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Universal mobile analytical complex for research of respiration and gas exchange in man and animals

Experimental model of universal mobile and compact analytical complex for continuous monitoring of O_2 consumption and CO_2 emissions in breathing humans and laboratory animals has been developed. These gas exchange parameters are calculated based on the simultaneous recording of expiratory flow rate and partial pressures of oxygen (pO_2) and carbon dioxide (pCO_2) in the exhaled air during each respiratory cycle (for a man), and the dynamics of the partial pressures of O_2 and CO_2 in a metabolic chamber (for animals and other biological objects). An analytical complex has a small size, light weight, and measure human respiration and gas exchange immediately during each breathing cycle. The analytical complex consists of two units - the measuring and informational. The first unit consists of a sample preparation module, the sensor module, data logging module and the module data transmission through the channels wired and wireless communications in the information unit. The second unit consists of a module data reception from the measuring unit and the processing module, for the analysis and storage of data. The experimental results showed that the generated mobile analytical complex allows to measure with high precision volumetric expiratory flow rate and the partial pressure of O_2 and CO_2 in the breath of man, as well as the partial pressures of O_2 and CO_2 in a metabolic chamber with the animal The complex has been tested in human studies and in studies on laboratory animals.

INTRODUCTION

The state of energy and plastic metabolism, determined by the intensity of O_2 consumption and CO_2 emissions, is the leading method for diagnosing the functional state of humans and animals [1, 3, 4]. For the determination of these parameters is necessary for a certain period of time continuously, synchronously and accurately carry out measurements space velocity of breathing and the content of O_2 and CO_2 in air exhaled during each breathing cycle.

Currently on the market there are a considerable number of instruments for recording these parameters (EOS-Sprint, ER 800, ER 900, Ergo-line, Oxycon 5, Meta Max 3B, Rapidlab 840, Synthesis 15, Omni 3). The main disadvantages of most of these devices - a complicated procedure of removing moisture from exhaled air, large size, stationary conditions of exploitation, the high cost of the devices themselves and expendable materials.

The purpose of this work - the development of universal, high-speed, compact, mobile and economic access analytical complex for the diagnosis of energy metabolism in humans and animals with the use of new technology, constructive and informational solutions.

DESCRIPTION OF THE DIAGNOSTIC SYSTEM

The analytical complex consists of two units - the measuring and informational. The measurement unit is intended for registration the parameters of external respiration and gas exchange of subjects and transfer this data into information block. The information unit is intended to receive data from the measuring unit and determination on the basis of their state of energy and plastic metabolism, physical efficiency and physical health subjects on the whole complex of recorded and calculated parameters.

The first unit consists of a sample preparation module, the sensor module, electronic data logging module and the data transmission module through the channels a wired or wireless communications to the information unit. The second unit consists of a module data reception from the measuring unit and the processing module for the analysis and storage of data.

Sample preparation module provides a continuous flow of exhaled air in the sensor module. It is thermostatic breathing tube that contains sensors for monitoring the parameters of respiration and gas analysis.

Sensor module consists of three electrodes (sensors), each of which has a high sensitivity to the main determining respiration and gas exchange parameters: volume expiratory flow rate q (l / sec), the partial pressure of O_2 and CO_2 in expired air (mm Hg). Control of the partial pressures of O_2 (amperometry method) and CO_2 (infrared spectroscopy method) is carried out continuously during each exhalation. Each of the sensors generates its electrical potential.

Electronic data logger module (based on microprocessor) performs high-precision measurement of the electrical potentials of the electrodes (measuring range +12.0 V, permissible limit of error ± 0.005 mV) and transmission of these data in the information unit. This information is statistically processed and displayed graphically on the computer screen.

Transmitting and receiving modules sends the data from the measuring unit in the information unit through the channels wired or wireless connection.

Module handling, analysis and storage of recorded data provides their mathematical treatment, visual display of the calculated indicators and storing them in an array of data, tables and graphs.

The basic continuously measured parameters: the volume rate of exhaled air during the respiratory cycle, the content of O_2 and CO_2 in exhaled air and the environment, temperature of the environment, atmospheric pressure.

