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Investigation of the Respiratory System Function in Relation to the Blood Oxygen Levels in a COVID-19 Pandemic Among the Humans Living a Healthy Lifestyle

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Abstract. The need to monitor the health status of the population in the pandemic conditions has actualized the technologies development aimed at assessing the health status of the various population groups in general and assessing the function of the respiratory system, in particular. The aim of this investigation is to evaluate the respiratory system functions of relatively healthy humans having healthy lifestyle during the COVID-19 pandemic.
Participants (n=330): students (n=123), university teachers and staffs (n=32), residents of Krasnoyarsk city (n=175) participated in this study. Methods of the respiratory system function assessment were used for the medical and pedagogical control, individual health and health of different population groups monitoring in the educational, medical and sports institutions.
It was established that the results of the respiratory system of the life capacity index calculation and the levels characteristics will have to correspond to the "clinical picture" of the patients obtained as a result of the clinical methods application and that the saturation level of the studied people group (78 % of the total number of subjects) having healthy lifestyle in the pandemic conditions is within the boundaries of the medium–high levels on the interval saturation scale.
This research showed that the saturation level of the most part of the studied subjects (78 % of the total number of subjects) living a healthy lifestyle in the conditions of the

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pandemic is within the boundaries of the medium–high levels on the interval scale of the saturation which corresponds to the “general average norm of saturation” (95–100 %) for a practically healthy persons, who regularly engaged in the physical activity. The highest rates reflecting the working level of saturation are inherent with a person leading a healthy lifestyle in the middle of the day with an average active motor regime of health-improving physical training in the absence of illness and fatigue.

Keywords: pandemic, respiratory system function, life capacity index of respiratory system, medical and pedagogical control, health monitoring, population groups, healthy lifestyle.

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Research area: physical education and vocational physical training.

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Исследование функции дыхательной системы в зависимости от уровня содержания кислорода в крови у людей, ведущих здоровый образ жизни во время пандемии COVID-19

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Аннотация. Необходимость мониторинга уровня состояния здоровья населения в условиях пандемии актуализировала разработку технологий, направленных на оценку состояния здоровья различных групп населения в целом и оценку функции дыхательной системы в частности. Цель научной работы: оценить функции дыхательной системы относительно здоровых людей, ведущих здоровый образ жизни во время пандемии COVID-19.

В исследовании приняли участие: студенты (n=123), преподаватели и сотрудники вузов (n=32), жители города Красноярска (n=175). Методы оценки функционирования

дыхательной системы использовались для медико-педагогического контроля, мониторинга индивидуального здоровья и здоровья различных групп населения в образовательных, медицинских и спортивных учреждениях.
Установлено, что результаты расчета жизненного индекса и характеристики уровней функционирования дыхательной системы должны соответствовать «клинической картине» пациентов, полученной в результате применения клинических методов, и что уровень насыщения кислородом в исследуемой группе, ведущей здоровый образ жизни (78 % от общего числа участников) в условиях пандемии, находится в пределах от среднего до высокого по шкале сатурации.
Исследование показало, что уровень сатурации у большей части исследуемых лиц, ведущих здоровый образ жизни в условиях пандемии, находится в границах от среднего до высокого – по шкале сатурации, что соответствует «общей средней норме сатурации» (95–100 %) для относительно здоровых людей, регулярно занимающихся физическими упражнениями. Самые высокие показатели, отражающие рабочий уровень сатурации, присущи человеку, ведущему здоровый образ жизни, с активным двигательным режимом оздоровительных физических тренировок при отсутствии болезней и усталости.

Ключевые слова: пандемия, функции дыхательной системы, жизненный индекс, медико-педагогический контроль, мониторинг здоровья, различные группы населения, здоровый образ жизни.

