Condition of membranes of erythrocytes of peripheral blood of elderly people with chronic tiredness and low level of tolerance to physical load

Sergii Popel 1ABCD, Ivan Melnic 2ACDE, Ihor Churpiy 2ACDE, Przemek Bejga 3ACDE, Zbigniew Śliwiński 4ACDE

1 Vasyl Stefanyk Precarpathian National University, Ivano-Frankivsk
2 Ivano-Frankivsk National Medical University, Ivano-Frankivsk
3 Faculty of Medicine and Health Sciences, Department of Pharmacology and Toxicology, University of Zielona Góra, Polska
4 Zespol opieki zdrowotnej w Zgorzelcu, Stacjonarny Osrodek Rehabilitacji Chorob Naradu Ruchu dla Doroslych I dzieci Im. Prof. Degi w Zgorzelcu, Polska

Authors’ Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

DOI: https://doi.org/10.34142/HSR.2022.08.02.07

Corresponding author: Popel S.L. ORCID: 00001-9019-3966; Vasyl Stefanik Precarpathian University, Schevchenko str. 57, Ivano-Frankivsk, 76025, popelsergij@gmail.com

How to Cite
Popel SL, Melnic I, Churpiy I, Bejga P, Śliwiński Z. Condition of membranes of erythrocytes of peripheral blood of elderly people with chronic tiredness and low level of tolerance to physical load. Health, Sport, Rehabilitation. 2022;8(2):78-89. https://doi.org/10.34142/HSR.2022.08.02.07

Abstract

Purpose: The aim of the work is to study the osmotic stability and morpho-functional features of peripheral blood erythrocytes of patients with chronic fatigue syndrome depending on the level of exercise tolerance and associated risk factors. Groups of factors that may be the cause, so the development of measures to eliminate them is an urgent problem today, which requires the development of effective ways to correct chronic fatigue syndrome. It is known that the peripheral part of erythron actively responds to changes that occur in the whole body after the action of various factors, including those factors that lead to chronic fatigue syndrome.

Material and methods of research. The examination was performed on the basis of the Department of Vascular Neurology of the Central Clinical Hospital of Ivano-Frankivsk. The study involved 30 patients aged 55-65 years (mean age 60.6 ± 1.2 years), who were divided into 3 groups: 1 gr. included 10 patients with chronic fatigue syndrome and a high level of exercise tolerance. The 2nd group included 10 patients with chronic fatigue syndrome and the average level of exercise tolerance, the composition of 3 gr. included 10 patients with chronic fatigue syndrome associated cardiovascular pathology (angina pectoris, hypertension) and low exercise tolerance (3 gr.).

Results. It is established that chronic fatigue syndrome proceeds in 3 phases and has natural stages of development which are characterized by three groups of etiological factors and the corresponding levels of teletransitivity to physical activity, each of which corresponds to a certain erythrocyte profile and level of osmotic stability of erythrocytes which are offered to use as prognostic and diagnostic characteristics. Chronic fatigue syndrome.

Conclusions. The study of the quantitative composition of peripheral blood erythrocytes and hemoglobin, as well as their ratio (color index) in patients with chronic fatigue syndrome on the background of low levels of exercise tolerance revealed a decrease in erythrocytes and hemoglobin by 42% and 25%, respectively, indicating the presence of anemic hypoxia. 2. In conditions of chronic fatigue there is a decrease in osmotic resistance of erythrocytes, as evidenced by a decrease in the number of osmotically stable erythrocytes with a gradual decrease in the concentration of NaCl solution (3.0%; 0.5%; 0.46%; 0.3%).

Key words: chronic fatigue syndrome, exercise tolerance, peripheral blood erythrocytes, osmotic resistance of erythrocytes
Сергей Л. Попель. Состояние мембран эритроцитов периферической крови у людей пожилого возраста с хронической усталостью и низким уровнем толерантности к физической нагрузке

Цель: изучение осмотической стабильности и морфофункциональных особенностей эритроцитов периферической крови больных с хронической усталостью, а также их отношений с количеством эритроцитов периферической крови и гемоглобином, а также их кислородопоглощающей способностью.