Definable parameters: indicators of pulmonary ventilation, the intensity of O_2 consumption, CO_2 evolution intensity, the respiratory coefficient.

EXPERIMENTAL RESEARCH

Technical characteristics analytical complex (error measurements and dynamic parameters) determined using the calibration gas mixtures and the stand, simulated gas flow rate of during exhalation, are presented in Table 1.

Table 1. Technical characteristics of sensors.

Registered parameters	Range	Error limit of measurement
pO_2, mmHg	50–200	+0.2
pCO_2, mmHg	0–60	+0.3
Expiratory flow rate, l / s	0 – 12	+ 2%

Investigate the dynamic characteristics of sensors with step changes in the composition and flow rate of gas mixtures showed that the time to reach steady state of their evidence less than 0.1 seconds.

The developed analytical complex allows to carry out continuous measurements recorded parameters of human breathing (volumetric expiratory flow, the partial pressures of O_2 and CO_2 in exhaled air) during each exhalation individually for each measured parameter (Fig. 1), in any combination of the two analyzed parameters (Fig. 2) , as well as to determine their average values for the three parameters being measured in a given period of time of continuous respiration (Fig. 3), which allows to determine the intensity of O_2 consumption and CO_2 emissions.

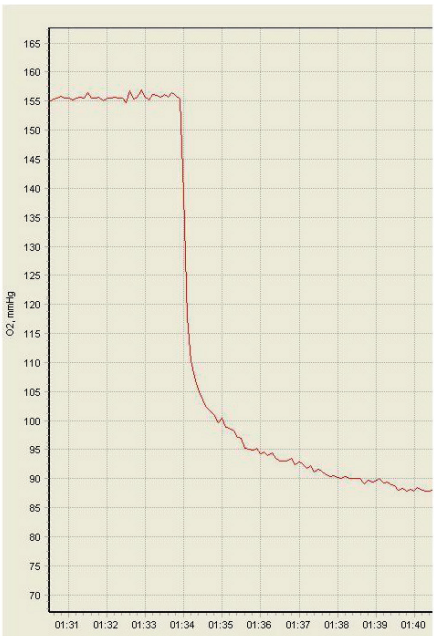

Figure 1. Measurements of the partial pressure of O_2 in the flow of exhaled air during prolonged exhalation. On the horizontal axis - time in minutes and seconds

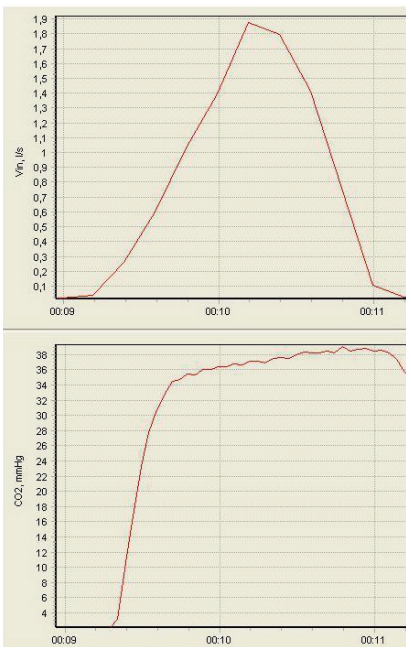

Figure 2. Simultaneous recording of expiratory flow rate (Vin) and the partial pressure of CO_2 in exhaled air. On the horizontal axis - time in minutes and seconds

For laboratory animals these indicators can be determined for a certain period of time in a closed space metabolic chamber (Fig. 4).