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Introduction

Nowadays it has become obvious that COVID-19 pandemic being one of the manifestations of the anthropological crisis of the modern civilization is not only a medical problem. In the history of a humans, all social, state and religious structures took part in the fight against the epidemics. The global scale of the epidemic which defined it as a pandemic posed the acute and vital questions to the modern human and undoubtedly being a negative phenomenon at the same time activated the world community and first of all the various scientific groups to solve the practical problems aimed at combating COVID-19 pandemic (Maison, et al., 2021; Han, 2020). Under the constraints of counteraction to the infection spread our country continued to carry out the highly productive activities. The tasks of the health monitoring and development of the health-saving technologies in the context of the fight against the epidemic acquire the priority importance (Derigny, et al., 2023; Semiz, 2022; Kokhan, et al., 2021; Nagovitsyn, et al., 2018). The Siberian Federal University (SibFU) is one of the leading universities in the country. The University is also a center of the active citizens of the various age groups who lead a productive and healthy lifestyle. Being participants of the educational process, the teaching, administrative, educational support staff and students of the university were in the group of the increased disease risk which actualized the adoption

of preventive measures in order to save their health. The increased interest of the researchers to the saturation allowed to form a sufficiently extensive empirical base allowing to make some conclusions and generalizations. Also, the finger heart rate monitor became as widely available and used device of "home first aid kit" as the thermometer and tonometer. At present, scientists & physicians presented the norms of the oxygen content in blood, specificity of manifestation of this index in various diseases, surgical interventions, dependence of saturation on natural and climatic conditions (Polevoy, 2023; WHO, 2022; Rauniyar, et al., 2020; Vold, et al., 2015).

This makes it possible to use estimation of the level of saturation in the development of health-saving strategies. The nature of disease courses and ways of the human infection with COVID-19 including by the airborne droplets as well as the "post-COVID" state of the human health once again emphasized the importance of respiration (especially the respiratory system providing it) as one of the most important functions of regulating the vital activity of the human organism (Singh, et al., 2022; Kim, et al., 2017). A healthy person with normally functioning lungs breathing air at the sea level will have arterial blood oxygen saturation about 95–100 % (Hennink, & Kaiser, 2022). The body's blood oxygen requirements may fluctuate for example during the exercises when more oxygen is required or when you are at high altitudes above sea level.

The main methods of study of the external respiratory function (ERF) at present are: spirometry, pneumotachometry, bodyplethysmography, pulmonary diffusion study, measurement and ergospirometry (Rauniyar, et al., 2020; Varentsova, et al., 2018; DeMeulenaere, 2007). However, the general disadvantage of these methods for assessing the function of the respiratory system is rather limited availability, costliness, the need for special and complex equipment as well as the lack of the comprehensive assessment of the parameters of the respiratory links.

Thus, the aim of this investigation to evaluate the respiratory system functions of relatively healthy humans leading a healthy lifestyle during the COVID-19 pandemic on the basis a comprehensive, non-invasive technique for assessing the function of the respiratory system taking into account the level of the oxygen content in the blood applicable for the purposes of medical and pedagogical control of the human physical development, diagnosis of pre-disease and self-assessment of health.

The particular tasks of this investigation are defined as:

– the study and analysis of the scientific literature;

– the development of the interval saturation scale (ISS) allowing to estimate the level of the oxygen content in the blood;

– the development of a calculating method of the vital capacity index of the respiratory system (LCIRS).

The conceptual study of this investigation

1. The General Systems Theory – a methodological concept that describes the structure regularities, behavior, functioning and development of the systems which is proposed by the Austrian philosopher of Biology – Ludwig von Bertalanffy (Assche, et al., 2019);

2. The concept of N.M. Amosov which defines the "health" as the sum of capacities reserves of the main functional systems of the organism (Ustinova, 2014);

3. The concept of the physiological shunt (when VA/Q is below normal). When VA/Q is below normal it is caused by the inadequate ventilation which is unable to provide the oxygen supply in the amount which is necessary for the complete oxygenation flowing through the alveolar blood capillaries (Radermacher, et al., 1988).

Material & methods

The general scientific methods for this investigation represented by the analysis methods, observation, experiment, measurement, hypothesis and logic.