Результаты. Установлено, что синдром хронической усталости протекает в 3 фазы и имеет закономерные этапы развития, которые характеризуются тремя группами этиологических факторов и соответствующими уровнями телераннитетности к физической нагрузке, каждый из которых соответствует определенному эритроцитарному профилю и уровню осмотической устойчивости эритроцитов, которые являются важным диагностическим признаком синдрома хронической усталости.

Мета: визначити осмотичну стійкість і морфо-функціональні особливості еритроцитів периферичної крові у людей пожилого віку при хронічній втомі.

Матеріал і методи. Обстеження проводили на базі відділення судинної неврології Центральної клінічної лікарні м. Івано-Франківська. В дослідженні приймали участь 30 пацієнтів віком 55-65 років (середній вік 60,6±1,2 роки), яких поділили на 3 групи: до складу 1 гр. ввійшли 10 пацієнтів з СХВ і високим рівнем толерантності до фізичного навантаження. До складу 2-ї групи ввійшли 10 пацієнтів з синдромом хронічної втоми і середнім рівнем толерантності до фізичного навантаження, до складу 3 гр. ввійшли 10 пацієнтів з асоціюваною з синдромом хронічної втоми стабільною (семандрід напруження, артеріальна гіпертонія) і низьким рівнем толерантності до фізичного навантаження (3 гр.).

Результати: Встановлено, що синдром хронічної втоми перебігає у 3 фази і має закономірні етапи розвитку, які характеризуються трьома групами етіологічних факторів і відповідними рівнями телераннитетності до фізичного навантаження. По відношенні до телераннитетності до фізичного навантаження, кожен з яких відповідає певному еритроцитарному профілю і рівню осмотичної стійкості еритроцитів, які пропонується використовувати в якості прогностично-діагностичних характеристик синдрому хронічної втоми.

Висновки. Дослідження кількісного складу еритроцитів периферичної крові і гемоглобіну, а також їх співвідношення (кольоровий показник) у пацієнтів при синдромі хронічної втоми на фоні низького рівня телераннитетності до фізичного навантаження виявило зменшення кількості еритроцитів периферичної крові і гемоглобіну відповідно на 42 % і 25 %, що свідчить про наявність анемічної гіпоксії. 2. В умовах хронічної втоми спостерігається зниження осмотичної резистентності еритроцитів, про що свідчить зменшення кількості осмотично стійких еритроцитів при постепенному зменшенні концентрації розчину NaCl (3,0 %; 0,5 %; 0,46 %; 0,3 %).

Ключові слова: синдром хронічної втоми, толерантність до фізичної навантаження, еритроцити периферичної крові, осмотична резистентність еритроцитів.
Introduction

At present, the problem of chronic fatigue and low tolerance to physical activity is acute all over the world. This is facilitated by the instability of the social situation, the economic crisis, changes in the system of personal values, and environmental factors (global warming). The total number of people with chronic fatigue syndrome reaches 200 million or 5% of the world's population [1]. The main "risk group" of people with low tolerance to physical activity includes young people and adolescents with chronic fatigue syndrome [2]. The constant accumulation of deoxidized substances in the body due to lipid peroxidation in chronic fatigue syndrome stimulates the launch of various pathological reactions affecting metabolic processes, leading to the development of cardiovascular disease and causing low tolerance to exercise. According to the World Health Organization (WHO), the clinical manifestations of chronic fatigue syndrome are: muscle and joint pain; fatigue after waking up, which indicates the lack of regenerative properties of sleep; constant headache; deterioration of health, which lasts for 24 hours after exercise, impaired concentration and memory; "Blurring" of vision; problems with the vestibular apparatus. The multifunctional role of peripheral blood erythrocytes in the mechanisms of adaptation to physical activity and compensation of negative consequences in hypoxia, gas transport processes and other vital functions explains the high informativeness of the results of studying structural and functional changes in these cells in various human conditions. At the same time, the enzyme regulation of the processes of formation and destruction of hydrogen peroxide (H₂O₂) in peripheral blood erythrocytes is an insufficiently studied aspect of hypoxia. Taking into account the data on the direct participation of reactive oxygen species and hydrogen peroxide (O₂, H₂O₂) and enzymes of the antioxidant defense system: superoxide dismutase (SOD) and catalase (CAT) in the oxygenation of hemoglobin [3, 4], is of interest changes in the activity of these enzymes, aimed at improving the structural and functional value of erythrocytes of peripheral blood, necessary for adequate transport of oxygen during exercise in chronic fatigue syndrome.

