ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8

International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com

Development of a Breathing Simulator with Dynamic Tracking of Lung Functions for Rehabilitation after Respiratory Diseases Including COVID-19

Alina Vasilyevna Kesaonova[1], Alexander Igorevich Kesaonov[1], Tatiana Igorevna Dantsevich[2], David Gelaevich Kaishauri[3], Darya Andreevna Ushakova[1], Fatima Magomedrasulovna Radzhabova[1], Khasan Nanurovich Arov[4*], Artem Evgenievich Mishvelov[1,5]

[1]Stavropol State Medical University, Stavropol, RUSSIA.
[2]Kuban State Medical University, Krasnodar, RUSSIA.
[3]Saratov State Medical University, Saratov, RUSSIA.
[4]Nevinnomyssk State Humanitarian and Technical Institute, Nevinnomyssk, RUSSIA.
[5]Socmedica, Skolkovo, Moscow, RUSSIA.
**Corresponding Author (Tel: +79183500889, Email: ruslankalmykov777@yandex.ru).*

Paper ID: 13A8R

Volume 13 Issue 8

Received 04 February 2022
Received in revised form 02 June 2022
Accepted 09 June 2022
Available online 16 June 2022

Keywords:
Respiratory simulator, Lung function, Rehabilitation, Respiratory diseases, COVID-19

Abstract

Rehabilitation of patients with respiratory diseases plays an important role in complex therapy. This article discusses the rehabilitation of patients with respiratory diseases using training using an individual breathing simulator with dynamic lung function control and software.

Disciplinary: Medicine, therapy

Cite This Article:

Kesaonova, A.V., Kesaonov, A.I., Dantsevich, T.I., Kaishauri, D.G., Ushakova, D.A., Radzhabova, F. M., Arov Kh. N., Mishvelov, A.E. (2022) Modern view on the mechanism of development of carpal tunnel syndrome in the prenatal period in women. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 13*(8), 13A8R, 1-12. http://TUENGR.COM/V13/13A8R.pdf DOI: 10.14456/ITJEMAST.2022.165

1 Introduction

According to WHO, respiratory diseases account for 40% of the total morbidity [1]. This problem has become particularly relevant in connection with the pandemic caused by the new coronavirus infection COVID-19. In 70% of COVID-positive patients, pathological changes in the lungs of varying severity were found. At the same time, even a low-symptomatic course of the disease does not guarantee the absence of respiratory damage [2]. Patients with moderate and severe forms of the disease develop bilateral changes in the lungs, which are accompanied by acute respiratory failure. And even after the cure of COVID-19, many patients have residual phenomena accompanied by a decrease in respiratory volume [3,4]. In such cases, the method of restorative training with the help of breathing simulators can be successfully used in the complex rehabilitation of the patient [5]. In this project, it is proposed to develop a breathing simulator with a number of functions that are absent from analogues: the ability to determine the parameters of breathing; the selection of an individual training regime; the presence of an archive with which you can track the dynamics of changes in the patient's condition [6].

2 Literary Review

All breathing gymnastics hardware can be divided into two large classes: 1) breathing simulators that create resistance to breathing and breathing simulators that change the gas composition of the alveolar air; 2) breathing simulators that create resistance to breathing [7].

The first class of breathing simulators is based on a local reduction in the cross-section of the respiratory tract due to the introduction of technical means into the respiratory tract. This contributes to a training increase in the power and endurance of the respiratory muscles and improves breathing [8].

When using these simulators, a slight increase in the concentration of CO2 and a decrease in the concentration of O2 in the alveolar air is possible [9-11].

The second class of breathing simulators includes models that combine the ability to change the composition of alveolar air. This class of simulators can be divided into two groups:

- breathing simulators that create hypoxia.

Devices from this group of simulators, as a rule, are designed for group training, which significantly saves time, but has a number of disadvantages: bulkiness, high cost, and complexity of use.

- breathing simulators that create hypoxia and hypercapnia (hypercapnic hypoxia). Simulators of this group are the most promising since they summarize the therapeutic effects of both oxygen deficiency and excess carbon dioxide. The basis of the work of these breathing simulators is the return breathing (re-respiration), which can be carried out by breathing from a closed circuit or through an "additional volume of dead space" (DOMP).