Demonstrated research results indicate the possibility of using the analytical complex in physiological studies of the functional state

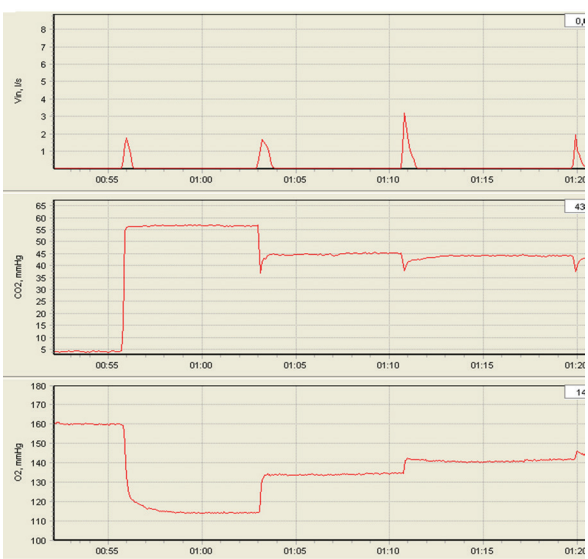

Figure 3. Simultaneous recording of three parameters (volume expiratory flow rate (Vin), the partial pressure of O_2 and CO_2 in exhaled air) after a delay of breathing (55 seconds). On the horizontal axis - time in minutes and seconds

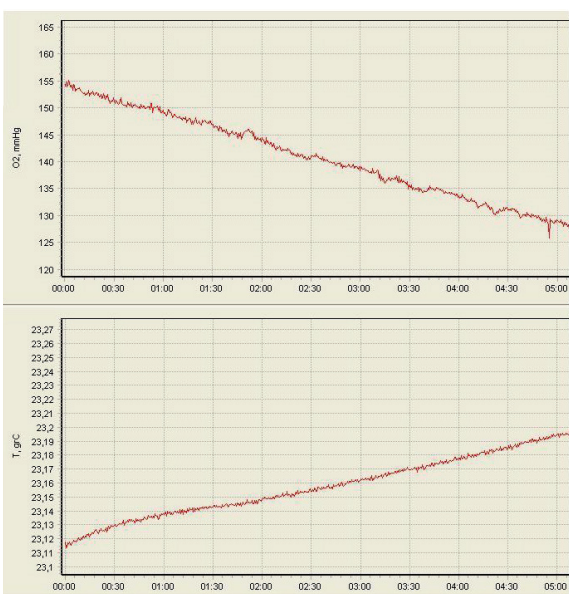

Figure 4. Changes O_2 partial pressure and temperature in the metabolic chamber for 5 minutes stay a rat in it. On the horizontal axis - time in minutes and seconds

of gas exchange and respiratory systems of humans and animals, as well as to measure the basic parameters of the gas exchange of the body (the intensity of O_2 consumption and CO_2 emissions) characterizing its metabolism in normal, pathological and extreme situations [2].

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UNIVERSAL MOBILE ANALYTICAL COMPLEX FOR RESEARCH OF RESPIRATION AND GAS EXCHANGE IN MAN AND ANIMALS

Разработан экспериментальный образец универсального мобильного малогабаритного аналитического комплекса для непрерывного контроля параметров дыхания, потребления O_2 и выделения CO_2 человеком и лабораторными животными. Показатели газообмена вычисляются на основе данных одновременной регистрации объемной скорости выдоха и парциальных давлений кислорода (pO_2), углекислого газа (pCO_2) в выдыхаемом воздухе в процессе каждого дыхательного цикла (для человека) и по динамике парциальных давлений O_2 и CO_2 в метаболической камере (для животных и других биологических объектов). Аналитический комплекс имеет малые габариты, небольшой вес и измеряет параметры дыхания и газообмена человека непосредственно в процессе каждого дыхательного цикла. Он состоит из двух блоков –измерительного и информационного. Измерительный блок включает модуль пробоподготовки, сенсорный модуль, модуль регистрации данных и модуль передачи данных в информационный блок по каналам проводной или беспроводной связи. Информационный блок включает модуль приема данных от измерительного блока и модуль обработки, анализа и хранения зарегистрированных данных. Проведенные экспериментальные исследования показали, что созданный мобильный аналитический комплекс позволяет измерять с высокой точностью объемную скорость выдоха и парциальные давления O_2 и CO_2 в выдыхаемом воздухе человека, а так же парциальные давления O_2 и CO_2 в метаболической камере с животным. Комплекс был испытан в исследованиях на людях и лабораторных животных.

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