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Synglet oxygen therapy influence on physical activity of patients suffering from bronchial asthma
Вплив синглетно − кисневої терапії на фізичну активність у хворих на бронхіальну астму

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Abstract

Objective: To study and analysis of physical activity, assessment of the impact of singlet - oxygen therapy. dysfunction of the cardiorespiratory system during maximal exercise in patients with bronchial asthma persistent disease course.

Materials and Methods: The study included 30 patients with persistent disease course. In all patients, the diagnosis of asthma has been installed correctly, confirmed clinically and functionally. As a control, were selected and examined 15 healthy volunteers who had no severe clinically significant pathology, aged on average (45,0 ± 4,2) years. Studies of lung ventilation function performed in all patients according to the analysis of the curve spirogram "flow - volume" forced expiratory and total body plethysmography on the unit «Master Scope» and «MasterScreen BodyDiff» company "Erich Jaeger" (Germany). Indicators of gas composition and acid-base status (CBS) capillary blood was evaluated using the analytical micromethod ABL5 "Radiometer". Diffusion capacity of the lungs was investigated using the module for the study of the diffusion of spirometric lung function "VIASYS Healthcare GmbH". Determination of exercise tolerance, the level of implementation of maximum load, physical activity was performed using ergospirometric cardiorespiratory exercise test. To perform the dosage of exercise used ergometer EP / 2 ("Erich Jaeger", Germany)

and Ergoselect 1000 LP Basic auto power dissipation regardless of the speed of pedaling. Statistical data processing was performed using the licensed software products included in the software package Microsoft Office Professional 2000 on a personal computer IBM Celeron in Excel

Results The study found that in patients with persistent asthma current physical activity is reduced, as compared with healthy individuals by 10.5% during exacerbation and 2.5% - in remission. Compliance with the appropriate level of work performed was happening with a tendency to irrational function cardiorespiratory system. Namely, when the maximum effort respiratory system lost the ability to adequately improve pulmonary ventilation and maximum absorb oxygen, which was offset by an increase in respiratory minute volume by increasing the frequency and thus reducing the depth of inhalation and exhalation. In turn, on the part of the cardiovascular system was observed compensatory hyperfunction with a tendency to excessive growth of systolic blood pressure, heart rate, a fall in diastolic blood pressure (to reduce the peripheral circulation and improve microcirculation in the muscles). During the test, for 2-3 minutes, maximum load, in patients with asthma compensation mechanisms rapidly depleted: decreased cardiac output of blood falling systolic pressure and heart rate, etc. All the above changes with a reduction in the functional activity of the cardiorespiratory system when performing maximal exercise require the development of new methods of prevention to reduce the progression of the deterioration of its functioning and to prevent deterioration of activities of daily living and quality of life in patients with asthma. Singlet-oxygen therapy in treatment of asthma gives possibility improve physical activity.

Key words: singlet oxygen therapy, bronchial asthma, physical activity, cardiorespiratory system.

Вплив синглетно − кисневої терапії на фізичну активність у хворих на бронхіальну астму

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Резюме

Мета дослідження : дослідження та аналіз оцінка впливу синглетно - кисневої терапії на. дисфункцію кардіореспіраторної системи при максимальному фізичному навантаженні у хворих на бронхіальну астму персистуючого перебігу захворювання.

Матеріали і методи: в дослідження увійшло 30 хворих з персистуючим перебігом захворювання. У всіх хворих діагноз БА був встановлений правильно, підтверджений клінічно і функціонально. В якості контролю було обрано й обстежено 15 здорових добровольців, які не мали важкої клінічно значимої патології, віком в середньому (45,0 ± 4,2) року. Дослідження вентиляційної функції легень проводилося всім хворим за даними спірограми аналізу кривої "потік - об'єм" форсованого видиху і загальної плетизмографии тіла на апараті «Master Scope» і «MasterScreen BodyDiff» фірми "Erich Jaeger" (Німеччина). Показники газового складу і кислотно-основного стану (КОС) капілярної крові оцінювали мікрометодом за допомогою аналізатора ABL5 "Radiometer". Дифузійну здатність легень досліджували з використанням модуля для вивчення дифузійної функції легень спірометричний системи "VIASYS Healthcare GmbH". Визначення толерантності до фізичного навантаження, рівня виконаної максимального навантаження, фізичної активності проводилося із застосуванням ергоспірометрічного кардіореспіраторної навантажувального тесту. Для виконання дозованого фізичного навантаження використовувався велоергометр EP / 2 ("Erich Jaege", Німеччина) і Ergoselect 1000 LP Basic з автоматичним розсіюванням потужності незалежно від швидкості педалювання. Статистична обробка отриманих даних виконувалася за допомогою ліцензійних програмних продуктів, що входять в програмний пакет Microsoft Office Professional 2000, на персональному комп'ютері IBM Celeron в Excel.