Thus, it was revealed that the most preferable for practical application is the principle of resistance to both inhalation and exhalation, which will be used in the design of the simulator being developed [11-14].

3 Method

3.1 Development of the Design of an Individual Breathing Simulator with the Function of Dynamic Control of Lung Function

The breathing simulator must have the function of evaluating the parameters of external respiration. All spirometric devices can be divided into open and closed type devices. In open-type devices, inhalation and exhalation are actually produced from the atmosphere. Such devices work on the principle of a pneumotachograph, primarily measuring the speed of air movement, and volumetric indicators are obtained by integrating the flow over time. In closed-type devices, the patient exhales into the device or breathes from some closed (closed) reservoir of variable volume. This design allows, in addition to measuring respiratory volumes and calculating flows, to analyze the gas composition of the respiratory mixture, which is the main advantage of closed-type devices [15,16].

The principle of operation of devices based on a differential pressure gauge is that the respiratory flow is directed into a pipe in which there is an obstacle (actually a narrowing). Another option may be the so-called Pitot tube, in which there is an additional measuring tube in the main pipe with an opening directed parallel to the flow [17]. When the gas flow moves, the pressure in front of the obstacle increases, and after it decreases. There is a relationship between the volumetric flow velocity and the magnitude of the pressure drop, which is determined by the design of the obstacle and a number of other factors [18]. The measured pressure difference can then be converted into the magnitude of the flow that caused the pressure drop. To measure the pressure drop, thermoanemometric sensors and load cells are used, which are the most common at present. The former has greater sensitivity, but is more inertial, and may require a short warm-up so that their character becomes stable [19].

The operation of the turbine converter is based on the proportionality of the speed of rotation of the impeller (rotor) of the gas flow velocity. In modern devices, the number of rotations of the rotor, as a rule, is calculated by the optical method: the rotor, when rotating, periodically blocks the flow of light that is captured by the photodetector [20]. The electronic part of the device counts the number of pulses generated by the photodetector [21]. The obvious advantage of a turbine converter is the simplicity of calculations. The most significant drawback is the inertia of the turbine: it continues to rotate even after the impact of the airflow ceases. In addition, a significant factor is the complexity of the sanitary treatment of sensor parts, which led to the appearance of devices with replaceable turbines.

The ultrasonic flow sensor uses the Doppler effect to measure the linear velocity of the gas flow. Ultrasonic emitters and receivers are located, as a rule, at a minimum angle to the axis of the tube. An essential condition for the operation of such a sensor is the presence in the air of a sufficient concentration of small particles with which ultrasound interacts. The disadvantage of the ultrasonic sensor is low sensitivity, especially at low flows. The most significant advantage lies in the possibility of creating such a structure in which the patient contacts only with a single replaceable individual part - the actual tube through which breathing occurs [22]. This actually solves the problem of preventing the transmission of infections during spirometry, there is no need for regular calibration, but it is necessary to take into account the high cost of such tubes [23-28].

Thus, the optimal solution for the simulator being developed is the use of an ultrasonic sensor measuring the linear velocity of the exhaled air flow to assess the function of external respiration.

With the help of spirometry, the following static lung volumes and capacities can be measured:

− respiratory volume is the volume of air that is inhaled and exhaled during the respiratory cycle;

− reserve exhalation volume - the maximum volume of air that can be exhaled after a calm exhalation;

− reserve inhalation volume - the maximum volume of air that can be inhaled after a normal calm inhalation;

− the vital capacity of the lungs is the maximum volume of air that can be inhaled or exhaled.

Thus, the design of the simulator being developed should provide the measurement of respiratory volumes with the subsequent automated selection of the training mode depending on lung function indicators.

The breathing simulator should be light in weight, mobile, easy to hold in your hand, and equipped with a replaceable mouthpiece. The approximate dimensions of the simulator are 30x20 cm.

The material of the case is plastic. The breathing simulator must contain a tube through which breathing is carried out. An air volume and pressure sensor should be installed in the tube to assess the patient's lung function (vital capacity of the lungs).

The simulator should contain elements of the type of vertical plates, which should be located in the lumen of the breathing tube so as to block the access of air. Vertical plates should be able to change their position by turning (maximum 180-degree rotation) to create resistance to exhalation and inhalation in training mode (Figure 1).

