Frequency Structure of Heart Rate Variability

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Correlations of heart rate variability (HRV) in humans with different physiological states and ecological environment let us to hope for using of its analysis as a new quantitative diagnostic means. But, there are not reliable diagnostic techniques based on analysis of HRV so far (Paraty at al., 2006). "Complex and largely undiscovered physiology" (Taylor & Studinger, 2006) of HRV is a probable cause of this. Physiological validity of the most parameters of HRV is doubtful. Thus, there is not sufficient evidence (Vetter, 1998) that there are separate frequency ranges and strong boundaries between them. Authors define them voluntary as most probable frequencies of the modulation phenomena (table 1). But the actual ranges may overlap. There may also be any other physiological mechanisms causing periodical modulations of heart rate at the same frequency ranges or at other ones. The aim of this study was to detect the frequency structure of periodical modulations of heart rate in short records.

Methods. ECG was recorded in two groups of 168 and 19 healthy volunteers. In order to avoid a contradiction when series of time intervals (RR) are analyzed as a function of the same time we analyze them as a function of number. 150 harmonics were defined by digital Fourier transformation technique. In order to normalize the distribution of frequency values they were logarithmically transformed. Then factor analysis of the frequencies was carried out.

Results and discussion. The results in each group were similar. Forms of the diagrams of factor loadings of the four first factors are like wave (fig. 1). If we interpret the waves as physiological phenomena of periodical modulation of heart rate, we conclude that there are at least four such phenomenon instead of the two ones mainly being discussed now. The wave of the fourth factor is about from 0.09 to 0.15 1/beat and has peak at 0.13 1/beat. These frequencies coincide with the so called low frequency modulations related with Mayer waves of blood pressure (Hyndman, 1998). Second factor has the wave at about 0.14 – 0.24 1/beat and peak at 0.18 1/beat. It may only be the frequencies of respiratory sinus arrhythmia. The wave of the third factor is about 0.21 – 0.31 1/beat with peak is at 0.26 1/beat. First factor has the wave at frequencies from 0.25 up to 0.5 1/beat and peak 0.35 1/beat. Last two factors have not physiological interpretation.

In conclusion. The results let us suppose that there are at least four periodical phenomena of HRV. Two of them have not been discovered and physiologically explained yet. It has also been confirmed that heart rate oscillations are quasiperiodic and their frequencies vary widely over the main frequencies. Despite of difference of the peak frequencies the waves of factor loadings are overlapped. Therefore, power of spectral density within any frequency range could not measure activity or it's changing of a modulating physiological mechanism.

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Table 1. Frequency ranges of heart rate periodogram by different authors.

№	Name	Frequency	Corrected frequency*, $beat^{-1}$	Author
1	Respiratory effects	0.25-0.40 $beat^{-1}$	--	Sayers B McA, 1973
2	Respiratory frequencies	0.2-0.3 Hz	0.20-0.45	Taylor JA et al., 1998
3	Respiratory waves	0.23-0.19 Hz	0.190-0.345	Aksionov VV, 1986
4	HI-FR	0.224-0.280 Hz	0.224-0.420	Pomeranz B. at al., 1985
5	Mid-frequency	0.12 Hz	0.12-0.18	Akselrod S. at al., 1981
6	Low frequency	0.1 Hz	0.10-0.15	Sayers B McA, 1973
7	Slow waves 1	0.09-0.14 Hz	0.09-0.21	Aksionov VV, 1986
8	Low frequency	0.05-0.15 Hz	0.050-0.225	Taylor JA et al., 1998
9	LO-FR	0.04-0.12 Hz	0.04-0.18	Pomeranz B. at al., 1985
10	Low frequency	0.04 Hz	0.04-0.06	Akselrod S. at al., 1981
11	Slow waves 2	0.027-0.074 Hz	0.027-0.110	Aksionov VV, 1986
12	Very low frequency	0.003-0.03 Hz	0.003-0.045	Taylor JA et al., 1998

* Corrected frequency is frequency measured in 1/beat units calculated on the base of frequency measured in hertz. Its low bound is equal to initial frequency (Hz) because low bound of normal average heart rate equals to 1 Hz, its upper frequency is initial frequency multiply by 1.5 because the upper bound of normal average heart rate equals to 1.5 Hz.

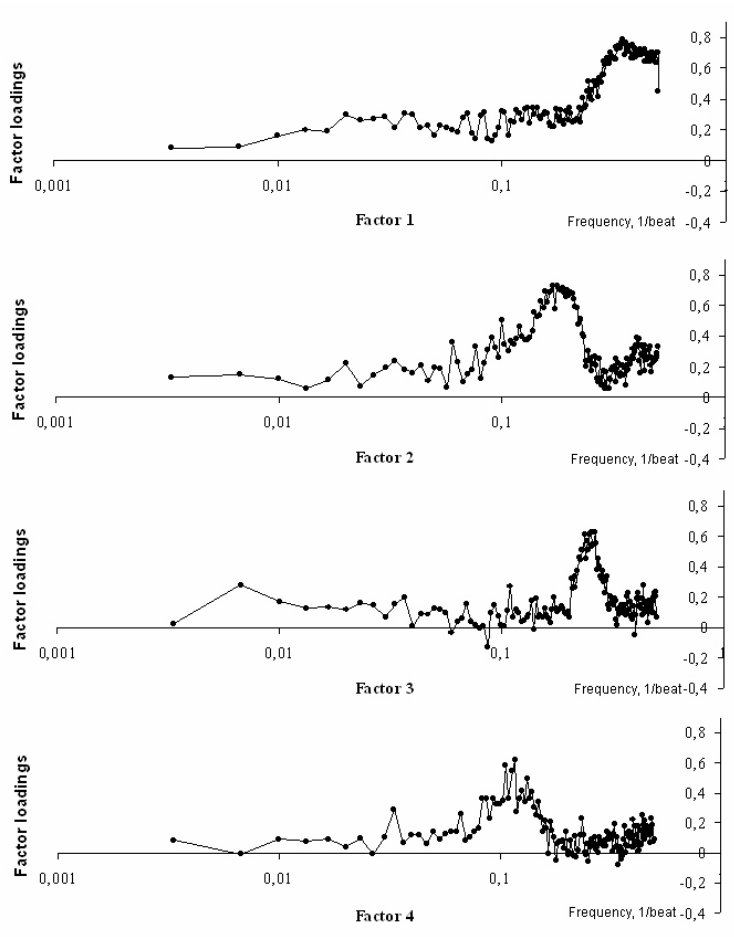

Fig. 1. Diagrams of factor loadings.