Chronic fatigue syndrome is diagnosed after 6 months of clinical signs. The disease is divided into 3 phases:
• Prodromal phase: which is characterized by symptoms of chronic fatigue, manifested by physical and mental exhaustion. At this stage, the patient can get rid of chronic fatigue syndrome by changing their lifestyle.
• Acute phase: characterized as a disease of systemic intolerance to physical activity or low tolerance to physical activity. The inability to get out of bed is compounded by impaired thinking and concentration. Characteristic attacks of panic and depression.
• Recovery phase: during which the patient tries to return to normal life, feeling tired and weak.

Etiology of the disease. The causes of chronic fatigue syndrome are classified into three groups: the first group includes physiological problems. These are stressful situations, outbursts of strong negative emotions and depression. The second group includes somatic health problems, such as: anaemia; malnutrition; hypothyroidism; sleep apnea; diabetes; adiposity. The third group includes lifestyle problems: alcohol abuse; hypokinesia; caffeine abuse; irregular diet. Among the causes of chronic fatigue syndrome is not the last place overload at work and work at night. All these factors are characteristic of the daily professional activities of a teacher in higher education.

Pathogenesis

At present, the pathogenesis of chronic fatigue syndrome has not been fully elucidated. The disease is based on an abnormal level of chemicals synthesized in the system "hypothalamus - pituitary - adrenal glands". This system is responsible for controlling many physiological functions: sleep, vitality and stress reactions. At the same time, patients with chronic fatigue syndrome have low levels of serotonin and dopamine in the body. Signs of chronic fatigue syndrome often develop after a violation of the immune system. In general, the prognosis for recovery is favorable with timely medical attention. However, in the scientific literature there are no criteria for this timeliness.

Therefore, there is an urgent need to establish objective criteria for the course and predict the treatment of a patient with chronic fatigue syndrome with professional help. At long action of stress factors there is a steady disturbance of a metabolism in an organism which are the reason of many comorbid diseases and, as a consequence of decrease in level of protective forces of an organism; the level of human social activity, his ability to work and the adequacy of behavior decreases [5].

Under the action of toxic substances, conditions are created for the intensive formation of products of lipid peroxidation, which leads to the development of oxidative stress and, accordingly, to the peroxide destruction of cell membranes.
Activation of free radical oxidation processes is the basis of many pathological processes, and in particular low tolerance to exercise. It is known that hypokinesia and hypoxia as constant companions of chronic fatigue syndrome affect the key stages of intracellular metabolism and, above all, the processes of energy metabolism, which relate mainly to aerobic oxidation of fatty acids and glucose [6]. As a result of lipophilic effects of lipid peroxidation on cell structures, the properties of cell membranes, their liquid crystal structure, viscosity and stability change, which is especially evident in cells with low adaptive capacity, such as peripheral blood erythrocytes. This is accompanied by suppression of all functions and premature aging of the body.

Erythrocytes of peripheral blood, in close contact with all tissues and entering into morphological functional relationships with them, their own qualitative and quantitative adjustment reflect the physiological and pathological changes that occur throughout the body, thus causing the so-called "exquisite" (reflected) reactions as prognostic markers for a number of chronic diseases [7].

The aim of the study was to study the osmotic stability and morpho functional features of peripheral blood erythrocytes of patients with chronic fatigue syndrome depending on the level of tolerance to exercise and risk factors associated with chronic fatigue syndrome.

