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Connection Between Heart Control and Lungs Pathology Based on The Analysis of An Electrographic Signal Recorded by The Cardiac Monitor CardioQVARK.

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ABSTRACT

An identification method of the pathology of smoker's lungs based on the analysis of an electrographic signal recorded by the cardiac monitor CardioQVARK is suggested and researched in this article.
Keywords: noninvasive screening, ECG, Cardiointerval recording, heart rate variability, pathology of lungs, pathology identification.

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INTRODUCTION

A timely detection of socially significant diseases is an important aim of medical prevention, therefore, the development of new methods and tools for an early detection of deviations in human physiological processes is required. The availability of the method of obtaining initial data for mass screening is also important.

One of the informative and accessible signals of the human body is the electro-cardio signal (ECS). With the introduction of innovative systems of telemetric ECS monitoring this signal became available for mass personalized survey of the organism functional state under free conditions.

As the task of identifying not cardiovascular disease with ECS is new and not enough investigated, it was decided to investigate approaches to the detection of deviations in the organism on the basis of data on smoking, because this information is more available. At the same time, smoking is a not insignificant negative factor leading to pathological changes in the human body.

The non-invasive diagnostic methods, where a large number of indicators of human body state is registered with one measurement and an analysis-interpretation is performed, are being developed. In electrocardiography practice two methods are used: the assessment of the functional state of the sympathetic and parasympathetic divisions of the autonomic nervous system with analysis of heart rate variability (HRV) [1-4] and the comparison of the electrocardiogram (ECG), cardiointervalogram (KIG) of the patient and healthy person [5, 6]. A mathematical analysis of the data obtained by these methods allows to give a prediction about the general state of the nervous system, to determine the nature of cardiac or other disease, the organism's adaptive capability under stress or physical activity [7-11].

The aim of this study is to develop and apply the software and hardware devices for distinguishing between smokers and non-smokers (identification of lungs and other organs abnormalities caused by smoking) based on the analyses of ECG signals received by the CardioQVARK system [1, 12]. The CardioQVARK system is built on the structure of personal telemedicine system (figure 1).

MATERIAL AND METHODS

Personal recording device CardioQVARK (Fig.2) allows to record the ECG signal of the 1st cardiac deflection and send data to cloud server where data storage and analysis is performed [1]. Thus, the CardioQVARK system can be a good means of mass medical personal protection measures.

Figure 1: A schematic description of the CardioQVARK system: a heart rate monitor built into a phone case, an application for the patient, the cloud processing, data transmission and storage, an application for the doctor.

Figure 2: Recording device CardioQVARK

The solution of the problem was based on the hypothesis about the dependence of heart rate variability (HRV) on the organism functional state, known in the works of R. M. Baevsky. This dependence includes the feedback by the peripheral nervous system through the brain that control blood flow, including through dynamic control of heart rate [2].

The experiment consists of three parts:

1) study of connection between heart control and breathing,
2) development of a recognition method of smokers and non-smokers,
3) verification of the results obtained through a representative sample.

1) The experiment was set up using the CardioQVARK system. Figure 3 shows the experiment that was carried out: in the first phase that lasting two minutes, a test person breathes normally; in the second phase that lasting three minutes, a test person produces hyperpnoe (deep respiration). The results of the experiment in the form of fragments of ECG strips and KIG for the whole time period are presented in figure 3. A registered KIG confirms a well-known fact: when you inhale the heart rate increases and during exhalation decreases (respiratory sinus arrhythmia), i.e. the heart work is modulated by lungs function.

Figure 3: A fragment of the ECG strip and KIG of test persons. The KIG vertical axis displays the time intervals between R-waves of ECG, and the horizontal axis displays the moments of occurrence of the R-waves of ECG during the recording.

2) An obvious factor, affecting on both cardiovascular and respiratory system of the person is smoking [13, 14]. As shown earlier, the heart function is modulated by lungs function, and thus, this influence may differ depending on the state of the pulmonary system, pathologies, etc. Two samples (training and control) were collected to conduct the study differences between smokers and non-smokers. The training sample contains 100 unique labeled observations: 50 observations of smokers, 50 observations of non-smokers. A control sample contains 250 observations of unmarked smokers and non-smokers.