Результати В результаті проведеного дослідження встановлено, що у хворих БА легкого персистуючого перебігу фізична активність знижена, порівняно зі здоровими особами на 10,5 % при загостренні і на 2,5 % - в ремісії. Дотримання належного рівня виконаної роботи відбувалося з тенденцією до нераціонального функціонуванню кардіореспіраторної системи. А саме: при виконанні максимального зусилля дихальна система втрачала здатність адекватно підвищувати легеневу вентиляцію і максимально засвоювати кисень , що компенсувалося збільшенням хвилинного об'єму дихання за рахунок збільшення частоти і відповідно зменшення глибини вдиху і видиху. У свою чергу, з боку серцево - судинної системи спостерігалася компенсаторна тенденція до гіперфункції з надмірним зростанням систолічного артеріального тиску, частоти серцевих скорочень, падінням діастолічного тиску (для зменшення периферичного кровообігу і поліпшення мікроциркуляції у м'язах). При проведенні тесту, на 2-3 хвилині максимального навантаження, у хворих БА механізми компенсації швидко виснажувалися : зменшувався хвилинний об'єм крові , падало систолічний тиск і частота серцевих скорочень і т.д. Всі вищевказані зміни зі зниженням функціональної активності кардіореспіраторної системи при виконанні максимальної фізичної навантаження вимагають розробки нових методів профілактики для зниження прогресування погіршення її функціонування та попередження погіршення повсякденної активності та якості життя у хворих БА. Синглетно-киснева терапія в комплексному лікуванні БА дає можливість поліпшити фізичну активність.

Ключові слова: бронхіальна астма у дорослих, фізична активність, якість життя у хворих БА, кардіореспіраторна система.

Влияние синглетно-кислородной терапии на физическую активность у больных бронхиальной астмой

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Резюме

Цель исследования: исследование и анализ физической активности, оценка влияния синглетно − кислородной терапии на. дисфункцию кардиореспираторной системы при максимальной физической нагрузке у больных бронхиальной астмой персистирующего течения заболевания.

Материалы и методы: в исследование вошло 30 больных с персистирующим течением заболевания. У всех больных диагноз БА был установлен правильно, подтвержден клинически и функционально. В качестве контроля было выбрано и обследовано 15 здоровых добровольцев , не имевших тяжелой клинически значимой патологии, в возрасте в среднем (45,0 ± 4,2) года. Исследования вентиляционной функции легких проводилось всем больным по данным спирограммы анализу кривой "поток – объем" форсированного выдоха и общей плетизмографии тела на аппарате «Master Scope» и «MasterScreen BodyDiff» фирмы "Erich Jaeger" (Германия). Показатели газового состава и кислотно-основного состояния (КОС) капиллярной крови оценивали микрометодом с помощью анализатора ABL5 "Radiometer". Диффузионную способность легких исследовали с использованием модуля для изучения диффузионной функции легких спирометрический системы "VIASYS Healthcare GmbH". Определение толерантности к физической нагрузке, уровня выполненной максимальной нагрузки, физической активности проводилось с применением ергоспирометричного кардиореспираторного нагрузочного теста. Для выполнения дозированной физической нагрузки использовался велоэргометр EP / 2 ("Erich Jaeger", Германия) и Ergoselect 1000 LP Basic с автоматическим рассеянием мощности независимо от скорости педалирования. Статистическая обработка полученных данных выполнялась с помощью лицензионных программных продуктов, входящих в программный пакет Microsoft Office Professional 2000, на персональном компьютере ИБМ Celeron в Excel

Результаты В результате проведенного исследования установлено, что у больных БА персистирующего течения физическая активность снижена, по сравнению со здоровыми лицами на 10,5 % при обострении и на 2,5 % – в ремиссии. Соблюдение надлежащего уровня выполненной работы происходило с тенденцией к нерациональному функцыонированию кардиореспираторной системы. А именно: при выполнении максимального усилия дыхательная система теряла способность адекватно повышать легочную вентиляцию и максимально усваивать кислород, что компенсировалось увеличением минутного объема дыхания за счет увеличения частоты и соответственно уменьшение глубины вдоха и выдоха. В свою очередь, со стороны сердечно-сосудистой системы наблюдалась компенсаторная тенденция к гиперфункции с чрезмерным ростом систолического артериального давления, частоты сердечных сокращений, падением диастолического давления (для уменьшения периферического кровообращения и улучшения микроциркуляции в мышцах). При проведении теста, на 2-3 минуте максимальной нагрузки, у больных БА механизмы компенсации быстро истощались: уменьшался минутный объем крови, падало систолическое давление и частота сердечных сокращений и т.д. Все вышеуказанные изменения со снижением функциональной активности кардиореспираторной системы при выполнении максимальной физической нагрузки требуют разработки новых методов профилактики для снижения прогрессирования ухудшения ее функционирования и предупреждения ухудшения повседневной активности и качества жизни у больных БА. Синглетно-кислородная терапия в комплексном лечении БА даёт возмложность улучшить физическую активность.

Ключевые слова: бронхиальная астма у взрослых, физическая активность, качество жизни у больных БА, кардиореспираторная система, синглетно-кислородная терапия.

Bronchial asthma (BA) is one of the most common diseases of respiratory apparatus that affects up to 8% of adults worldwide (1, 2, 3, 4). The associated lesions of respiratory' and cardiovascular systems continue to pose quite a difficult problem in the treatment of this category of patients (4). Cardiorespiratory system (CRS) is a dynamic self-regulating structure; the final beneficial result of its activity consists of an adequate supply of tissues with oxygen and the removal of carbon dioxide (CO_2) and of other metabolites thanks to the synchronized interaction of the respiratory', hemodynamic', metabolic' and tissular segments that are part of the system (6, 9). The main diagnostic criteria of its functional effectiveness are based on the evaluation of the informative parameters of external respiration, the integrated indicators of the cardiovascular system' function and the deviation of the constant of the partial pressure of oxygen and carbon dioxide in the arterial blood (7).

