FREQUENCY OF THE BLOOD-PRESSURE SPECTRAL PEAK AROUND 0.1 Hz AND BAROREFLEX SENSITIVITY IN MAN

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Abstract: According to the mathematical model of the vascular component of baroreflex, the gain of the heart-rate baroreflex sensitivity (BRS) positively correlates with the resonance frequency of the peak in the range of 0.05 - 0.15 Hz. In this study the relationship between BRS and the frequency of the peak in blood-pressure (BP) spectra around 0.1Hz was evaluated. BP was recorded by Finapres in 58 subjects (aged 21 – 22 years) for 18 minutes (3 min at rest - R1, exercise 0.5 W/kg of body weight 9 min analysed in two halves as E1, E2, and 6 min in the recovery period - R2). BRS was calculated by the spectral method. A positive correlation between BRS and the frequency of the spectral peak in systolic BP was found in periods E1 (r=0.436, P<0.01), E2 (r = 0.412, P<0.01), and R2 (r=0.292, P<0.05). A positive correlation between the frequency of the peak in BP-spectra around 0.1 Hz and BRS was confirmed during exercise and during the recovery period respectively. At rest this correlation was not found. This could be explained by the role of autonomic nerves in blood-pressure and heart-rate regulation. BRS mainly corresponds to the gain of parasympathetic activity, which is high at rest. Sympathetic activity, which determines vascular resistance, dominates during exercise.

Introduction

The baroreflex is the main mechanism controlling blood pressure in man. Studies of baroreflex sensitivity have been mostly limited to the heart-rate baroreflex sensitivity. Decreased heart-rate baroreflex sensitivity is an important risk factor in patients after myocardial infarction [1]. There is little information about baroreflex sensitivity of the peripheral resistance.

As peripheral resistance is determined by the activity of the sympathetic nervous system, we have applied the results of studies of the transfer function of the influence of sympathetic nervous activity on peripheral resistance. Japanese authors [2] took advantage of an older study of Penaz' and measured the transfer function by the method of a frequency modulation of stimulation of the efferent peripheral sympathetic system and evaluated the amplitude and the phase shift of the frequency response of peripheral resistance (by a Bode diagram). They found out that this transfer function corresponds to a low-pass filter of the second order with a self-frequency of 0.13 Hz linked in series with a constant lag of 0.4 s. We have applied this finding into a model of the feedback system [3] in which we simulated changes of the feedback gain. This served as a model of baroreflex with variable gain. The resonance peak of the system generated by white noise moved to higher frequencies with increasing gain. According to this model, the peak of a frequency of 0.1 Hz corresponded to a gain G = 1.5. Higher gains shifted this resonance peak to higher frequencies (G = 2, f = 0.13 Hz; G = 3, f = 0.17 Hz; g = 4, f = 0.2 Hz). A gain equal to 1 corresponded to a frequency of 0.05 Hz.

The baroreflex heart-rate sensitivity and the baroreflex sensitivity of peripheral resistance have a partially different control area in the central nervous system, but an identical receptor. We hypothesized that there exists a correlation between the magnitude of the heart-rate baroreflex sensitivity and the shift of the resonance peak to higher frequencies (in a range of 0.1 Hz) in spectra of spontaneous variability in blood pressure. We tested this hypothesis in young healthy subjects at rest and during cycling.

Materials and methods

Blood pressure was recorded by a continuous non-invasive method from finger arteries by Finapres in 58 healthy subjects (21–22 years of age) for 18 minutes. The record was divided into four consecutive intervals: 3 min at rest (R1), exercise 0.5 W/kg of body weight for 9 min (analysed in two halves as E1, E2), and 6 min in the recovery period (R2). At rest and recovery interval controlled breathing, 0.33 Hz was applied. A blood pressure waveform was sampled at 250 Hz, from the sampled signal the inter-beat-interval (IBI) and systolic and diastolic blood pressure (SBP, DBP) sequences were determined, interpolated by cubic splines, resampled at 10 Hz, and filtered by a low-pass filter with an 0.8 Hz cut-off frequency and a linear phase. Finally, the sampling frequency was reduced to 2 Hz. Prior to further processing the mean value and very low frequency components of the signal were removed by a low pass filter with a cut-off frequency of 0.02 Hz and a linear phase.