The private methods for this investigation are:

1. The study and analysis of the scientific knowledge of the health monitoring, diagnosis of the lung diseases, respiratory system function;

2. The methods of the study of the morphological and functional data determining the features and state of the respiratory system as well as the somatometric indicators;

3. The mathematical methods – ranking, scaling and methods of the mathematical statistics.

This investigation was conducted from October 2019 to January 2022. Participants: 330 volunteers of both genders (males and females) aged from 17 to 73-years-old of different health status and professions took part in this investigation: students of the SibFU aged 17–23-years-old (n=123), teachers and specialists of educational support staff (ESS) of the different SFU schools aged 31–73-years-old (n=32), the residents of Krasnoyarsk sity – people of different gender aged 17–57-years-old (n=175). All ethical principles were observed in full. All participants were previously informed of the study purposes, associated benefits, and experimental procedures. Informed consents from participants to conduct investigation and publish the results were received. This investigation was implemented after approval by the university ethics committee SibFU (Institute of Physical Culture, Sport and Tourism, Protocol no. /2020) following the Helsinki declaration for work with humans.

The categorization by age (Swift, et al., 2018; WHO 2000–2025 standard. Age standardization of rates) was used for the age group distribution with the division applied in this study of the "the youth" group into subgroups of 18–23-years-old (the age of the student's youth) and the youth group is 23–44-years-old.

In order to take into account the saturation (in the medicine the indicator determining the level of blood hemoglobin oxygen saturation) in the complex estimation of the respiratory system function it is necessary to develop a scale allowing to determine the limits of the blood oxygen content levels according to the oxygen content levels determined by the world practice among the healthy people and people wo are at the initial stages of diseases (taking into account that chronic lung diseases are diagnosed too late). At the same time, it is necessary to take into account first of all the dependence of saturation on individual characteristics (congenital or formed anomalies in ontogenesis), natural and climatic conditions, pathologies, current state of the organism in its dependence of the specific conditions of the vital activity (e.g. the physical activity) i.e. the factors affecting the saturation level of the healthy people.

Among the factors determining the level of saturation of the healthy people, first of all, the physiological shunt, as well as the natural and climatic conditions (first of all, the location of a person relative to the sea level) are noted (Vold, et al., 2012).

The quantitative expression of the indicator (in our case, the oxygen percentage in blood hemoglobin) allows grading the limits of this indicator as high and low and taking into account the "nature" of the physiological shunt affecting the oxygen content in the blood of a healthy person allows us to talk about the individual or working saturation level of a particular person. In this development, taking into account that the level of oxygen in blood is one of the key indicators in diagnostics all over the world we have introduced the operative term – the operative saturation level – it is the level of the oxygen saturation of blood in the organism of a certain person which provides the energy production for the functioning of all organs and systems of the body, it allows a person to feel comfortable and lead the normal life activity.

In various sources the lower boundary of the saturation norm among the healthy people is defined as 95 % and 96 % and the upper boundary is 99 % and 100 %. In our development we were guided by WHO recommendations on the pulse oximetry. The pulse oximetry is a non-invasive method of determining the degree of blood oxygen saturation where the limits of this norm are defined as 95–100 % (Marinari, et al., 2022).

It is obvious that the existing and used in practice scales have only two limits – the upper one, more often defined as 100 % and the lower one, in various variants defined as 90 % and below. Thus, the scales reflect the percentage of the oxygen content in arterial blood hemoglobin as a general (average) norm which makes it difficult to assess this criterion for the use of the medical and pedagogical control, and the health monitoring by both as the specialist and

the patient. When considering the health of a particular person with its individual: the genotypic and phenotypic peculiarities, the concept of the average norm has only a tentative value. On the basis of the established saturation norms, we have developed an interval scale defining the boundaries of the zones of the oxygen content levels in blood which allows us to determine the individual saturation level of a particular person.

The extreme points of the proposed scale are 100 % and 91 % of the blood oxygen content. The indicators which are below 91 % are marked as the critical. When developing the scale, a simple grouping into 5 groups with equal intervals was made. The interval width is determined by the formula i = (xMax – xMin)/n 2 where i – the value of equal interval; xMax, xMin – the highest and lowest values of the trait; n – the number of groups. In our case (100–91)/5= is equal to 1,8. Since our indicators are integers numbers so we should round it to 2. Thus, the received intervals are 91–92; 93–94; 95–96; 97–98; and 99–100 are obtained (Table 1).