Test people in training and control samples are different. Each case was registered, collected and calculated by the CardioQVARK system contains 1) the original ECG signal, 2) anthropometric factors: age, gender, weight, height, 3) HRV indicators: heart rate, number of extrasystoles, standard deviation, coefficient of variation, pNN50, TP, VLF, LF, HF, LF/HF, 4) the array of RR-distances, 5) the average cardiac cycle and its parameters. Data were collected in accordance with the methodical recommendations of Ministry of Health of the Russian Federation [4] and were selected with priority of maximum diversity of people in the sample by gender and age.

A set of parameters was also standardized to range from 0 to 1. To eliminate the difference in variables scale.

A development of software and algorithmic models was made, where an identification and calculation of sensitivity and specificity of smokers and non-smokers were performed.

As a space of input features to build the model, we used the following parameters:

1. Data of the test person: age, sex, weight, height.
2. Indicators of heart rate variability (HRV): heart rate, number of extrasystoles, standard deviation, coefficient of variation, pNN50, TP, VLF, LF, HF, LF/HF, the stress index, IARS.

Several approaches to the solution of the problem were investigated, but the basis of the applied methods formed a spectral Fourier analysis, time-frequency wavelet analysis and neural network analysis.

A multilayer perceptron was chosen as a basic model of artificial neural network (ANN), because it showed positive results under the results of literature and experimental researches. An ANN model used in the study is a classical structure of multi-layer perceptron shown in figure 4.

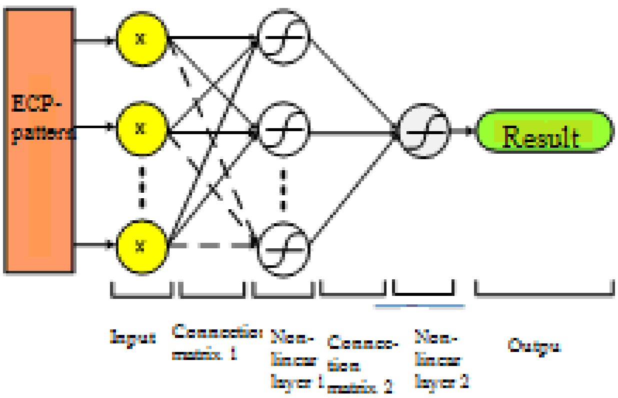

Figure 4: A multilayer perceptron

Structural features:

1) An input layer is used to store and transmit an input pattern and does not contain threshold elements;
2) A hidden and the output layer contain logistic non-linear elements for modeling of neurons action potential;
3) In the output layer there is one neuron, whose signal is connected to the output directly.
4) An output signal is limited to range from 0 to 1.

DISCUSSION OF RESULTS

The artificial neural network model combined with the parameters of heart rate variability and anthropometric data allowed us to obtain identification efficiency indexes of smokers: sensitivity is 84%, specificity is 74%. The predictive significance of a positive result is 76% and negative result is 82%.

Another model based on the selection of maxima in the Fourier spectrum, scaling, selection of characteristics and wavelet analysis gave a result with a sensitivity of 60, 94% and specificity of 78, 57%.

The solution of the problem by different approaches confirms the informative value of cardio signals in the selected task.

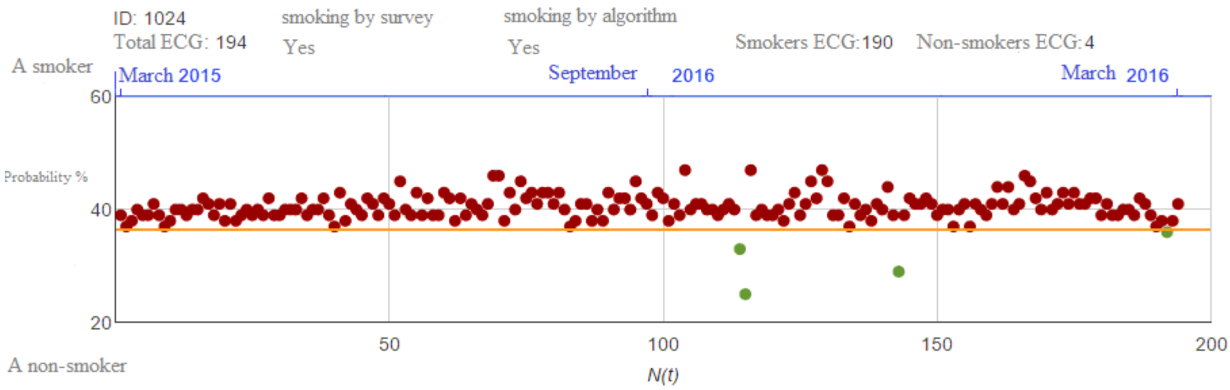

Figure 5: Test person - I., male, 48 years, a smoker, smoking history is 28 years.

