

# Dynamics of Low-Frequency Components of Photoplethysmogram Signals in Hypertension

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**Abstract**— Oscillations in the low-frequency range of heart rate variability and photoplethysmogram signals are associated with processes of autonomous control of the cardiovascular system. We have previously shown that synchronization of such processes may be a sensitive indicator of the development of certain diseases. In the course of the study it was shown that these processes are accompanied by a change in power spectral density. The work compared the dynamics of power density in healthy people and patients with hypertension.

**Keywords**— Autonomic control, spectral analysis, heart rate variability, photoplethysmogram

## I. INTRODUCTION

Heart rate variability (HRV) processes and fluctuations in the blood supply to the arterial vessels are distinguished by a complex chaotic dynamics [1]. In a number of works, the degree of irregularity of such fluctuations was associated with the state of health [1-3]. For historical and technical reasons, it was mainly the processes of heart rhythm

regulation that were investigated. At the same time, fluctuations in the blood supply can carry important information about the state of the arterial vessels and the peculiarities of blood flow regulation. Such oscillations are recorded, in particular, using the method of photoplethysmography. In this case, using the open optocoupler, oscillations of the light transmission of the tissues of the limbs are recorded. This is a cheap and non-invasive method. However, the amplitude of the received signals is difficult to calibrate and its depends on many factors. At the same time, the normalization of the oscillation power to the intensity of the characteristic spectral component allows comparing the results of studies of healthy people and patients. In our works, it was previously shown that the assessment of the degree of synchronization of the low-frequency components of photoplethysmogram (PPG) and HRV makes it possible to diagnose the development of certain diseases [3], personalize the choice of therapy [4-5] and predict the survival of patients after myocardial

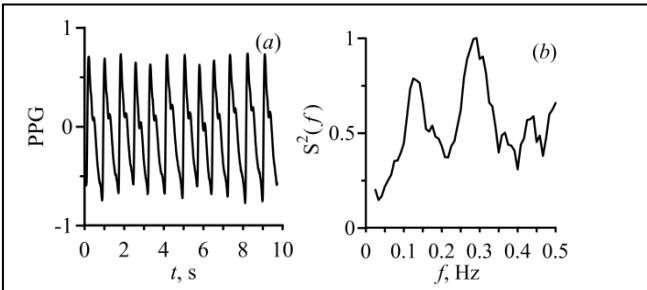


Fig. 1. An example of a typical PPG signal from a healthy subject. (a) - The time series of PPG and (b) - its power spectrum

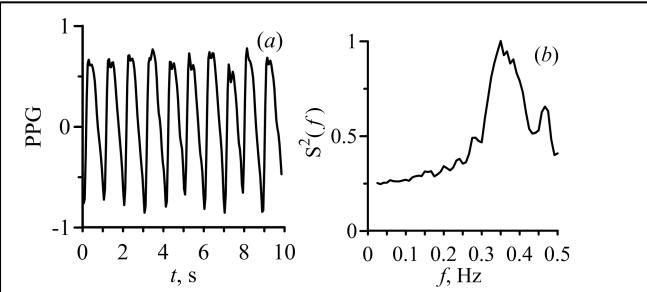


Fig. 2. An example of a typical PPG signal of a patient with arterial hypertension. (a) - The time series of PPG and (b) - its power spectrum

infarction [6]. The purpose of this work is to study the dynamics of the power spectral density in the low-frequency range of the univariate signal of PPG in healthy people and patients with hypertension.

## II. MATERIALS

The study analyzed 12 records of healthy subjects and 12 records of patients with hypertension. The duration of each entry was 10 minutes. The signal of PPG was recorded from a finger sensor. The sensor contained the light-emitting diode and a phototransistor which worked in the infrared range in transmitted light.

Signals were recorded with a standard instrument with a sampling rate of 250 Hz. The bandwidth for  $-3\text{dB}$  power levels was 0,016-30 Hz.

## III. METHODS

In the course of data analysis, signal power spectra were estimated. The periodograms method of Welch was used for this. Time series were divided into 9 windows with a duration of 2 minutes, which shifted with an overlap of 1 minute along the signal. Periodograms were evaluated in each window, which were then averaged. Further, the power spectral density was estimated in the LF (0,04–0,15 Hz) and HF (0,15–0,4 Hz) bands. In accordance with the work of [7–8], the LF range is associated primarily with the sympathetic control of the arterial vessels, and the power in the HF range is associated mainly with parasympathetic activity and the respiratory process. Therefore, the comparison was carried out for the normalized quantities  $\text{LFn}=\text{LF}/\text{HF}$ .

## IV. RESULTS

A typical PPG signal and power spectrum for a healthy subject are presented in Figure 1. Figure 2 shows a typical PPG signal and power spectrum for a patient with hypertension. The spectra are normalized to the maximum

power in the HF band. It is seen that the patient power in the LF range is significantly lower than in healthy.

Statistical analysis of the results shows that  $\text{LFn}$  values in patients with  $0,59\pm0,42$  (mean and standard deviation) are significantly lower than in healthy  $2,34\pm1,92$ . Thus, it was shown that the normalized power of  $\text{LFn}$  in the low-frequency region of the PPG spectrum is significantly reduced in patients with hypertension.

## V. CONCLUSIONS

The obtained results are interesting from the point of view of understanding the work of a complex multicomponent object of biological nature the cardiovascular system. The results may also be relevant for the development of medical diagnostic methods.

## VI. ACKNOWLEDGMENT

The study was carried out as part of the scientific work “Development of a technology for screening health status based on the assessment of nonlinear biophysical properties of blood circulation regulation processes for the primary prevention of chronic cardiovascular diseases”, carried out at the Saratov State Medical University named after VIRazumovsky of the Ministry of Health of Russia in accordance with the state task of the Ministry of Health of Russia for 2019-2021, (development of the method) and was supported by the Grant of the President of Russian Federation (project MD-2202.2019.8) (registration, preliminary analysis and processing of experimental data, spectral analysis).

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