**Material and methods**

**Participants**

The examinations were performed on the basis of the neurological department of the Central Clinical Hospital in Ivano-Frankivsk. The study involved 30 patients aged 55-65 years (mean age 60.6 ± 1.2 years), who were divided into 3 groups: 1 g. included 10 patients with chronic fatigue syndrome and a high level of tolerance to exercise. The 2nd group included 10 patients with chronic fatigue syndrome and moderate tolerance to exercise, the 3rd group included 10 patients with associated with chronic fatigue syndrome cardiovascular disease (stress angina, hypertension) and low physical tolerance. load (3 group). Among the patients were 15 teachers of higher education institutions with at least 15 years of teaching experience.

All participants were informed about the purpose of the study and gave written consent to participate in the study, which was conducted in accordance with the Helsinki Declaration of the WMA - Ethical Principles of Medical Research for Human Subjects, 2013.

**Morpho-biochemical methods of erythrocyte analysis**

Morphological studies of erythrocytes were performed in a scanning electron microscope "JEOL-25M-T220A" (Japan) according to the generally accepted method [3]. Used, where A is the total number of erythrocytes, B is the number of irreversibly altered forms of erythrocytes, B is the number of inversely altered forms of erythrocytes. The low level of conformational ability of erythrocytes is determined at values of erythrocyte deformation index from 1.6 to 2.5, medium - in the range of 2.6-3.9, high - at 4.0-6.0. To determine the electrolyte composition of erythrocytes in a muffle furnace at a temperature of 800 °C ash was 2 ml of erythrocyte mass. The ash was pressed, after which the surface of the mold was sprayed with carbon (10 nm). Determination of erythrocyte concentration of macronutrients such as sodium (Na), potassium (K), iron (Fe), magnesium (Mg) and calcium (Ca) was performed using a computer program "SELMI" and a prefix for energy-dispersive X-ray microanalysis EDAR "On the REMMA-102E scanning electron microscope (SELMI, Ukraine) with an accelerating voltage of 20 kV in the energy range from 960 to 19600 kiloelectron-volts (keV). Morpho functional parameters and osmotic resistance of erythrocytes (WEM) were studied in the blood, which was determined by the Janowski microscopic method using descending (3%, 0.5%, 0.46%, 0.3%) concentrations of NaCl solution. The number of peripheral blood erythrocytes was determined in Goryaev's chamber. The hemoglobin concentration was determined with a hemometer. Erythrocyte sedimentation rate was determined by the unified Panchenkov micromethod [5].

The level of tolerance to physical activity was determined by cycling ergometry (cycling ergometer "Kettler" Germany) according to the PWC100 protocol.

The surface architecture of peripheral blood erythrocytes was studied using scanning electron microscopy (SEM) (electron microscope "JEOL 25A T3225"; Japan) with the preparation of samples according to the method of Romashchenko O.V., V.F. Kamenev [7] and GI Kozinets and co-authors [3]. The calculation of different morphological forms of EPA was performed according to the classification of GI Kozynets and co-authors [3]. Some of the studies were performed on a hemoanalyzer (Lab Analyt30000Plus) (Finland).
Determination of the microelement composition of EPA (nitrogen, calcium, magnesium) was performed using energy-dispersed X-ray structural scanning on the attachment for microanalysis "EDAR" to the scanning electron microscope "REMMA 202E" (Sumy, Ukraine).

Determination of erythrocyte deformability index was performed by the method of C. Tannert, V. Lux in modification Z.D. Федоровой, М.О. Котовчикова [8]. Oxygen saturation was determined by pulse oximetry on a Jziki-Fingertip oximeter.

Statistical analysis

Statistical analysis was performed using the standard software package SAS 8.0 (SAS Inc., USA). Criteria t and χ² were used. Statistical processing of quantitative indicators was performed using the computer software package "Statistica 6.0" [10]. Data are presented as arithmetic mean ± standard deviation (M ± SD). The obtained results were not subject to the law of normal distribution according to the Kolmogorov-Smirnov criterion, therefore the statistical significance of the intergroup difference was estimated using the Mann-Whitney test and the nonparametric Kruskal-Wallace test using the nonparametric Spearman correlation coefficient. The difference was considered statistically significant at a bilateral level of p <0.05.