The quantitative approach to the concept of "health" where the health amount is the total capacity reserves of the main functional systems of the organism and taking into account the concept of the general theory of the systems allow us to determine the quality level of the respiratory system functioning. Thus, when assessing the function of the respiratory system it is logical to take into account: the lung vital capacity index – a criterion that characterizes the reserves of the external respiratory function where by the term 'reserve' (Fr. reserve from Latin reservare – to save, preserve) we understand the oxygen amount in the atmospheric air reserved by the possibilities of the lung vital capacity (LVC) and distributed to the body weight of a particular person. The consideration of this criterion is conditioned first of all by its basic component – lungs vital capacity (LVC) which is the first link of the energy formation.

The ability to provide the cardiovascular system in the removal of the carbon dioxide from the body – a criterion is characterized by the breath-holding duration. This indicator is revealed by applying the hypoxic test of Genchi.

The level of blood oxygen saturation (saturation) is a criterion characterizing the amount of the blood hemoglobin bound to the oxygen which is established by using a clip-on heart rate monitor and is determined by the proposed interval saturation scale.

Thus, the calculation of LCIRS is a calculation of the arithmetic mean score obtained by adding the scores of the life lung index, the Genchi test and the proposed interval saturation scale.

$$\text{LCIRS} = \frac{(\text{ZHI}) + \text{Sp02} + \text{HL}}{3}$$

Where: LLI – life long index in points; Sp02 – blood oxygen saturation level in points; GL – Genchi level in points.

The gradation for 5 groups with equal intervals was applied for level estimation of life capacity index of respiratory system. The step length = 0,8.

Thus, the following intervals were obtained: 1,0–1,8; 1,9–2,6; 2,7–3,4; 3,5–4,2; 4,3–5,0 – including the upper boundary. Thus, the level evaluation of the functioning quality by the CLIRS is presented in Table 2.

Table 1. Saturation interval scale

Level	Score	Blood oxygen content
High	5	99–100
Above average	4	97–98
Average	3	95–96
Below average	2	93–94
Low	1	91–92

The life index assessment is assessed according to the scale of Apanasenko, & Mil'ner, (1988) (Table 3).

The level of Genchi test in points presented in the gradation of Khoruzhev, (1993) in Table 4.

The methods of the descriptive statistics which summarizes data using indexes such as mean, median, standard deviation and another data, were used in this study. All calculations were carried out with the help of recommendations by selection of appropriate statistical methods for data analysis (Mishra, et al., 2019).

Results

A total of 330 subjects participated in this study. Age groups: "student youth" – 18–23-years-old (n=178); "youth" – 23–44-years-old (n=62); "middle age" – 44–60-years-old (n=46); "old age" – 60–75-years-old (n=44).

According to the results of the study of saturation level taking into account the age, the investigated persons were distributed as follows (Table 5)

The categorization by age (Swift, et al., 2018) was used for the age group distribution with the division applied in this study of the "the youth" group into subgroups of 18–23-years-old (the age of the student's youth) and the youth group is 23–44-years-old. There were no persons of the age groups "old age" and "long-livers" among the participants of the experiment.

Table 2. The respiratory system levels of the life capacity index

Level	Score	Scale
High	5	4,3–5,0
Above average	4	3,5–4,2
Average	3	2,7–3,4
Below average	2	1,9–2,6
Low	1	1,0–1,8

Table 3. The scale of Apanasenko, & Mil'ner, (1988) for the life index assessment

Score	Indicators ml/kg	
	males	females
5	More than 66	More than56
4	61–65	51–56
3	56–60	46–50
2	51–55	41–45
1	Less than 50	Less than 40

Table 4. Evaluation of the Genchi test (Khoruzhev, 1993)

Score	Indicators (s)	
	males	females
«5»	58 and above	38 and above
«4»	50–57	32–37
«3»	35–49	21–31
«2»	18–34	9–20
«1»	17 and below	8 and below

