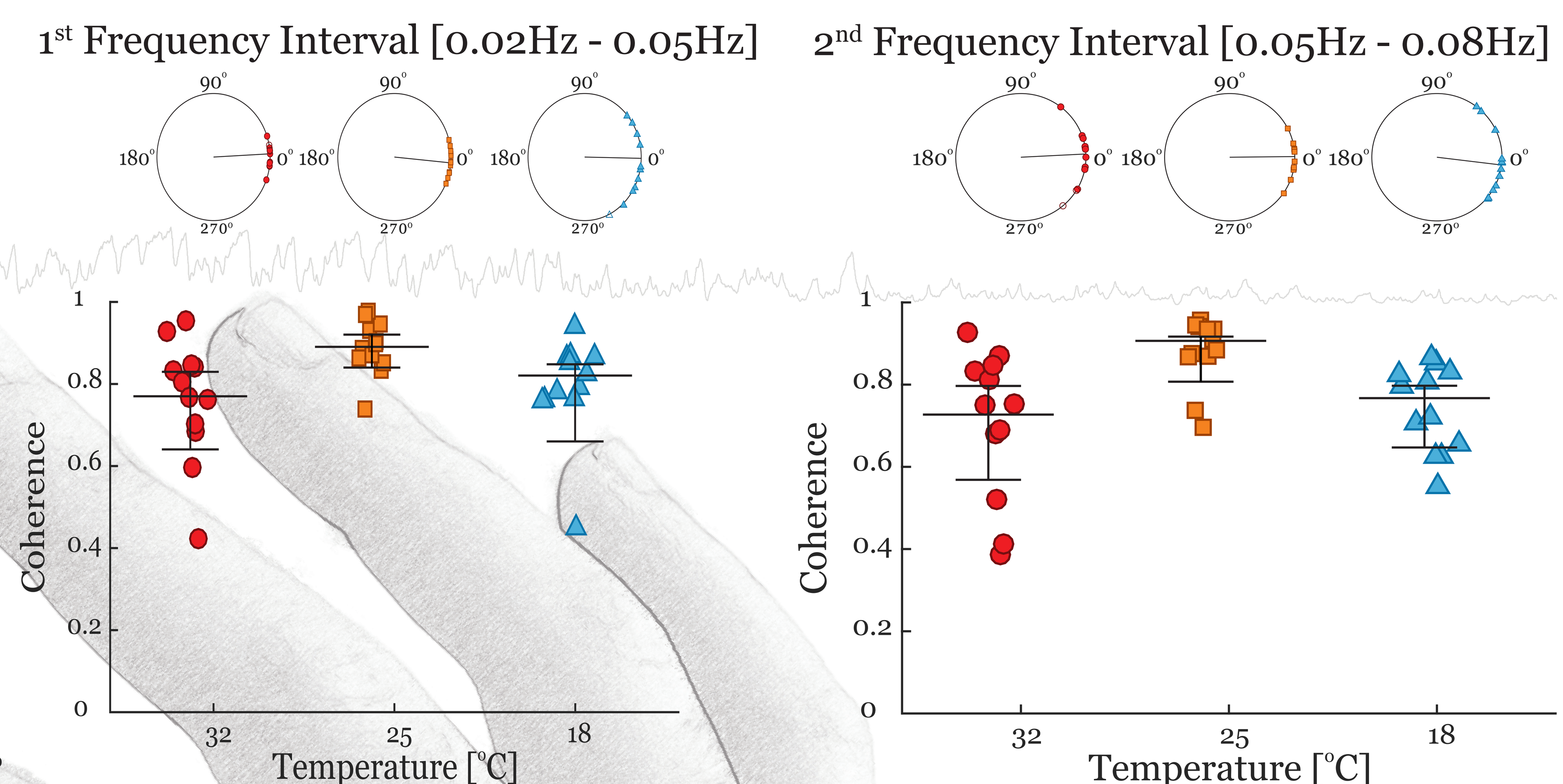

Figure 6: Phase angles and coherence between laser Doppler flux in the right and left finger pulp at three room temperatures. The upper circles show the individual phase angles between laser Doppler flux of the right and left finger pulp (unfilled point markers indicate coherence below 0.5). The angle of each circle's radius corresponds to the median phase angle. The lower graphs depict the individual coherence between laser Doppler flux of the right and left finger pulp. The horizontal lines indicate the median coherence and 95% CI.

RESULTS

- The laser Doppler flux integrals from the two finger tips were similar and their oscillations were in phase and thus only the values from the right fingertip are reported.
- The fluctuations in laser Doppler flux at [0.02Hz -0.05Hz] were stable at 32°C, during the transition 32°C-25°C, and at 25°C.
- During the transition 25°C-18°C the fluctuations decreased ($p=0.005$) and then decreased further at 18°C ($p=0.0005$). At this frequency [0.02Hz -0.05Hz], the coherence between the oscillations of the signal from right and left finger tips was high during the transition 32°C-25°C, at 25°C and during the transition 25°C -18°C, while lower at 32°C ($p=0.02$) and 18°C ($p=0.03$).
- The fluctuations in laser Doppler flux at[0.05Hz -0.08Hz] were stable at 32°C, during the transition 32°C-25°C and at 25°C, whereas decreased during the transition 25°C-18°C ($p=0.002$) and decreased further at 18°C ($p=0.0005$).
- At this frequency the coherence between the oscillations of the signal from right and left finger tips was high at 25°C and during the transition 25°C-18°C, whereas lower at 32°C ($p=0.003$), during the transition 32°C -25°C ($p=0.04$) and at 18°C ($p=0.007$).

CONCLUSIONS

- The AVA vasomotion is modified by ambient temperature within the thermoneutral zone. The oscillatory pattern of AVA is more stable at 0.02-0.05 Hz as compared to 0.05-0.08 Hz.
- At 25°C ambient temperature, the laser Doppler flux integrals was high at 0.02-0.05 Hz, while lower values were observed at 0.05-0.08 Hz.

References: 1.**Thoresen M, Walloe L. Skin** blood flow in humans as a function of environmental temperature measured by ultrasound. Acta Physiol Scand. 1980;109(3):333-41. • 2.**Elstad M, Vanggaard L, Lossius AH, Walloe L, Bergersen TK.** Responses in acral and non-acral skin vasomotion and temperature during lowering of ambient temperature. J Therm Biol. 2014;45:168-74. • 3.**Iatsenko D, McClintock PVE, Stefanovska A.** Linear and synchrosqueezed time-frequency representations revisited: Overview, standards of use, resolution, reconstruction, concentration, and algorithms. Digit Signal Process. 2015;42:1-26. • 4.**Stefanovska A, Bracic M, Kvernmo HD.** Wavelet analysis of oscillations in the peripheral blood circulation measured by laser Doppler technique. IEEE Trans Biomed Eng. 1999;46(10):1230-9. • 5.**Hollander M, Wolfe DA.** Nonparametric Statistical Methods: John Wiley & Sons, Inc.; 1999.

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