A liquid crystal display reflecting data from sensors and buttons for selecting the training mode should be located on the body of the simulator. Training modes are displayed on the display with numbers from 1 to 3 and depend on the condition of the lungs, intensity and frequency of training.

The simulator must run on batteries with the possibility of recharging. Battery life without charging is at least 24 hours. Working time with a load without charging is at least 4 hours.

To implement the tasks set, the following design elements of the breathing simulator were selected: MPX5010DP air pressure sensor; reusable D-Lite flow sensor; 16X2 I2c character LCD display; Arduino Nano board; plastic breathing tube; elements by the type of vertical plates (material of manufacture - plastic), which should be located in the lumen of the breathing tube so that to block air access; servos that change the position of vertical plates in the lumen of the breathing tube; the body of the device; removable mouthpiece (mouthpiece); battery.

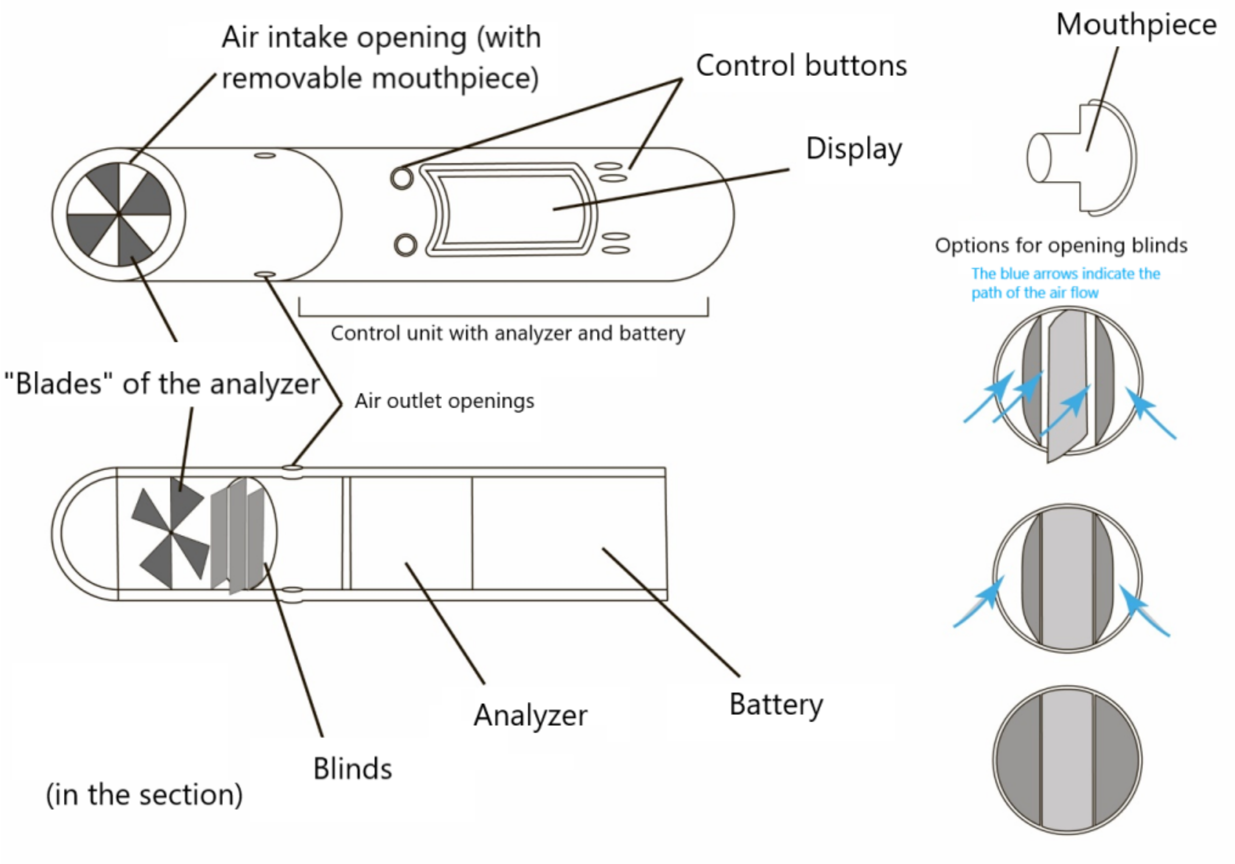


Figure 1: The main design elements of the breathing simulator and their mutual arrangement