The problem of the associated lesions of lungs and heart in the patients suffering from bronchial asthma is quite urgent in modern pulmonology (5, 8, 14, 15). Among the clinically significant aspects of the cardiovascular pathology' development during BA the following pathogenetic interdependences are singled out: the formation of pulmonary hypertension, the development of mutual aggravation and the presence of certain clinical course' traits. Judging by the data published by various authors, BA is complicated by the circulatory system disturbances in 35-72.5% of cases (9, 15). Those disturbances mutually aggravate each other, which draws one's attention to the comorbidity problem existing in the "lungs-heart" system. It has been established that the disturbances of the intracardial hemodynamics of BA patients are conditioned by the intensity of the obstructive syndrome and develop in stages, simultaneously with changes in lungs and the changes in hemodynamics of the pulmonary circulation. At the early BA stages a physical load application induces the myocardial hyperfunction where the hemodynamics is restructured hyperkinetically (the arterial blood pressure level is raised, as are the values of the heart rate (HR), the stroke volume (SV) and the minute volume of blood circulation (MVBC)). While the pulmonary dysfunctions progress, a eukinetic type of central hemodynamics develops followed by a hypokinetic one. Nevertheless, it is known that the hypokinetic type of hemodynamics can form at the early BA stages, too. The eukinetic type is characterized by the reduced SV values, the increased HR values, and the unaltered MVBC values. While studying the pulmonary hemodynamics, a moderate pulmonary hypertension and an overstressing of the right ventricle are found, both of which are related to the progressing pulmonary vascular resistance. An opinion exists according to which the drop in SV against the background of the general peripheral resistance in BA patients constitutes a compensatory-adaptive reaction that lowers the pulmonary circulation load. The adequate level of blood supply is maintained due to the reflectory redistribution of peripheral blood circulation and the necessity to maintain the MVBC support function by the way of raising the HR values (10, 11, 14).

The problem of quality of life of this category of patients continues to present a challenge; this quality depends on the functional state of the cardiorespiratory system, since the majority of the patients are young, physically active people (12, 27). The issues of defining the patients' capability of withstanding the ultimate physical load (i.e., physical working capacity) are of particular interest for the investigators. The term "physical working capacity" defines the general potential capability of a person to exert maximum effort during the dynamic', static' or mixed labor (8, 18, 25, 29). Based on such positions, it would be expedient to deepen our knowledge about the mutually influencing mechanisms of the adaptive responses of the united cardiorespiratory system' constituent elements to the disturbances of the lung ventilation function in the bronchial asthma patients.

Till the present day an active accumulation of scientific materials related to the detection of early disturbances of the cardiorespiratory system' function and the ability of the patients of the said category to exert the ultimate physical efforts (depending on the severity and the phase of the disease) is going on. Quite often, it is impossible to detect the early functional disturbances in the cardiovascular and respiratory systems with the use of common scanning methods; it is possible to do only during physical stressing (14, 16, 17).

That is why *the main purpose* of the work that has been completed was the assessment and analysis influence singlet oxygen therapy on physical activity, as well as the evaluation of the early manifestations of the cardiorespiratory system' dysfunction during the ultimate physical stressing of the bronchial asthma patients suffering from the mild persisting form of the disease.

Materials and methods

The study performed on the department of the bronchial obstructive lung diseases of tuberculosis patients of the "National Institute of Phthisiology and Pulmonology named after F. G. Yanovskyi of the National Academy of Medical Sciences of Ukraine" State Institution.

30 persons entered into the study, that have been suffering from the mild persisting form of the disease (which means that the symptoms have been appearing at least once a week but less frequently that once a day for more than 3 months; during aggravations the symptoms could interfere with normal activity and sleep; the chronic symptoms requiring symptomatic treatment have been appearing almost daily; the night asthma symptoms have been appearing more than twice a month; the value of the forced expiratory volume (FEV_1) amounted to 80% of the norm, the diurnal fluctuations of the values of the peak expiratory velocity (PEV) or the FEV_1 – to 20-30%). 15 patients treated with singlet-oxygen therapy course l4 days, 14 patients in group 2 received standard therapy of bronchial asthma. While diagnosing BA, the case history data, the clinical symptoms, the respiratory function indices, and the reversibility of the obstruction in the bronchial spasmolytic test were taken into account. The selection of patients based on the BA severity grade was performed in accordance with the provisions of the Order No. 128 "On the approval of clinical protocols of the pulmonological medical help" of the Ministry of Health of Ukraine of March 19, 2007 (24). BA was properly diagnosed in all the patients; the diagnosis was confirmed both

clinically and functionally (with the help of spirometry and the bronchial obstruction reversibility' test with a short-acting beta agonist). The duration of the illness among the patients of the group, on average, amounted to (4.1±2.2) years, the BA aggravations frequency – to (0.4±0.1) times a year. None of the patients smoked at the time of the scanning and none of them had been a smoker before or had been exposed to occupational hazards. None of the studied patients had a severe concomitant pathology. All of the patients, after the screening period was over, in their treatment of the aggravated conditions received the therapy recommended in the Order No. 128 of the Ministry of Health of Ukraine. The control group consisted of 15 healthy volunteers that had no severe clinically significant pathology; the said volunteers whose age varied in the range of (45.0±4.2) y.o. have been randomly selected and examined. More details can be found in Table 1.