Table 5. Distribution of the study group by Sp02 level with regard to age

Sp02 Level	% Sp02	Number of subjects	The youth is 18–44 age		Average age 44–60-years-old	Old age 60–75-years-old
			18–23 age	23–44 age		
Low	91–92	16	–	–	9	7
Below average	93–94	55	6	5	19	25
Medium	95–96	109	75	17	10	7
Upper medium	97–98	121	79	32	6	4
High	99–100	29	18	8	2	1

The largest group was represented by the subjects with blood oxygen content above the average level – 121 subjects (36 %), the second largest group was the group of average saturation level – 109 subjects (33 %), the group below the average level was represented by 55 subjects (17 %), high level of blood oxygen content was detected among 29 subjects (9 %). The smallest group is the group with low saturation level – 16 subjects (5 %) of the examined.

It is obviously that the obtained data correspond to the "general average saturation norm" for a healthy person, 259 subjects (78 %) out of 330 examined have saturation 95–100 % within the boundaries of the medium-high levels on the interval saturation scale.

We have conducted a lot of tests (more than 1000), 100 % saturation was noted in 5 cases. When monitoring the examined person to identify the "working" saturation at different times of the day and during the various stress tests of 5–7 samples the data of 100 % were repeated only twice but the level did not fall below 98–99 % which allowed us to define the level as high.

The low saturation levels were not found in the youth groups. The below average levels were found in this group in 11 cases. 5 of these were among the individuals with the established clinical diagnoses predominantly aged 39–44-years-old. In two cases, when the saturation level was monitored for a week and found to be 93 % among young people of 18- and 20-year-olds the recommendations were made to contact the polyclinic at the place of residence.

The data obtained by the investigation do not contradict the knowledge obtained in the world practice regarding the age-adjusted saturation norms. As a result of this investigation, it was revealed that among the young and middle-aged subjects without pulmonary pathology the saturation values are 96–98 % and among the elderly subjects – Sp02 94–96 %.

So, in the middle-aged group the saturation levels were established: low level was among 9 subjects and below average level was among 19 subjects and they were mainly detected in the age range of 49–60-years-old among the subjects with the chronic diseases of the cardio-respiratory system. In the elderly group, 7 low level and 25 below average cases were distributed throughout the "age scale" but they were also associated predominantly with the chronic diseases.

The following results were obtained when calculating the LCIRS using the proposed formula. Taking into account the identified level, the participants of the experiment were distributed into groups as follows (Table 6).

The next results (Table 7) showed that the largest group of those surveyed was the above-average group – 142 subjects (43 %), the second largest group was the high-level group with 76 surveyed subjects (23 %), the third largest group was the medium-level group with 63 subjects (19 %), the below-average level was represented by 36 subjects (11 %) and the smallest group was the low-level group with 13 subjects (4 %).

These results (Table 7) shows the distribution of the experimental participants according

Table 6. The characteristics of the LCIRS levels and the distribution of the participants

LCIRS level	The characteristics of the LCIRS levels	Level scale	Scores	Number of participants
High	High level of respiratory system functioning: normal state of cardio-respiratory system, health high level, absence of the pathologies and diseases of cardio-respiratory system, high level of working capacity	4,3–5,0	5	76
Above average	Above average: (high) functioning of the respiratory system, normal cardio-respiratory system, above average health, absence of pathologies and diseases of the cardio-respiratory system, high level of working capacity	3,5–4,2	4	142
Medium	Average level: normal functioning of the respiratory system – normal condition of the cardio-respiratory system, average state of health, absence of the pathologies and diseases of the cardio-respiratory system, average level of workability	2,7–3,4	3	63
Below average	Reduced functioning of the respiratory system – significantly reduced level of health, possible chronic diseases of the initial stages of the cardio-respiratory system, pre-disease state, workability is significantly reduced	1,9–2,6	2	36
Low	Low functional capacity of the respiratory system, low level of health status, possible pathologies, chronic and ongoing diseases of the cardio-respiratory system of medium and high degree, low level of working capacity	1,0–1,8	1	13

Table 7. Distribution of the group under study by the LCIRS levels with regard to age of the participants