3.2 Selection of Materials Taking into Account Their Safety for Health

The device must be safe for patients, medical and service personnel and comply with GOST 20790-93 "Interstate standard. Medical devices, apparatuses and equipment. General technical conditions". The material of the case is plastic. Certain requirements are imposed on the polymers from which the body and some elements (breathing tube, vertical plates, mouthpiece) will be made:

– high chemical resistance to liquid media (contact of mouthpiece with saliva, breathing tube with exhaled air moisture);

– minimal content of easily volatile components (complete absence of odor);

– the ability to print parts on a 3D printer.

These requirements are met by engineering plastics for general and special purposes: ABS plastic, polycarbonate PC, PC/ABS, polybutylene terephthalate PBT, polyamide PA, polymethylmethacrylate PMMA [29].

ABS plastic is the most suitable material for the production of the device body. The combination of acrylonitrile and butadiene links with styrene fragments provides ABS plastic with elasticity and the necessary impact resistance, which makes it one of the most popular plastics for the production of complex molded products with a high degree of extraction. Cheap ABS plastic is produced stabilized in the form of white granules or powder [30, 31].

ABS plastic has a higher resistance to shock loads compared to general-purpose polystyrene, impact-resistant polystyrene and other styrene copolymers.

Thus, the material for the manufacture of the body and parts of the breathing simulator by 3D printing has high chemical resistance, moderately high thermal stability, resistance to gamma and X-ray radiation, good mechanical processing performance, low moisture absorption and scratch resistance.

3.3 Development of the Breathing Simulator Software

The optimal dimensions of the simulator are selected dimensions of 20x30 cm. To implement this, a programmable microcontroller of the Arduino family – the Arduino Nano model - was used as the hardware part of the project. Arduino Nano is a board with minimal dimensions that are best suited for creating compact devices.

The ICSP interface is used to program Atmel controllers on which the Arduino module is assembled. The ICSP pinout for Arduino Nano is shown in Figure 2.

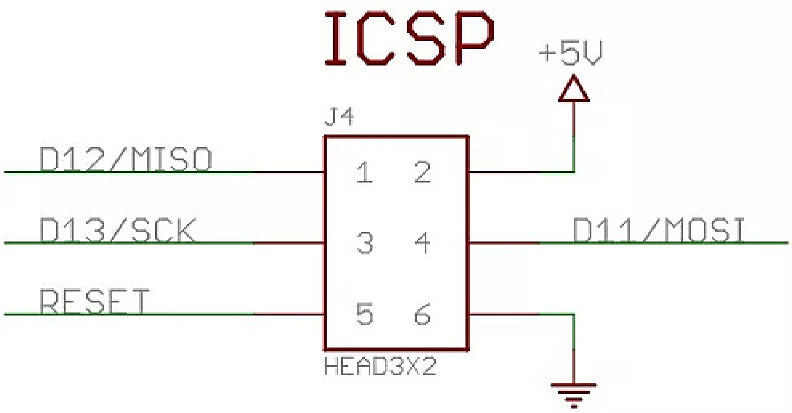


Figure 2: A fragment of the schematic diagram of the Arduino Nano board. The first pin of the 6-pin connector is numbered clockwise:

1. MISO (master accepts from slave);
2. +5V (power supply);
3. SCK (clock pulse);
4. MOSI (master passes to slave);
5. RESET (reset);
6. GND (earth).

Arduino Nano supports an I2C interface for communication with various devices and peripherals. One of the most common applications is communication with the display via the I2C bus. Thanks to this technology, it is possible to output character sets and data to the display using only 2 pins D4 (SDA) and D5 (SCL). In this project, to connect the MPX5010DP air pressure sensor and Arduino Nano, the sensor is connected to pin A0, and the I2C LCD data lines are connected to pins A4 and A5 (Figure 3)

The Arduino IDE development environment and the high-level C++ language are used for programming. The Arduino IDE allows you to compose programs in a convenient text editor, compile them into machine code and upload them to all versions of the Arduino board. The application is completely free.