The lung ventilation function of all the patients have been studied based on the spirogram results; in the process the "flow-volume" curve of the forced expiration and the general body plethysmogram were analyzed; the "Master Scope" and the "MasterScreen BodyDiff" devices have been used built by Erich Jaeger (Germany). The following respiratory function parameters have been studied: the lung vital capacity (VC), the forced lung vital capacity (FVC), the forced expiratory volume in 1 s (FEV1), the forced expiratory volume in 6 s (FEV6), the peak expiratory flow rate at 25, 50 and 75% of the lung vital capacity (MEF 25%, MEF 50%, MEF 75%), the peak expiratory flow (PEF), the total airways resistance (R tot), the total lung capacity (TLC), the pulmonary residual volume (RV), the expiratory reserve volume (ERV), the inspiratory capacity (IC). The patients were examined in the mornings, after a 12-14 hour long break in the drugs intake. The respiratory function was studied 15-30 minutes before and after the 2 standard values developed by R.F. Clement et al. have been registered (13, 28).

Table 1 – The general description of the studied patients (M ± m)

Parameters	Healthy individuals (n = 15)	BA patients suffering from mild persisting form of the disease (n = 30)
1	2	3
Frequency of the BA aggravations (incidents per year)	-	0.4±0.1
Duration of illness (years)	-	5.2±2.2
Number of patients that have regularly received inhaled corticosteroids (%)	-	-
Men (persons)	9	10
Women (persons)	6	18

As can be seen from the results presented in Table 1, the comparison groups were comparable by the indicators of age, gender and the absence of a clinically significant concomitant pathology.

The parameters of the gas composition and the acid-base balance (ABB) of capillary blood have been evaluated with the use of micromethod based on the data registered by ABL5 analyzer (the "Radiometer") (19 -21).

The following parameters were analyzed:

– pH.

– carbon dioxide tension (pCO2, mm Hg).

– actual plasma bicarbonate concentration (HCO3-, mmol/L).

– standard plasma bicarbonate concentration (HCO3-, mmol/L).

– standard base excess (SBE, mmol/L).

– oxygen tension (pCO2, mm Hg).

– hemoglobin's (Hb, g/L) saturation with oxygen (sO2, %).

The diffusion capacity of lungs has been studied with the use of the diffusion capacity of lungs' study module that is part of the "VIASYS Healthcare GmbH" spirometry system. The parameters of the diffusion capacity of lungs (DLCO in % to proper values), namely, the volume (mL) of gas that passes through the alveolar-capillary membrane in 1 min when the difference of the partial pressure between the end diffusion points amounts to 1 mm Hg, were taken into account. With the purpose of determining the leading mechanism of DLCO disturbances the transfer factor was evaluated (KCO, in percentage to proper values), which is the relation of DLCO to the alveolar volume (VA) (35, 36).

The level of tolerance to physical loading, the level of the performed ultimate loading and the level of physical activity were determined with the use of the ergo-spirometric cardiorespiratory loading test. To perform the dosated physical loading the EP/2 bicycle ergometer ("Erich Jaeger", Germany) and the Ergoselect 1000 LP Basic bicycle ergometer with the automatic power dissipation irrespective of pedaling speed were used. The main parameters of lung ventilation and of gas exchange, as well as the heart beat frequency and the electrocardiogram parameters were registered and automatically processed with the use of "Ergopneumotest" OM/05-Ц device ("Erich Jaeger", Germany) and of the Oxycon Pro – Version JLAB 4.67 ergo-spirometric system (VIASYS Healthcare, Germany) that includes a pneumotachograph with an integrator, oxygen' and carbon dioxide' gas analyzers and an electrocardiography device ("Hellige", Germany). In the process of the bicycle ergometry study (the bicycle ergometry assessment), the general test requirements for the sub-maximal physical loads were observed. Before the study was conducted the patients had to discontinue the intake of drugs affecting the functional state of the cardiorespiratory' and nervous systems. Smoking was prohibited for two or more hours before the test. The physical load was applied at least 1 hour after a food intake. The absolute and relative contraindications for testing and the conditions requiring special attention and care were taken into account, based on the ERS School Courses recommendations (2006) (26, 30 – 34). The environmental temperature could vary from + 18 °C to + 25 °C; the patients had to wear light body wear that would freely let the air and moisture through; on their feet the patients wore light shoes with firm soles. Prior to the testing the patients were made acquainted with the purpose and the order of the motive test' conducting. The intensity of loading, the maximum oxygen consumption, the minute lung ventilation volumes, and the heart beat frequency were prognosticated with the use of extrapolation method, with the age, gender and the anthropometric parameters of the subjects taken into account. The physical working capacity was evaluated in accordance with the RA – 150 – IB 3 – BP 2 – EC 1 protocol. The work continued until refusal or was discontinued upon the emergence of subjective or objective symptoms that would limit the further load build-up, namely: the pronounced shortness of breath, the registering of sub-maximal heart beat frequency, the emergence of the electrocardiographic signs of coronary insufficiency. The deviation of the pedaling rate from the set level (lower than 60 rpm) due to the muscle weakness or insufficient motivation towards the application of ultimate load were considered the subject's refusal to further continue testing. The maximum level of the performed loading was considered to constitute the limit of the body's functional capabilities. The testing consisted of four phases:

- phase 1 – three minute long period of adaptation for breathing in mask in rest.
- phase 2 – three minute long period of resistance-free pedaling (0 W) with the speed of 40 rpm.
- phase 3 – working period. The pedaling speed was raised to 60 rpm.
- phase 4 – 10 minute long restoration period.

While evaluating the parameters the gender, age and the anthropometric data were taken into account. According to the test protocol, the same patients were tested in a phase of moderate non-complicated aggravation of the disease (for 2 weeks after finishing the course of a parenteral glucocorticoid), which constituted the initial examination; the secondary examination was performed during a remission phase (3 and 12 months after the last BA aggravation).