LCIRS levels	LCIRS/The number of participants		The youth group 18–44-years-old		Average age 44–60-years-old	Older age 60–75-years-old
			18–23-years-old	23–44-ears-old		
low	1,0–1,8	13	2	1	3	7
Below average	1,9–2,6	36	6	1	11	18
average	2,7–3,4	63	28	7	13	15
Above average	3,5–4,2	142	101	25	14	2
high	4,3–5,0	76	41	28	5	2

to the levels of the LCIRS with regard to age. It is obvious that the levels – high and above average are represented by the group's "youth" 195 subjects (59 %), of which 142 subjects "student youth" (43 %) and 53 subjects (16 %) of the group "youth" (23–44-years-old). These levels in the "middle age" group are represented by 19 subjects (6 %), and in the "older age" group by 4 subjects (1 %).

The low and below average levels of the CLIRS levels in the group "youth" were found among 10 (%) subjects predominantly the persons with the low and below average of the CLIRS were distributed in the groups "middle age" 14 (4 %) subjects and "old age" 25 (8 %) subjects.

Discussion

The authors believe that the results of this investigation complement the current scientific knowledge about the functional status of a person leading a healthy lifestyle during a COVID-19 pandemic. The obtained data confirm the trends reflected in the world practice about the decreasing level of the respiratory system functioning with the age (Thomas, et

al., 2019; Kim, et al., 2017) and the influence of living conditions and bad habits on the level of functioning. Levels of respiratory system functioning in pandemic conditions among the subjects of different ages do not exceed the norm. This is probably related to the social status of the examined persons leading a healthy lifestyle which allows taking into account and implementing recommendations of the preventive measures in the conditions of the epidemic as well as the fact that 98 % of the examined persons have higher education or they are university students who have the opportunity to engage in physical education, fitness and sports in accordance with their preferences and physical data (Osipov, et al., 2018). The obtained results do not contradict the data on the statistics of the respiratory diseases and the health state of the population groups and confirm the tendencies defined in the world practice about the decrease of the functioning level of the respiratory system with age and also about the influence on the increase of the functioning level of the respiratory system of the physical exercises, healthy lifestyle, rules observance of the reasonable rational balanced nutrition and provided that there are no bad habits (Baginska, et al., 2023; Kudryavtsev, et al., 2016).

First of all, the obtained results are explained by the fact that 240 (73 %) of the studied subjects are the representatives of the "youth" group aged 18–44-years-old, among them are the student's youth (18–23-years-old) is represented by 178 participants and mostly without bad habits, leading an active, healthy lifestyle 117 subjects (35 %) among them who has the high and above average saturation levels (97–100 %). Here we should pay attention to the absolutely fair comment of the physicians, who suggests to beware of the pulse oximeters writing optimistic saturation of 100 % when breathing atmospheric air (Shvets, 2014; DeMeulenaere, 2007) with which we fully agree. As a rule, this indicator is associated with the low quality of the device.

Also, taking into account the parameters of the respiratory links in complex when assessing the function of the respiratory system obtained as a calculation result of the LCIRS allows to obtain a more complete picture of the functioning level of the respiratory system which, in its turn provides an opportunity to assess the general health state of the representatives of the different age and professional groups of the population leading a healthy lifestyle and provides an opportunity to diagnose the conditions of pre-diseases which can contribute to the relief in the work of the physicians and medical organizations.

Conclusions

This investigation showed that the saturation level of the most part of the studied subjects (78 % of the total number of subjects) living a healthy lifestyle in the conditions of the pandemic is within the boundaries of the medium levels – high on the interval scale of the saturation which corresponds to the "general average norm of saturation" (95–100 %) for a practically healthy persons, who regularly engaged in the physical activity. Also, the proposed interval saturation scale allows to determine the level of "working" saturation of a person living a healthy lifestyle. The most "accurate" indices reflecting the working level of saturation are inherent with a person leading a healthy lifestyle in the middle of the day with an average active motor regime of health-improving physical training with the absence of illness and fatigue.

Limitations

All findings made in this investigation have some important limitations. These limitations associated with the total low number of male and female subjects (n=330), who participated in this study. Also, is possible that restrictive measures related to the COVID-19 pandemic could provide an impact on the overall findings of this investigation.

Conflicts of interest

The authors declare that this scientific work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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