The project uses the libraries LiquidTWI2 (fast library for LCD displays on MCP23008 or MCP23017 controllers), LCD_1602_RUS (Russian font library for LCD displays), EventManager (library for working with events), GyverStepper (high-performance library for stepper motor control) and CapacitiveSensor (library for creating touch buttons).

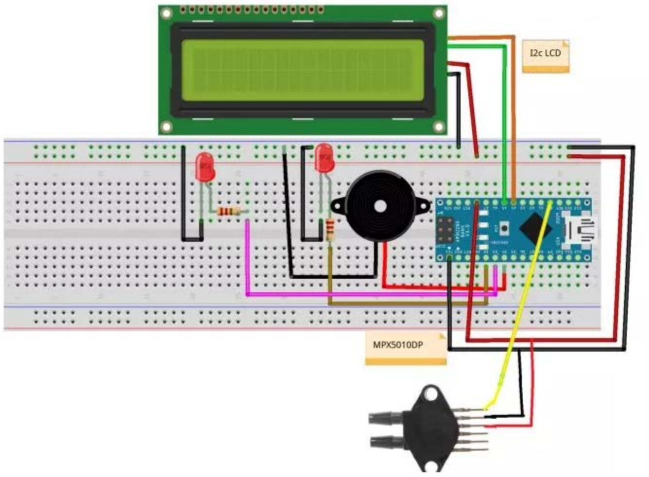


Figure 3: Connection diagram of the air pressure sensor and the Arduino Nano board in a breathing simulator

3.4 Software Setup and Debugging

Debugging a program is one of the most difficult stages of software development. For the purpose of debugging, source code testing and functional testing were carried out. The verification of the claimed functionality was carried out in two directions – to determine the parameters of the vital capacity of the lungs based on the airflow velocity data obtained using sensors, and for the modes of operation of the breathing simulator:

Mode 1 –when the values of the vital capacity of the lungs are from 3500 to 3200 cm3, the rotation of the vertical blinds should ensure the overlap of the lumen of the breathing tube by 75%.

Mode 2 - with values of the vital capacity of the lungs from 3200 to 2900 n cm3, the rotation of the vertical blinds should ensure that the lumen of the breathing tube is blocked by 50%.

Mode 3 - when the values of the vital capacity of the lungs are from 2900 to 2600 cm3, the rotation of the vertical blinds should ensure the overlap of the lumen of the breathing tube by 25%.

If the values of the vital capacity of the lungs are less than 2600 cm3, the display should display the inscription "Low values of the vital capacity of the lungs. See a doctor."

After debugging the software, the system functions smoothly, implementing the actions necessary for the simulator being developed.

4 Result and Discussion

1. The design of an individual breathing simulator with the function of dynamic control of lung function has been developed. The main components of the device are a tube with installed flow sensors (D-Lite) and pressure sensors (MPX5010DP) of air to assess the vital capacity of the lungs; elements of the type of vertical plates to create resistance to exhalation and inhalation in training mode; as well as a 16X2 I2c character LCD display and training mode selection buttons depending on lung functions. An Arduino Nano programmable microcontroller is used as the hardware part. The simulator must run on batteries with the possibility of recharging.

2. Materials have been selected taking into account their safety for health. ABS plastic is the most suitable material for the production of the body and parts of the breathing simulator by 3D printing. The material has high chemical resistance, moderately high thermal stability, resistance to gamma and X-ray radiation, good mechanical processing performance, low moisture absorption and scratch resistance.

3. The breathing simulator software has been developed. The Arduino IDE development environment and the C++ language are used for programming. The project uses the libraries LiquidTWI2 (fast library for LCD displays on MCP23008 or MCP23017 controllers), LCD_1602_RUS (Russian font library for LCD displays), EventManager (library for working with events), GyverStepper (high-performance library for stepper motor control) and CapacitiveSensor (library for creating touch buttons).

4. The software has been configured and debugged. The verification of the claimed functionality was carried out in two directions – to determine the parameters of the jet based on the data of the airflow velocity obtained using sensors, and for the modes of operation of the breathing simulator. There are 4 modes of operation of the device – 1 diagnostic and 3 training modes.