The statistical processing of the obtained data was performed with the use of licensed

Microsoft Office Professional 2000 software applications; the IBM Celeron PC was used, and the Microsoft Excel application (22, 23). The work was financed from state funds.

Results and their consideration

During the aggravation of BA in patients suffering from a mild form of the disease the changes were observed in the velocity-related parameters of the respiratory function; the data is presented in Table 2. The values of the lung vital capacity, the forced lung vital capacity, the forced expiratory volume in 1 s, the peak expiratory flow rate, and the maximum expiratory flow were lowered in patients with a mild form of bronchial asthma in the aggravation phase, but returned to their norm in the remission phase. Thus, the ventilation disturbances in the patients with a mild form of bronchial asthma were insignificant; no hyperinflation has been detected.

Table 2 – The indices of lung volumes, capacities, bronchial patency in the BA patients suffering from a mild persisting form of the disease, in the aggravation' and remission stages (M m)

Indices	BA patients with a mild persisting form of the disease, aggravation phase (n = 30)	BA patients with a mild persisting form of the disease, (received singlet oxygen therapy remission phase (n = 15)	BA patients with a mild persisting form of the disease, (received standard therapy) remission phase (n = 15)
1	2	3	4
R tot (%)	125.9 ± 94.2	122.8 ± 94.2	120.8 ± 94.2
IC (%)	110.8 ± 5.4	112.3 ± 5.4	113.5 ± 5.4
VC MAX (%)	101.2 ± 5.9	102.2 ± 5.9	103.8 ± 5.9
ERV (%)	104.3 ± 8.5	109.3 ± 8.5	110.3 ± 8.5
RV (%)	94.6 ± 8.7	99.5 ± 8.7	101.2 ± 8.7
ITGV (%)	95.6 ± 7.2	93.4 ± 7.2	94.1 ± 7.2
TLC (%)	100.6 ± 9.2	99.6 ± 9.2	98.6 ± 9.2
FEV_1 (%)	68.7 ± 6.5	78.8 ± 6.5*	88.7 ± 6.5*
FVC (%)	89.2 ± 2.4	100.1 ± 2.4*	100.9 ± 2.4*
FVC (abs)	2.8 ± 2.3	3.4 ± 2.3*	3.2 ± 2.3*
FEV_6 (L)	2.78 ± 2.3	3.28 ± 2.3*	3.18 ± 2.3*
FEV1/VC MAX (%)	87.5 ± 4.9	91.3 ± 4.9	89.6 ± 4.9
FEV1/FEV_6 (%)	73.5 ± 6.9	79.6 ± 6.9	75.2 ± 6.9
MEF_{75} (%)	61.3 ± 8.0	79.7 ± 8.0*	78.6 ± 8.0*
MEF_{50} (%)	52.6 ± 9.9	65.4 ± 9.9*	63.1 ± 9.9*
MEF_{25} (%)	32.6 ± 12.0	42.5 ± 12.0*	39.5 ± 12.0*
PEF (%)	72.3 ± 14.6	99.5 ± 14.6*	96.5 ± 14.6*

Note: * – the difference between this index value and the value in the aggravation phase has been statistically confirmed ($p < 0.05$).

The values of the total airways resistance (R tot) and of the pulmonary residual volume (RV) in the group as a whole have not been changed both in the aggravation' and in the remission stages: (125.9 ± 94.2) percentage and (94.6 ± 8.7) percentage for the aggravation, and (122.8 ± 94.2) percentage and (99.5 ± 8.7) percentage for the remission. The values of the intrathoracic gas volume (ITGV) and of the inspiratory capacity (IC) have also stayed unchanged – only insignificant fluctuations have been observed, depending on the disease phase: (95.6 ± 7.2) percentage and (110.8 ± 5.4) percentage for the aggravation, (93.4 ± 7.2) percentage and (112.3 ± 5.4) for the remission.

No disturbances of the diffusion capacity of lungs have been registered both in the aggravation' and in the remission periods. Namely, the value of the DLCO parameter during the aggravation amounted to (78.4 ± 5.1)%, and during the remission – to (88.4 ± 5.1)%; the transfer ratio indicator (KCO) – to (82.2 ± 7.0) during the aggravation, and to (86.2 ± 7.0) during the remission, the VA indicator – to (94.4 ± 5.7)% and (102.4 ± 5.7)%, respectively. The detailed information is given in Table 3.

Table 3 – The indices of the diffusion capacity of lungs in the BA patients suffering from a mild persisting form of the disease, in the aggravation' and remission phases (M m)

Indices	BA patients with a mild persisting form of the disease, aggravation phase (n = 20)	BA patients with a mild persisting form of the disease, (received singlet oxygen therapy remission phase (n = 15)	BA patients with a mild persisting form of the disease, (received standard therapy) remission phase (n = 15)
DLCO	82.4 ± 5.1	87.4 ± 5.1	88.4 ± 5.1
KCO	82.2 ± 7.0	81.2 ± 7.0	86.2 ± 7.0
VA	94.4 ± 5.7	103.4 ± 5.7	102.4 ± 5.7
VIN	110.2 ± 6.7	110.3 ± 6.7	112.3 ± 6.7
FRC	95.3 ± 5.4	101.3 ± 5.4	105.3 ± 5.4

Note: No significant difference in the values of the evaluated parameters has been observed.