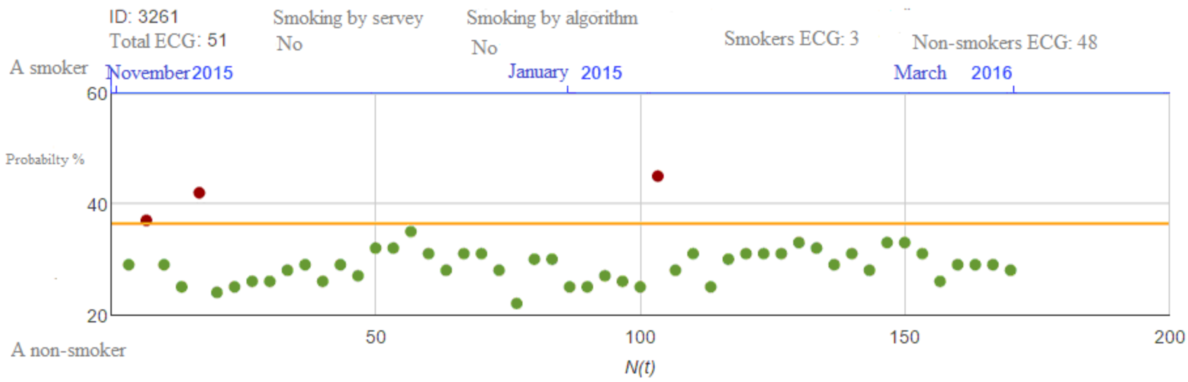

Figure 6: Test person- K., male, 71 years, a non-smoker, no smoking history.

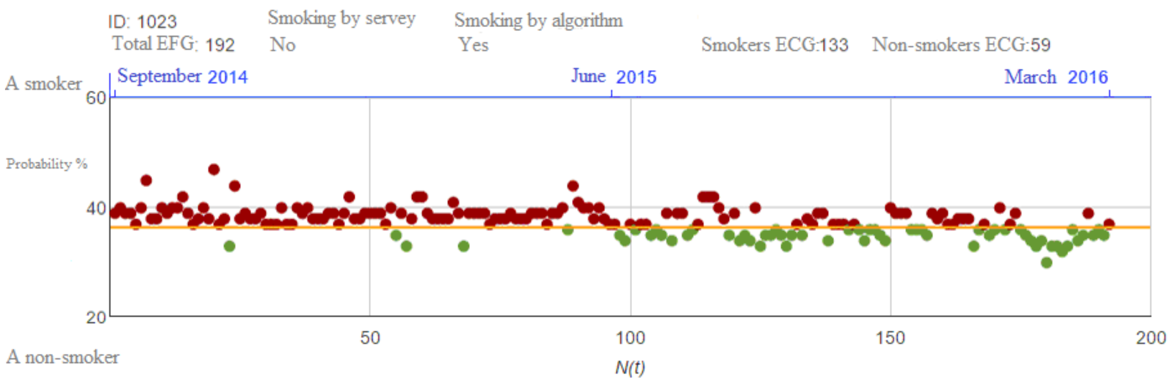

Figure 7: Test person -M., female, 33 years, non-smoker, smoking history - 12 years, nicotine withdrawal sympthoms since August 2015.

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The developed models were applied practically up to the collected base of ECG signals consisting of five minute duration 6650 records and calculated HRV parameters owned to 913 users. Examples of identification are shown in figures 5, 6 and 7, which demonstrate the total number of ECG-recordings of a specific test person, period of their registration, personal data and a result of identification of ECG recordings with signs of a smoker are highlighted in red circles, and signs of a non-smoker are in green.

CONCLUSIONS

An identification method of smokers and non-smokers with a sensitivity of 84% and a specificity of 74% under ECG signals of the 1st standard lead by a heart rate monitor CardioQVARK was proposed and implemented. The final task, in practice, solved by the survey is an exaggerated case of identification; however the results of the study demonstrate the potential feature detection of uncordial-vascular pathologies (including the lungs) according to the cardiac monitoring.

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