The novelty of the project is to create a breathing simulator with sensors that measure the volume and velocity of the exhaled air flow, according to which it is possible to assess lung function. Based on the individual parameters of the patient, the optimal mode of respiratory training will be selected using algorithms implemented in the software. The method of breathing training is based on the creation of resistance to inhalation and exhalation to a certain extent, depending on the state of the respiratory system. In response to the formation of hypercapnia, respiratory patterns are stimulated and, as a result, respiratory muscles are trained, followed by the restoration of respiratory volumes.

5 Conclusion

The design of an individual breathing simulator with the function of dynamic control of lung function has been developed. The elements of the simulator being developed should provide the measurement of respiratory volumes with the subsequent automated selection of a training regime depending on lung function indicators. The main components of the device are a tube with installed air volume and pressure sensors to assess the vital capacity of the lungs, elements of the type of vertical plates that are able to change their position by rotation (maximum rotation by 180 degrees), to create resistance to exhalation and inhalation in training mode, as well as a liquid crystal display reflecting data from sensors, and training mode selection buttons depending on lung function.

Materials have been selected taking into account their safety for health. For the production of the body and parts of the breathing simulator by 3D printing, the most suitable material is ABS plastic.

The breathing simulator software has been developed. The Arduino IDE development environment and the C++ language are used for programming.

The software has been configured and debugged.

Thus, based on scientific analysis, the design of an individual breathing simulator with the function of dynamic control of lung function and software for its operation has been developed.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

7 Acknowledgment

The work was carried out using the Center for Collective Use of the North Caucasus Federal University.

8 References

[1] Gold MS, Sehayek D, Gabrielli S, Zhang X, McCusker C, Ben-Shoshan M. COVID-19 and comorbidities: a systematic review and meta-analysis. Postgrad Med. 2020 Nov;132(8):749-755. DOI: 10.1080/00325481.2020.1786964.

[2] Rauf A, Abu-Izneid T, Olatunde A, Ahmed Khalil A, Alhumaydhi FA, Tufail T, Shariati MA, Rebezov M, Almarhoon ZM, Mabkhot YN, Alsayari A, Rengasamy KRR. COVID-19 Pandemic: Epidemiology, Etiology, Conventional and Non-Conventional Therapies. *International Journal of Environmental Research and Public Health*. 2020; 17(21):8155. DOI: 10.3390/ijerph17218155

[3] Magomedov, M. A., Shebzukhov, N. R., Timerbulatova, T. R., Amrakhov, E. M. ogly, Adzhieva, M. E., Murdalov, R. A., Ilbekov, R. K., Batalova, H. I., Isaeva, M. M., Ibragimov, A. M. and Povetkin, S. N. (2021) “A Proposed Insight into the Anti-viral Potential of Silver Nanoparticles against Novel Coronavirus Disease (COVID-19)”, *Journal of Pharmaceutical Research International*, 33(41B), pp. 79-93. DOI: 10.9734/jpri/2021/v33i41B32347

[4] Ayivi R, Ibrahim S, Colleran H, Silva R, Williams L, Galanakis C, Fidan H, Tomovska J and Siddiqui SA. COVID-19: human immune response and the influence of food ingredients and active compounds. Bioactive Compounds in Health and Disease. 2021;4(6):100

[5] Mishununa VV, Chapanov MM, Gakaeva KI, Tsoroeva MB, Kazanova SA, Gorlova MI, et al. Computed Quantum Chemical Modeling of the Effect of Nanosilver on Coronavirus COVID-19. Pharmacophore. 2021;12(2):14-21

[6] Elnady FA, Sheta E, Khalifa AK, Rizk H. Training of upper respiratory endoscopy in the horse using preserved head and neck. ALTEX. 2015;32(4):384-7. DOI: 10.14573/altex.1505111

[7] Panaviene J, Pacheco A, Schwarz CE, Grygoryev K, Andersson-Engels S, Dempsey EM. Gas in scattering media absorption spectroscopy as a potential tool in neonatal respiratory care. Pediatr Res. 2022 May 23. DOI: 10.1038/s41390-022-02110-y