While conducting the analysis of the obtained results of the ergo-spirometric study the following facts have been established. The maximum level of the performed loading in the BA patients with the mild persisting form of the disease, in comparison with the healthy individuals, is decreased by 10.5% during an aggravation and is decreased by 2.5% during the remission phase of the disease. Namely: in the BA aggravation phase, due to a restricted functional activity of the respiratory system, during an ultimate physical loading the limited oxygen supply and use were observed which were compensated by the cardiovascular system hyperfunction accompanied by the increase in the heart beat frequency, the drop in the arterial blood pressure level and a positive chronotropic reaction of the heart in the whole.

It is the biggest tendency of the oxygen (O_2) consumption that can be reached in the process of physical loading that constitutes the indicator of the ultimate capability of the O_2 assimilation at maximum load, or, in another words, it constitutes the manifestation of the cardiorespiratory endurance – ($V'O_2$/kg) – in the group it was lowered down to (6.2 ± 1.2) mL/min/kg and (78.9 ± 6.6)%, the oxygen consumption peak ($V'O_2$) – to (87.9 ± 6.1)%, $V'O_2$p (87.9 ± 5.2)%, $V'O_{2max}$ – to (97.6 ± 11.3)%, $V'O_2$ (V – slope) – to (2376.8 ± 145.8) mL/kg, $V'CO_2$ (V-slope) – to (2456.2 ± 122.6) mL/kg, RER – to (1.16 ± 0.2)%.

The decrease in the breathing reserve (BR) has been observed – down to (75.3 ± 7.4) percentage, which shows how close the ventilation volume (V′E) at the maximum (peak) load comes to the maximum value characterizing the lung ventilation. The detected changes constitute the manifestation of the impossibility of an adequate increase in the lung ventilation level, which is characteristic of the respiratory failure.

The values of the parameters characterizing the effectiveness of the cardiovascular system' operation, though not demonstrating a significant difference in comparison with the group of healthy individuals, were, nonetheless, lowered: dHR/dO_2 (78.6 ± 6.4)%, HR/VO_2 (2.1 ± 1.1) bps/mL/kg, HR (118.1 ± 8.1) 1/min and (90.1 ± 6.8)%, VO_2/HR (9.1 ± 2.6) bps/mL/kg and (82.9 ± 5.7)%, HR/Vkg to (8.1 ± 2.2) bps/s/kg, CAT (156.3 ± 6.9) mm Hg, the diastolic arterial blood pressure level – to (77.9 ± 4.9) mm Hg, SpO_2 – to (94.3 ± 5.5)%. As a result, the physical load tolerance and the level of the performed work were decreased, although not significantly: W to (85.9 ± 5.3) percentage, (1.8 ± 0.6) W/kg and (102.8 ± 6.2) Bt, dO_2/dW – to (18.6 ± 5.5) mL/min/W.

After 3 months of observation, in the BA remission, no difference in the evaluated indices has been found, compared with the aggravation phase. After one year of observations the obtained data did not display a significant difference, either, – both in comparison with the data characterizing the group of healthy individuals and with the data obtained in the aggravation phase. The detailed information is given in Table 3.

Table 3 – The indices of the cardiorespiratory loading test in the BA patients with a mild persisting form of the disease, (M ± m)