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Each interval of R1, E1, E2 and R2 has been processed separately. To get a standard of the spectra estimations, the signals of each interval were processed step by step from the beginning to the end of the interval in segments of 2 min length with the step of 1 sample (0.5 s). The autocorrelation series of IBI, SBP, DBP and the cross-correlation series of IBI and SBP for each segment were calculated. The length of correlation τ = 1 min was used. The mean correlation series CoIBI were determined as a mean of the correlation series of all segments of the interval. The same procedure was used for auto-correlations CoSBP, CoDBP and the cross-correlation CoIBISBP. The power spectra SpCoIBI, SpCoSBP, SpCoDBP, and the cross spectrum SpCoIBIDBP were calculated by FFT from these correlation series. The coherence (Coh), and two indices of baroreflex sensitivity (BRS_{CS}, BRS_{ALPHA}) as a function of frequency were determined from these spectra.

$$Coh(f_n) = \frac{SpCoIBISBP^{\,2}(f_n)}{SpCoIBI(f_n)\cdot SpCoIBI(f_n)}\ ,$$

$$BRS_{CS}(f_n) = \frac{SpCoIBISBP(f_n)}{SpCoSBP(f_n)}\ ,$$

$$BRS_{ALPHA}(f_n) = \sqrt{\frac{SpCoIBI(f_n)}{SpCoSBP(f_n)}}\ .$$

The *fn* is the frequency of n-th spectral component (n-th elements of the series). The symbol f_{SBP} has been chosen for a frequency of the SpCoSBP peak and f_{CS} for a frequency of the SpCoIBISBP peak in a range of 0.05 - 0.15 Hz.