[8] Magomedova UG, Khadartseva ZA, Grechko VV, Polivanova MN, Mishvelov AE, Povetkin SN, et al. The role of Covid-19 in the acute respiratory pathology formation in children, Pharmacophore. 2020;11(5):61-65

[9] Ghazy A, Chaban R, Vahl CF, Dorweiler B. Development and evaluation of 3-dimensional printed models of the human tracheobronchial system for training in flexible bronchoscopy. Interact Cardiovasc Thorac Surg. 2019 Jan 1;28(1):137-143. DOI: 10.1093/icvts/ivy215

[10] Maslova, A. Y., Tskaeva, A. A., Ashurova, Z. A., Abazova, A., Ismailov, M. M., Ismailova, M. M., Baklanov, I. S., Mishvelov, A. E., Povetkin, S. N. and Baklanova, O. A. (2021) "Study of the effect of Baricitinib on the Course of COVID-19", *Journal of Pharmaceutical Research International*, 33(35A), pp. 204-213. DOI: 10.9734/jpri/2021/v33i35A31890

[11] MacIntyre NR. Respiratory system simulations and modeling. Respir Care. 2004 Apr;49(4):401-8; discussion 408-9.

[12] Lopteva MS, Povetkin SN, Pushkin SV, Nagdalian AA. 5% suspension of albendazole echinacea magenta (Echinacea purpurea) Toxicometric Evaluation Entomology and Applied Science Letters. 2018;5(4):30-34

[13] Siddiqui SA, Ali Redha A, Snoeck ER, Singh S, Simal-Gandara J, Ibrahim SA, Jafari SM. Anti-Depressant Properties of Crocin Molecules in Saffron. Molecules. 2022; 27(7):2076. DOI: 10.3390/molecules27072076

[14] West JB. Causes of and compensations for hypoxemia and hypercapnia. Compr Physiol. 2011 Jul;1(3):1541-53. DOI: 10.1002/cphy.c091007.

[15] Tovlahanova TJH et al. Study of the Effect of the Image Scanning Speed and the Type of Conductive Coating on the Quality of Sem-Micrographs of Oxide Nano Materials for Medical Use. Ann Med Health Sci Res. 2021;11:S3:60-64

[16] Orsaeva AT, Tamrieva LA, Mischvelov AE, Osadchiy SS, Osipchuk GV, Povetkin SN, Simonov AN. Digital clinic "smart ward. Pharmacophore. 2020;11(1):142-146

[17] Siddiqui, S.A., Ahmad, A. Implementation of Newton's Algorithm Using FORTRAN. SN COMPUT. SCI. 1, 348 (2020). DOI: 10.1007/s42979-020-00360-3

[18] Siddiqui S. A., Ahmad A., Siddiqui A. A. and Chaturvedi P. Stability Analysis of a Cantilever Structure using ANSYS and MATLAB. 2nd International Conference on Intelligent Engineering and Management (ICIEM), 2021, 7-12, DOI: 10.1109/ICIEM51511.2021.9445357

[19] Yasnaya MA, Blinov AV, Blinova AA, Shevchenko IM, Maglakelidze DG, Senkova AO. Determination of optimal modes for measuring the size of colloidal particles by photon-correlation spectroscopy and acoustic spectroscopy. Physical and Chemical Aspects of the Study of Clusters Nanostructures and Nanomaterials. 2020;12:232-242

[20] Siddiqui S. A. and Ahmad A., "Dynamic analysis of an observation tower subjected to wind loads using ANSYS," 2021 2nd International Conference on Computation, Automation and Knowledge Management (ICCAKM), 2021, pp. 6-11, DOI: 10.1109/ICCAKM50778.2021.9357728

[21] Lunin, LS, Lunina, ML, Kravtsov AA, Blinov AV. Effect of the Ag nanoparticle concentration in TiO2–Ag functional coatings on the characteristics of GaInP/GaAs/Ge photoconverters. Semiconductors. 2018;52:993-6. DOI: 10.1134/S1063782618080122

[22] Lunin, L.S., Lunina, M.L., Kravtsov, A.A. *et al.* Synthesis and study of thin TiO_2 films doped with silver nanoparticles for the antireflection coatings and transparent contacts of photovoltaic converters. *Semiconductors* 2016; 50, 1231-1235.