To determine the significance of the influence of qualitative value of the erythrocyte deformation index on the functional state of the cardioregulation system, a nonparametric analysis of variance of heart rate variability was performed [9] both before and after exercise at maximum aerobic capacity. The obtained data were subject to variational-statistical processing by the method of small sampling [10]. The difference was considered statistically significant at p <0.05 and below.

Results

The main complaints of patients with CFS are presented in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Clinical manifestations</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Women, n = 20</td>
</tr>
<tr>
<td>Sleep disorders</td>
<td>85.0</td>
</tr>
<tr>
<td>Impaired short-term memory and ability to concentrate</td>
<td>65.0</td>
</tr>
<tr>
<td>Feeling of constant unexplained fatigue for 6 months or more</td>
<td>100</td>
</tr>
<tr>
<td>Depression</td>
<td>65.0</td>
</tr>
<tr>
<td>Prolonged subfibrillation (37,2–37,4°C)</td>
<td>85.0</td>
</tr>
<tr>
<td>Headache, muscle and joint pain</td>
<td>70.0</td>
</tr>
</tbody>
</table>

Note: * - the difference is probable at p <0.05.

The state of the membrane of destabilizing processes is characterized by various criteria. This is primarily the level of functional activity of endogenous phospholipases and the dynamics of lipoperoxide accumulation. According to our results, the severity of membrane destabilizing processes increases from the minimum values in patients 1 gr. with a more favorable form of chronic fatigue syndrome and a high level of tolerance to physical activity to the maximum level in patients 2 gr. and patients 3 gr. (with a low level of tolerance to physical activity on the background of cardiovascular disease), which is manifested by the expansion of the hemogram and its change from normal, unimodal type of hemogram (Fig. 1, A) to bipolar type of peripheral blood erythrocytes (Fig. 1, B) by their corpuscular volume, with a significant shift of the distribution peak to the left (Fig. 1 B). This is closely correlated (r = 0.93) with the appearance of cells with irreversibly altered shape among erythrocytes (Fig. 1, A, B).

It was found that the level of tolerance to exercise 82% of patients with chronic fatigue syndrome had low physical performance, which averaged 0.87 + 0.02 W / kg, which is 25% less than the reference values. The number of peripheral blood erythrocytes depends on many factors, the general mechanism of action of which is expressed in a hypoxic state. Toxic substances (eg, lipid peroxidation products) may also be such factors [11, 12].

The results of the studies revealed significant changes in blood parameters in patients with chronic fatigue syndrome with a low level of exercise tolerance (Table 1). There is a decrease in
the number of peripheral blood erythrocytes by 42% compared to the reference values of physiological norm. Erythropenia accompanies the syndrome of chronic fatigue and is closely correlated \((r = 0.87)\) with a decrease in hemoglobin to 90 ± 8.2 g/l (Table 1) and with hemogram (Fig. 1).

![Fig. 1. A. Acanthocyte (a), erythrocyte with crest (b), erythrocyte with one outgrowth (c), erythrocyte with dome (e), spherocyte (e) echinocyte (i) in patients 3 gr. B: the arrow shows the "shadows" of erythrocytes](image)

**Table 2**

Blood parameters in chronic fatigue syndrome with low tolerance to exercise compared with reference data \((M \pm m, n = 10)\)

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Physiological norm</th>
<th>Chronic fatigue syndrome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (\times 10^{12}/l)</td>
<td>4.5 ±0.7</td>
<td>2.6±0.43 P&lt;0.001</td>
</tr>
<tr>
<td>Hemoglobin (g / l)</td>
<td>120.0±13.2</td>
<td>90.0±10.4 P&lt;0.001</td>
</tr>
<tr>
<td>Erythrocyte sedimentation rate (mm / hour)</td>
<td>11.4±1.0</td>
<td>9.6±0.4 P&lt;0.001</td>
</tr>
<tr>
<td>Color indicator</td>
<td>0.8±0.01</td>
<td>0.89±0.002 P&lt;0.001</td>
</tr>
</tbody>
</table>

Note: P is the degree of probability of the results in relation to the control

**Table 3**

Indicators of osmotic resistance in different states of the body \((n = 10)\)