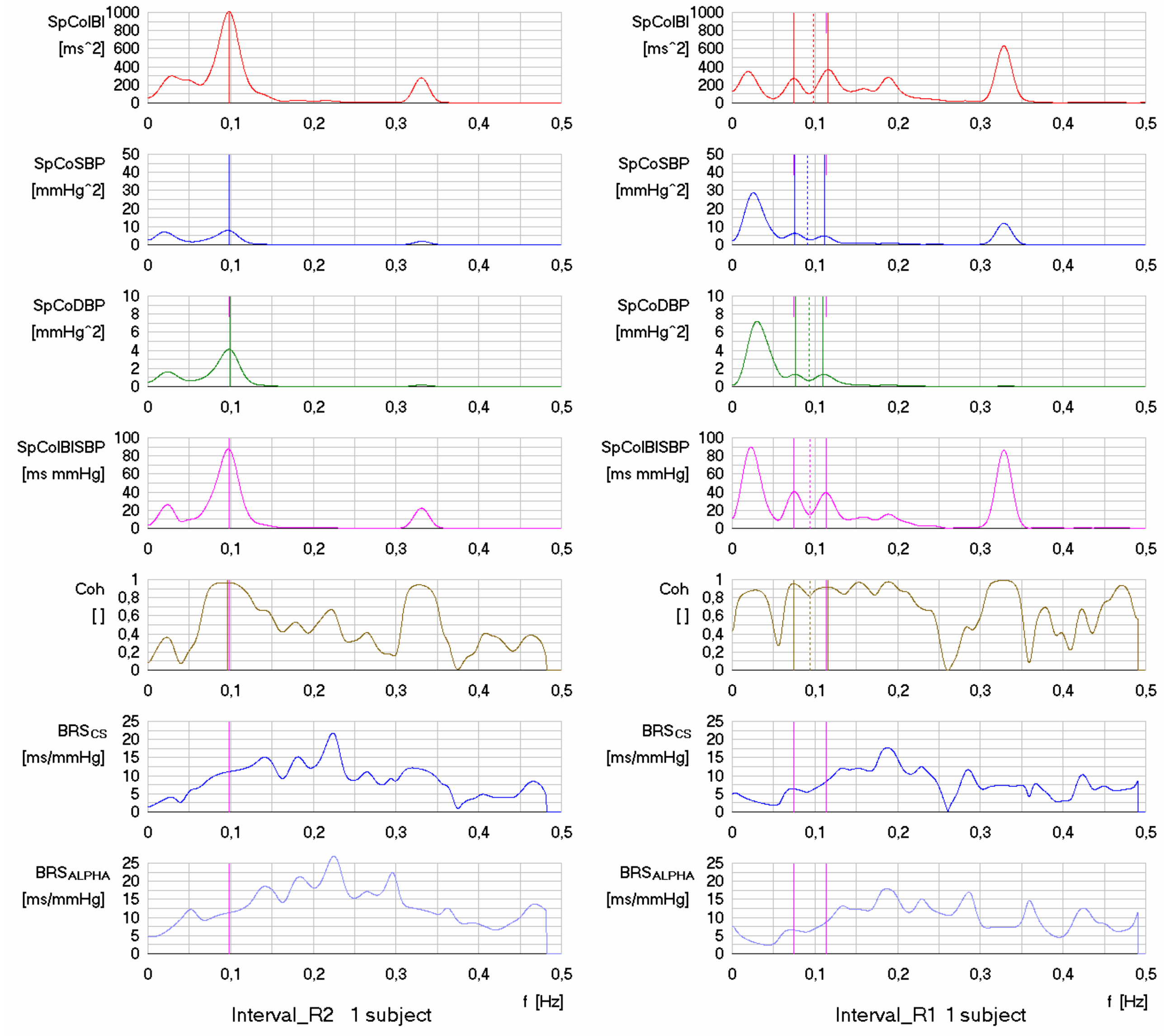

Figure 1: An example of the analysis. One dominant peak was present in a frequency range of 0.05 – 0.15 Hz in most cases (left); in some cases more than one peak existed (right). Abbreviations see in the text.

The values of the indices BRS_{CS} and BRS_{ALPHA} were compared at the frequency f_{CS} and at sufficiently high coherence (> 0.5) – Figure 1. Sometimes two (or more) peaks appeared in SpCoIBISBP, as shown in Figure 1, right. In such cases the corresponding values were determined as a mean of the readings, weighted by magnitudes of SpCoIBISBP peaks.

Results

A positive correlation between BRS and f_{SBP} in the 0.1 Hz range was found in the exercise intervals (E1, E2); it persisted in the recovery interval (R2), but was absent in the initial rest interval (R1) (Table 1).

Table 1: Correlation coefficient (c.c.) between BRS and f_{SBP}, SpCoIBISBP and coherence. p, significance, number of subjects = 58.

Interval	f_{SBP}		SpCoIBISBP		Coherence	
	c.c.	p	c.c.	p	c.c.	p
R1	0.139	-	-0.048	-	0.137	-
E1	0.436	0.01	0.304	0.01	0.354	0.05
E2	0.412	0.01	0.357	0.01	0.244	-
R2	0.292	0.05	0.041	-	0.128	-

The relationship between BRS and the frequency of a peak in a range of 0.05 - 0.15 Hz is demonstrated by mean spectra. In each interval we have summed up not only the spectra of all 58 subjects, but also the spectra of 20 subjects with the highest BRS and of 20 subjects with the lowest BRS.