Indices	Healthy individuals	BA patients, aggravation phase	BA patients with a mild persisting form of the disease, (received singlet oxygen therapy) remission phase	BA patients with a mild persisting form of the disease, (received standard therapy) remission phase
	(n = 15)	(n = 20)	(n = 15)	(n = 15)
1	2	3	4	5
Duration of the 3rd phase of the test (min)	13.05 ± 3.1	7.8 ± 1.8	10.9 ± 1.8	8.2 ± 1.9
$V'O_2$/kg (mL/min/kg)	7.9 ± 1.1	6.2 ± 1.2	7.1 ± 1.2	7.0 ± 1.3
$V'O_2$/kg (%)	89.2 ± 5.1	78.9 ± 6.6	79.3 ± 6.6	78.6 ± 6.7
$V'O_2$ (%)	102.8 ± 5.6	87.9 ± 2.1	98.3 ± 2.1#	98.1 ± 6.12
$V'O_2$p (%)	98.5 ± 8.2	87.9 ± 1.2	98.3 ± 1.2#	88.1 ± 5.2
V´O2max (%)	99.3 ± 10.3	97.6 ± 2.3	98.6 ± 2.2	98.1 ± 11.3
$V'O_2$ (mL/kg)	2498.3 ± 135.3	2376.8 ± 145.8	2409.9 ± 145.8	2401.9 ± 147.8
$V'CO_2$ (mL/kg)	2106.2 ± 125.3	2456.2 ± 122.6	2458.3 ± 122.6	2455.3 ± 122.3
RER (в. о.)	0.95 ± 0.1	1.16 ± 0.2	1.04 ± 0.2	1.08 ± 0.1
BR (%)	88.1 ± 6.2	75.3 ± 7.4	81.3 ± 7.2	81.0 ± 7.2
ti (min)	0.66 ± 0.1	0.58 ± 0.2	0.61 ± 0.2	0.60 ± 0.2
t-ex (min)	1.28 ± 0.2	1.32 ± 0.2	1.27 ± 0.2	1.29 ± 0.2
ti/tot (min)	0.51 ± 0.1	0.43 ± 0.2	0.50 ± 0.2	0.49 ± 0.2
BF (1/min)	46.5 ± 5.6	53.4 ± 6.1	47.2 ± 6.1	49.2 ± 6.1
BF (%)	88.6 ± 6.1	80.3 ± 6.0	81.5 ± 6.1	81.5 ± 6.2
VDe/VT (%)	11.1 ± 2.5	9.85 ± 2.5	10.9 ± 2.5	11.2 ± 2.6
VDc/VT (%)	19.3 ± 1.2	17.9 ± 2.7	18.4 ± 2.7	17.8 ± 2.7
V´E (L/min)	7.1 ± 1.5	7.0 ± 1.9	7.2 ± 1.9	7.5 ± 2.0
V´E (%)	58.3 ± 2.1	57.2 ± 5.7	57.6 ± 5.7	56.9 ± 5.5
$V'E/VCO_2$ (%)	23.6 ± 2.2	24.1 ± 2.6	23.8 ± 2.6	24.9 ± 2.5
V´E/VO2 (%)	23.9 ± 1.4	24.5 ± 2.5	23.9 ± 2.5	24.8 ± 2.5
AT (%)	49.65 ± 4.3	49.1 ± 11.3	49.3 ± 11.3	52.1 ± 11.5
SVc (mL)	8.4 ± 1.5	7.6 ± 2.7	7.9 ± 2.7	7.9 ± 2.8
$FECO_2$ (%)	4.01 ± 1.6	3.89 ± 1.1	3.95 ± 1.1	4.01 ± 1.2
$FETCO_2$ (%)	5.23 ± 1.2	5.0 ± 1.9	5.01 ± 1.9	5.9 ± 1.9
$FETO_2$ (%)	16.21 ± 4.4	15.74 ± 4.2	15.92 ± 4.2	15.44 ± 4.1
FEO_2 (%)	15.25 ± 5.3	15.84 ± 6.1	15.95 ± 6.1	15.99 ± 6.2
$FECO_2$ (%)	2.6 ± 0.9	2.1 ± 1.2	2.4 ± 1.2	2.2 ± 1.1
$PETO_2$ (kPa)	14.82 ± 3.2	13.01 ± 4.1	13.25 ± 4.1	12.99 ± 3.8
DI (в.о.)	0.69 ± 0.2	0.51 ± 0.2	0.56 ± 0.2	0.59 ± 0.1
W (%)	95.4 ± 3.1	85.9 ± 2.2	90.6 ± 2.3#	87.5 ± 2.1
W (W/kg)	2.8 ± 1.1	1.8 ± 0.6	2.6 ± 0.6#	2.1 ± 0.5
1	2	3	4	5
W(Bt)	116.0 ± 6.1	102.8 ± 6.2	110.9 ± 6.2	104.8 ± 6.3
dO_2/dW (mL/min/W)	11.51 ± 1.2	18.6 ± 5.5	12.2 ± 5.5	19.1 ± 5.6
dHR/dO_2 (spec./min/mL)	78.6 ± 4.5	78.6 ± 6.4	77.5 ± 6.5	78.5 ± 5.2
HR/Vkg (1/mL/kg)	8.9 ± 1.5	6.2 ± 2.2	8.2 ± 2.2#	8.0 ± 2.1
HR/VO_2 (bps/ mL/kg)	2.7 ± 1.6	2.1 ± 1.1	2.9 ± 1.0	2.2 ± 1.1

HR (L/min)	112.5 ± 8.6	118.1 ± 8.1	118.8 ± 8.1	120.1 ± 8.1
HR (%)	94.5 ± 8.9	90.1 ± 6.8	90.2 ± 6.8	92.1 ± 6.6
VO_2/HR (mL)	10.8 ± 2.5	8.1 ± 2.6	9.2 ± 2.6	9.4 ± 2.4
VO_2/HR (%)	89.5 ± 3.1	77.9 ± 2.1	83.2 ± 2.3#	83.9 ± 5.5
SpO_2 (%)	98.9 ± 2.2	94.3 ± 5.5	94.9 ± 5.5	95.3 ± 5.6
САТ (mm Hg)	155.3 ± 6.2	156.3 ± 6.9	157.2 ± 6.9	155.3 ± 6.7
ДАТ (mm Hg)	80.3 ± 5.6	77.9 ± 4.9	78.8 ± 4.9	78.9 ± 4.7
$EqCO_2$ (%)	24.3 ± 2.3	23.6 ± 4.0	24.8 ± 4.0	24.6 ± 4.1
EqO_2 (%)	25.2 ± 1.2	25.0 ± 5.9	25.5 ± 5.9	25.0 ± 5.9
MET (kcal/kg)	6.6 ± 1.5	4.8 ± 1.2	5.9 ± 1.2#	5.4 ± 1.3
RW (relative workload) (W/kg)	1.2 ± 0.1	1.0 ± 0.1	1.1 ± 0.1	1.1 ± 0.1
PMA (patient maximally achieved) (%)	89.3 ± 6.2	78.3 ± 6.1	89.3 ± 6.1#	88.7 ± 6.1

Note: # − the difference between this index value and the value in the aggravation phase has been statistically confirmed ($p < 0.05$).

After 3 months of observations no difference between the evaluated parameters of the remission' and aggravation phases has been detected. The breathing reserve value (BR) amounted to (81.3 ± 7.2) percentage (aggravation – (75.3 ± 7.4) percentage, healthy individuals – (88.1 ± 6.2) percentage). An efficiency of the muscle performance that was adequate to the load was observed – (12.2 ± 5.5) mL/min/W (during aggravation – (18.6 ± 5.5) mL/min/W, in the healthy individuals – (11.42 ± 1.3) mL/min/W). The respiratory rate (BF) within the group was (47.2 ± 6.1) 1/min and (81.5 ± 6.1) percentage, during aggravation – (53.4 ± 6.1) 1/min and (80.3 ± 6.0) percentage, in the healthy individuals – (46.5 ± 5.6) 1/min and (88.6 ± 6.1) percentage, respectively. The level of the carbon dioxide emission ($V'CO_2$) at the maximum load was somewhat increased in the patients group; since simultaneously with the carbon dioxide' evacuation from the blood the approximately equal number of hydrogen ions (H^+) disappear from the blood, one can speak of an intensification of the processes of the acid-base balance' maintenance and of the compensation of the patients' tissue acidosis due to the lung ventilation' intensification: (2458.3 ± 122.6) mil/min in the remission phase and (2456.2 ± 122.6) mil/min during aggravation (for the healthy individuals it is (2106.2 ± 125.3) mil/min).