<table>
<thead>
<tr>
<th>Concentration NaCl</th>
<th>Physiological norm (the number of erythrocytes)</th>
<th>Chronic fatigue syndrome</th>
<th>Tolerance to physical activity, (W / kg) body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%</td>
<td>4.5±0.9</td>
<td>2.6±0.04</td>
<td>3.0±0.04</td>
</tr>
<tr>
<td>0.5%</td>
<td>2.1±0.6</td>
<td>1.5±0.8</td>
<td>1.2±0.8</td>
</tr>
<tr>
<td>0.46%</td>
<td>1.3±0.1</td>
<td>0.7±0.03</td>
<td>0.5±0.03</td>
</tr>
<tr>
<td>0.3%</td>
<td>1.1±0.2</td>
<td>0.5 ± 0.1</td>
<td>0.5±0.1</td>
</tr>
</tbody>
</table>

In order to maintain homeostasis, the blood system responds not only to quantitative but also qualitative changes in its composition to any exogenous or endogenous factors [12].

As a result of the study in patients of group 3 with chronic fatigue syndrome with a low level of tolerance to exercise, specific features of the indicators of osmotic resistance of erythrocytes were established. Compared with the physiological norm with a low level of tolerance to exercise, there is a decrease in the number of erythrocytes at a concentration of NaCl 3% by 42.2%, at a concentration of 0.5% by 28.6%, at a concentration of NaCl 0.46% - by 46.2% and at a concentration of NaCl solution of 0.3% by 54.5% (Table 2).
Our data on the decrease in the resistance of peripheral blood erythrocytes in chronic fatigue syndrome with low tolerance to exercise can be explained by the fact that the products of lipid peroxidation are included in the lipid layer of membranes, increasing the surface area of cytoplasmic membrane in erythrocytes. Therefore, the condition of peripheral blood erythrocytes is a sensitive indicator of changes in the normal course of physiological, biochemical and biophysical processes in the body, which are due to the influence of external or internal factors, including physical factors, which is exercise. Determination of osmotic resistance of erythrocytes is an important research method for diagnosis in sports medicine, used to study the mechanism of pathological processes and the impact of certain types of exercise [13]. This changes the biochemical parameters of peripheral blood erythrocytes (table 1), which is especially evident when comparing the indicators obtained in patients with low and high levels of tolerance to exercise (table 3).

**Table 4**

<table>
<thead>
<tr>
<th>Indicators</th>
<th>High level of tolerance to physical activity, control group (n=5)</th>
<th>Patients with chronic fatigue syndrome, n=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phospholipases -α2, % hemolysis</td>
<td>4.44±0.22</td>
<td>21.9±1.73*/**</td>
</tr>
<tr>
<td>diene conjugates, nmol ·ml</td>
<td>47.9±1.51</td>
<td>155.77±5.5*/**</td>
</tr>
<tr>
<td>Schiff compounds, conventional units</td>
<td>17.89±1.03</td>
<td>29.33±1.11*/**</td>
</tr>
</tbody>
</table>

Примітка:* – вірогідність статистичної різниці між показниками з високим і низьким рівнем толерантності до фізичного навантаження (p<0.05); ** – вірогідність статистичної різниці між показниками з високим і середнім рівнем толерантності до фізичного навантаження (p<0.05).

Thus, in patients with chronic fatigue syndrome, regardless of the level of tolerance to exercise, there was a multiple increase in the content of lipid peroxidation products (diene conjugates and Schiff compounds) and phospholipase-α2 activity relative to the control group (p <0.05) with a high level of tolerance to physical activity, the appearance of erythrocyte sludges in the form of "coin" columns and fibrin threads between individual erythrocytes after exercise (Fig. 2).

Fig. 2. Formation of local aggregates in the form of "coin columns" (1) and fibrin threads between individual erythrocytes in patients of the 3rd group with chronic fatigue syndrome, after bicycle ergometric testing according to the PWC100 protocol.
At the same time, as the level of exercise tolerance decreases, the content of lipid peroxidation products (diene conjugates, Schiff compounds) naturally increases (p <0.05) and closely correlates (r = 0.93) with an increase in the number of peripheral erythrocytes. Blood irreversibly changed shape (Fig. 1, B), which can be a prognostically unfavorable indicator, a reason to see a doctor and a more thorough examination by a specialist.