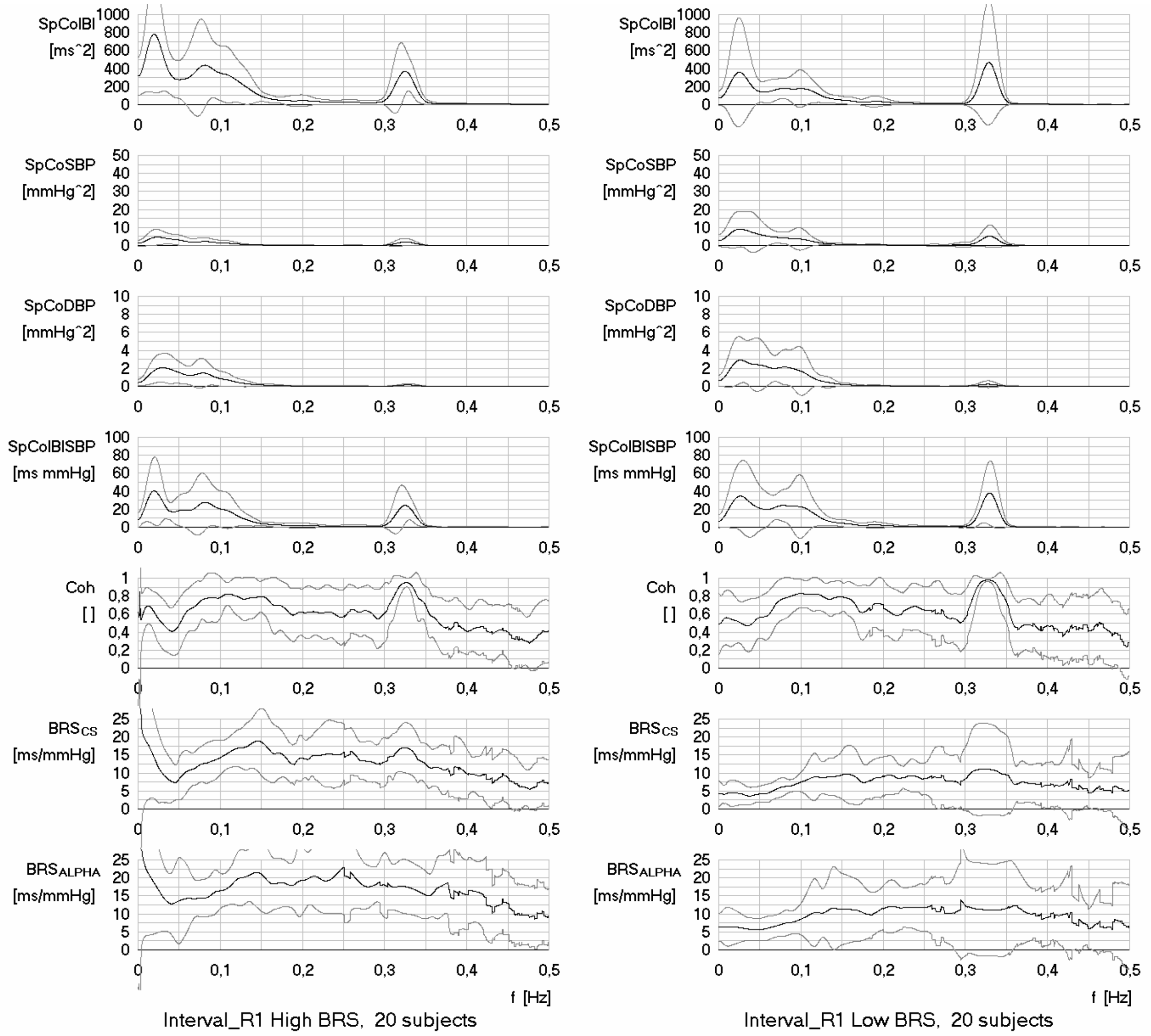

Figure 2: Mean spectra of 20 subjects in R1interval: left - with the highest BRS; right - with the lowest BRS.