[23] Katz S, Arish N, Rokach A, Zaltzman Y, Marcus EL. The effect of body position on pulmonary function: a systematic review. BMC Pulm Med. 2018 Oct 11;18(1):159. DOI: 10.1186/s12890-018-0723-4.

[24] Grübler MR, Wigger O, Berger D, Blöchlinger S. Basic concepts of heart-lung interactions during mechanical ventilation. Swiss Med Wkly. 2017 Sep 12;147:w14491. DOI: 10.4414/smw.2017.14491

[25] Li SN, Hobbins L, Morin JB, Ryu JH, Gaoua N, Hunter S, Girard O. Running mechanics adjustments to perceptually-regulated interval runs in hypoxia and normoxia. J Sci Med Sport. 2020 Nov;23(11):1111-1116. DOI: 10.1016/j.jsams.2020.04.001

[26] De Smet S, D'Hulst G, Poffé C, Van Thienen R, Berardi E, Hespel P. High-intensity interval training in hypoxia does not affect muscle HIF responses to acute hypoxia in humans. Eur J Appl Physiol. 2018 Apr;118(4):847-862. DOI: 10.1007/s00421-018-3820-4

[27] Shen YC, Chen L, Wen FQ. [Inter[retation of 2019 Global Strategy for the Diagnosis, Management and Prevention of chronic Obstructive Pulmonary Disease]. Zhonghua Yi Xue Za Zhi. 2018 Dec 25;98(48):3913-3916. Chinese. DOI: 10.3760/cma.j.issn.0376-2491.2018.48.001.

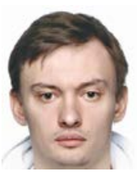
[28] Halpin DMG, Criner GJ, Papi A, Singh D, Anzueto A, Martinez FJ, Agusti AA, Vogelmeier CF. Global Initiative for the Diagnosis, Management, and Prevention of Chronic Obstructive Lung Disease. The 2020 GOLD Science Committee Report on COVID-19 and Chronic Obstructive Pulmonary Disease. Am J Respir Crit Care Med. 2021 Jan 1;203(1):24-36. DOI: 10.1164/rccm.202009-3533SO.

[29] Siddiqui, S.A., Pahmeyer, M.J., Mehdizadeh, M., Nagdalian, A.A., Oboturova, N.P., Taha, A. (2022). Consumer Behavior and Industry Implications. In: Galanakis, C.M. (eds) The Age of Clean Label Foods. Springer, Cham. DOI: 10.1007/978-3-030-96698-0_7

[30] Vijayan VK. Chronic obstructive pulmonary disease. Indian J Med Res. 2013 Feb;137(2):251-69.

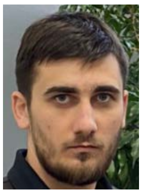
[31] Graham BL, Steenbruggen I, Miller MR, Barjaktarevic IZ, Cooper BG, Hall GL, Hallstrand TS, Kaminsky DA, McCarthy K, McCormack MC, Oropez CE, Rosenfeld M, Stanojevic S, Swanney MP, Thompson BR. Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement. Am J Respir Crit Care Med. 2019 Oct 15;200(8):e70-e88. DOI: 10.1164/rccm.201908-1590ST.

Alina Vasilyevna Kesaonova is a student of Stavropol State Medical University, Stavropol, Russia



Alexander Igorevich Kesaonov is a student of Stavropol State Medical University, Stavropol, Russia

Tatiana Igorevna Dantsevich is a student of Kuban State Medical University, Krasnodar, Russia



David Gelaevich Kaishauri is a student of Saratov State Medical University, Saratov, Russia

Darya Andreevna Ushakova is a student of Stavropol State Medical University, Stavropol, Russia

Fatima Magomedrasulovna Radzhabova is a student of Stavropol State Medical University, Stavropol, Russia

Dr.Khasan Nanurovich Arov (PhD) is an Associate Professor at Nevinnomyssk State Humanitarian and Technical Institute, Nevinnomyssk, Russia

Artem Evgenievich Mishvelov is a Junior Researcher at the 3D Technology Laboratory of Stavropol State Medical University, Stavropol, Russia. He is Head of Project Activities in the North Caucasus Federal District, Socmedica, Skolkovo, Moscow, Russia.