With the help of several noninvasive methods (V-slope, method of respiratory equivalents) it was automatically determined that all the patients in the group have achieved the anaerobic threshold during testing. There were no test interruptions due to adverse events. The values of the parameters of the anaerobic threshold, of the ventilation reserve and volume (and of their coordination), as well as of the pulmonary gas exchange ($PETCO_2$, $PETO_2$, $V'E/VCO_2$, $V'E/VO_2$, $FETO_2$, $FETCO_2$, FEO_2, $FECO_2$, $PETCO_2$, $PETO_2$, VDc/VT, VDe/VT) were somewhat altered in the aggravation phase, but came to a norm in the remission stage. The value of the RER indicator in the group exceeded 1 and amounted to (1.16 ± 0.2) conventional units during aggravation and to (1.04 ± 0.2) conventional units during remission (for healthy individuals it is (0.95 ± 0.1)), which was indicative not of the activation of the anaerobic energy retention processes, but of the development of hyperventilation at the ultimate physical load.

The parameters of the patient group that characterize the effectiveness of the cardiovascular system' function at the ultimate physical load were no different from the same parameters of the group of healthy individuals. Namely: the O_2 consumption was quite effective which was attested to by the high values of the oxygen pulse (O_2/HR) parameter which is the amount of oxygen extracted from one heart stroke volume: (9.2 ± 2.6) mL and (83.2 ± 5.7) percentage during aggravation, (9.1 ± 2.6) mL and (82.9 ± 5.7) percentage during remission; for the healthy individuals it is (10.2 ± 2.6) mL and (88.6 ± 3.6) percentage. The HR/Vkg and HR parameters were no different from those of the group of healthy individuals.

After a yearlong observation, the obtained results were indicative of the tendency for the ergospirometric parameters of the cardiorespiratory testing of the patients before a BA aggravation period to fall. Namely, the values of the parameters characterizing the respiratory system activity among the patients of the group were as follows: $V'O_2$/kg (7.0 ± 1.3) mL/min/kg, $V'O_2$/kg/% (78.6 ± 6.7) percentage, $V'O_2$ (percentage) (98.1 ± 6.12) percentage, $V'O_2$p (88.1 ± 5.2) percentage, VO_2max (98.1 ± 11.3) percentage, $V'O_2$ (V-slope) – (2401.9 ± 147.8) mL/kg, $V'CO_2$ (V-slope) – (2455.3 ± 122.3) mL/kg, RER – (1.08 ± 0.1) percentage, BR – (81.0 ± 7.2) percentage.

There were no significant differences between the values of the parameters characterizing the effectiveness of the cardiovascular system function in the group of patients and in the group of healthy individuals: dHR/dO_2 (78.5 ± 6.7)%, HR/VO_2 (2.2 ± 1.1) bps/mL/kg, HR (120.1 ± 8.1) 1/min and (92.1 ± 6.6)%, VO_2/HR (9.4 ± 2.4) bps/mL/kg and (83.9 ± 5.5)%, HR/Vkg (8.0 ± 2.1) bps/s/kg, CAT (155.3 ± 6.7) mm Hg, the diastolic arterial blood pressure level – to (78.9 ± 4.7) mm Hg, SpO_2 – (95.3 ± 5.6)%. As a result, the values of the physical stress tolerance and of the level of performed work remained lowered, although not significantly: W – down to (87.5 ± 5.5) percentage and (2.1 ± 0.5) W/kg, (104.8 ± 6.3) Bt, dO2/dW (19.1 ± 5.6) mL/min/W.

Conclusions

Based on the results of the conducted study it has been established that the level of physical activity in the BA patients suffering from a mild persisting form of the disease is lowered in comparison with the healthy individuals – by 10.5% during aggravation and by 2.5% during remission. The proper level of the performed work could be sustained only while being accompanied by the tendency toward an irrational operation of the cardiorespiratory system. Namely: while sustaining maximum load, the respiratory system was losing the capability of the adequate boosting of the lung ventilation and of assimilating oxygen to a maximum extent possible, which was compensated by the rise in the respiratory minute volume due to the rising of the frequency and, respectively, lowering of the depth of inspiration and expiration. In its turn, a compensatory tendency was observed on the part of the cardiovascular system towards hyperfunctioning, with the excessive rise of the systolic arterial pressure and the heart beat frequency, as well as the dropping of the diastolic pressure (to provide for the decrease of the peripheral blood circulation' volume and for the improvement of the muscle microcirculation). During testing, at minute 2-3 of the maximum loading, the mechanisms of compensation in the BA patients quickly drained out: the minute volume of blood would be decreased; the systolic pressure and the frequency of the heartbeat would drop etc. The fact that the cardiorespiratory system' functional activity would decrease while undergoing the ultimate physical loading requires the development of new prevention methods directed at the improvement of the cardiorespiratory system' functional state and the normalization of everyday activities and the BA patients' quality of life.

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