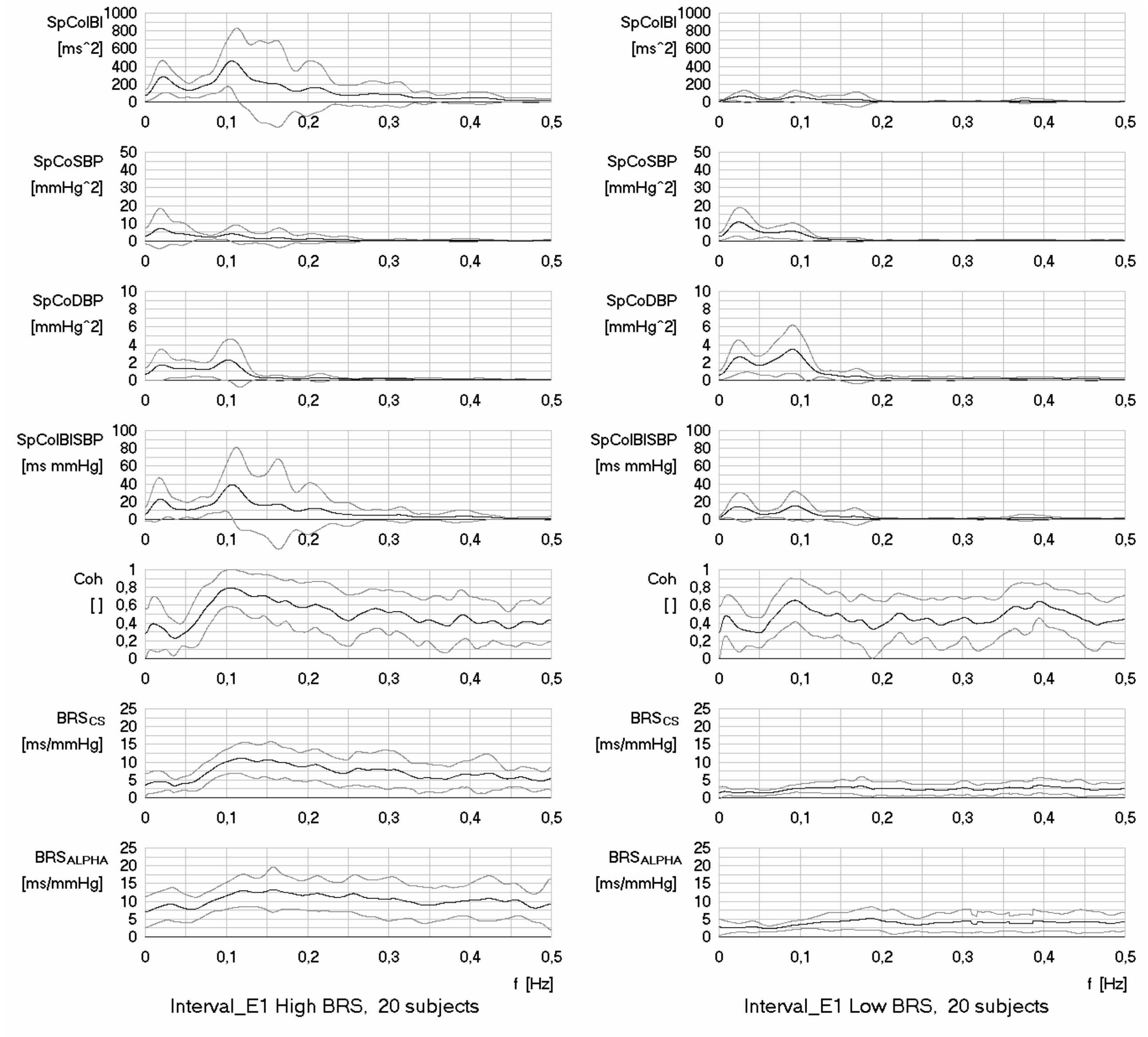

Figure 3: Mean spectra of 20 subjects in E1 interval: left - with the highest BRS; right - with the lowest BRS.

Characteristic results are shown in Figure 2 left (mean spectra of 20 subjects in R1 interval with the highest BRS), Figure 2 right (mean spectra of 20 subjects in R1 interval with the lowest BRS), Figure 3 left (mean spectra of 20 subjects in E1 interval with the highest BRS), and Figure 3 right (mean spectra of 20 subjects in E1 interval with the lowest BRS). In both cases we can see that the lower is the BRS, the higher is the variability of SBP and the lower is the variability of IBI, and vice versa. This corresponds to the role of baroreflex in dampening blood pressure variation. As we can see, during a load the frequency f_{SBP} is shifted toward the lower frequencies if BRS is lower, while at rest - during high parasympathetic reflex activity - the stabilization effect of high BRS on SBP dominates.

The relationship between BRS determined in 20 subjects with their lowest and highest values and f_{SBP}, variability in IBI, variability in SBP, and DBP respectively, calculated for all four periods, is shown in Figure 4. These results document both effects of the value of BRS, the dampening effect of variability of IBI on blood pressure, and the shift of the resonance peak in the blood pressure as well.

Discussion

The effect of the sympathetic and parasympathetic baroreflex control of blood pressure is not symmetric. Information from common baroreceptors activates different effects. While parasympathetic nerves regulate only IBI and, due to its changes, also cardiac output, sympathetic nerves control concomitantly and directly cardiac output and peripheral resistance. With the high gain of the parasympathetic heart-rate regulation, changes of IBI exert their dampening effect on systolic blood pressure variability. Sympathetic effects on both vessels and heart rate are dominant during physical exercise. Therefore, the influence of gain in regulation of the sympathetic system is masked at rest parasympathetic control and is demasked during exercise.

It was shown that the difference between the values of the indices BRS_{CS} and BRS_{ALPHA} at the frequency f_{CS} is almost negligible. The values of BRS_{SC} are a little higher than the BRS_{ALPHA} values.

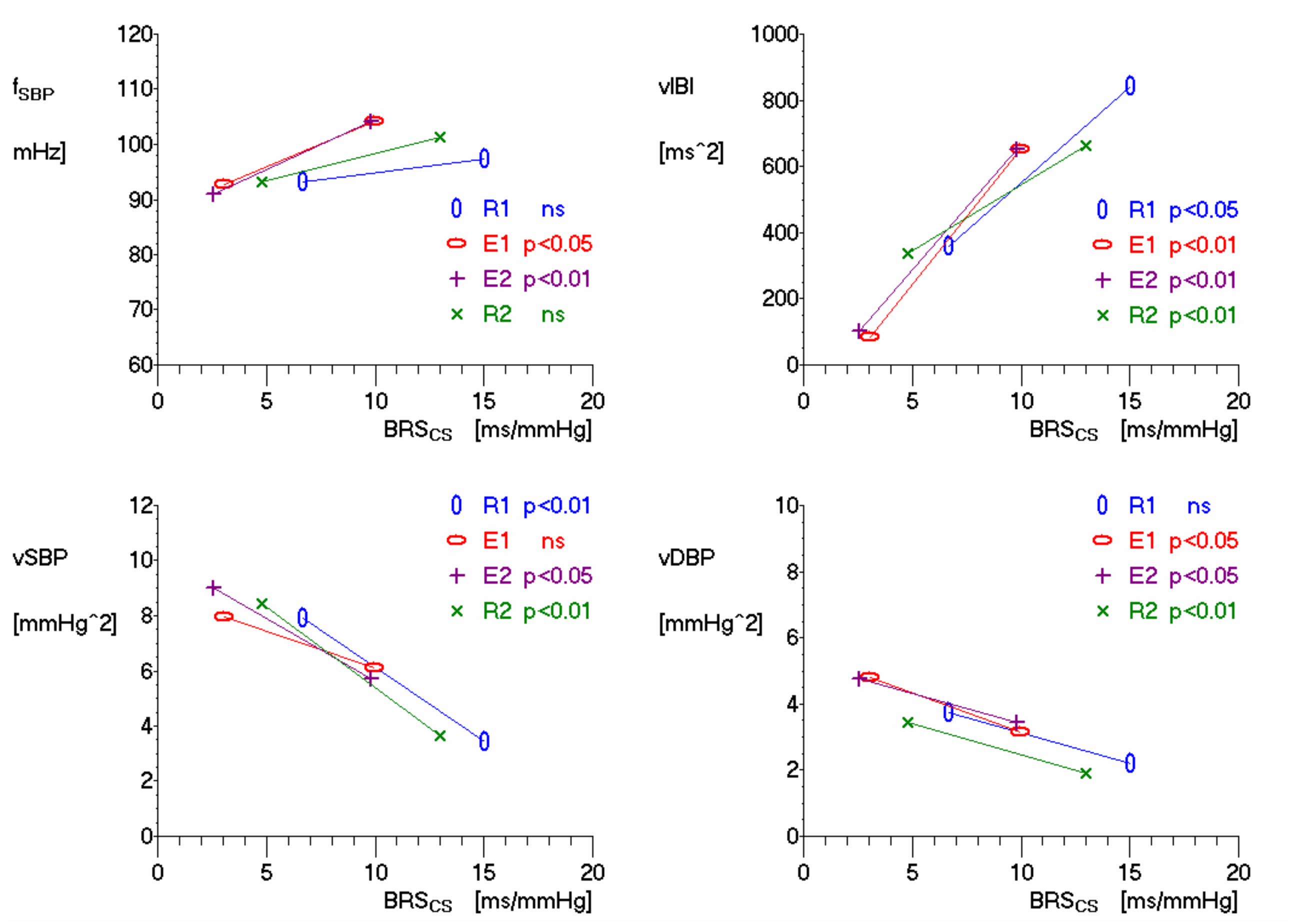

Figure. 4. The relationship between BRS determined in 20 subjects with their lowest and highest values and f_{SBP}, variability in IBI, variability in SBP, and DBP respectively, calculated for periods R1, E1, E2, and R2.

Conclusion

We did not expect any strong relationship between BRS and the frequency of the peak in blood pressure spectra around 0.1 Hz because the gain of the heart-rate component can be different in comparison to the vascular component, but we did expect their correlation because of common baroreceptors.. This assumption was confirmed during exercise, when we found a positive correlation between the frequency of the peak around 0.1 Hz and BRS. At rest no such correlation was found. BRS mainly corresponds to the gain of the parasympathetic activity, which is high at rest. During exercise the sympathetic activity dominates, and this determines vascular resistance.

Acknowledgement

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