**Discussion**

The idea that the level of physical performance is related to the main indicators of health [6, 7, 9], is more confirmed in patients 56-60 years (the correlation coefficient between the level of physical performance and the overall incidence is 0.345; index self-assessment of health r = -0.399, heart rate at rest -0.382, double product 0.371, stress index r = -0.333, p = 0.001 adaptive potential -0.319, % overweight r = -0.539, p = 0.001). In younger patients 40 to 55 years of age, such a dependence is absent, except for the relationship between the level of physical performance and the degree of risk of cardiovascular disease (r = -0.356, p = 0.006).

The degree of risk in patients aged 50-65 years is associated with overall morbidity (r = 0.311), health self-esteem index (r = 0.318; p = 0.006), blood pressure (r = -0.388), double product (r = 0.322), adaptive potential (r = -0.462), the amount of excess body weight (r = 0.463, volumetric size of the waist (r = 0.311) and pelvis (r = 0.341), as well as the level of daily motor activity (r = -0.486) (p <0.01). This explains the interdependence of the PWC test with the level of exercise tolerance in people aged 50-65 years with chronic fatigue syndrome, as in most of them in the absence of physical activity, when performing PWC100 loads, active and subjective signs of inadequate response of the body (hypertension, incoordination of the cardiorespiratory system [8], feeling of tension, headache, dizziness, nausea, discomfort, etc.), which is closely correlated (r = 0.93; p = 0.006) with increasing number of irreversibly altered peripheral erythrocytes blood.

Ignorance of such patterns can lead to incorrect calculation of maximum physical performance, its ergometric and metabolic parameters. This is confirmed by statistical differences in the main indicators of morphofunctional status, physical performance and morbidity in patients of different risk groups for the development of chronic fatigue syndrome and comorbid diseases [14, 15, 16] (Table 4).

**Table 5**

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Degree of risk</th>
<th>P 1,2</th>
<th>P 1,3</th>
<th>P 2,3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight, kg</td>
<td>low</td>
<td>67.2±2.14</td>
<td>71.4±3.06</td>
<td>98.3±3.17</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>average</td>
<td>15.2±0.28</td>
<td>18.0±0.93</td>
<td>22.5±1.11</td>
</tr>
<tr>
<td>Kettle Index, conventional units</td>
<td>high</td>
<td>24.9±1.23</td>
<td>28.4±1.46</td>
<td>30.5±1.61</td>
</tr>
<tr>
<td>Heart rate, beats / min</td>
<td>low</td>
<td>71.6±3.22</td>
<td>72.1±3.35</td>
<td>89.1±5.19</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>average</td>
<td>123.7±4.53</td>
<td>124.6±3.72</td>
<td>131.6±9.22</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>high</td>
<td>76.2±3.16</td>
<td>79.1±3.31</td>
<td>84.7±3.63</td>
</tr>
<tr>
<td>Voltage index, conventional units</td>
<td>low</td>
<td>111.5±8.17</td>
<td>123.4±9.02</td>
<td>149.9±9.85</td>
</tr>
<tr>
<td>Adaptive potential of the circulatory system to environmental factors, conventional units</td>
<td>low</td>
<td>1.5±0.09</td>
<td>1.6±0.12</td>
<td>1.7±0.15</td>
</tr>
<tr>
<td>Tolerable level of physical activity, W / kg</td>
<td>average</td>
<td>1.3±0.05</td>
<td>1.1±0.03</td>
<td>0.84±0.02</td>
</tr>
<tr>
<td>Oxygen uptake at a tolerable level of exercise,</td>
<td>high</td>
<td>35.1±2.03</td>
<td>31.4±1.82</td>
<td>27.7±1.53</td>
</tr>
<tr>
<td>ml / min / kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morbidity: number of days of temporary incapacity for work</td>
<td>low</td>
<td>7.8±1.96</td>
<td>9.2±1.44</td>
<td>12.2±2.42</td>
</tr>
</tbody>
</table>

85
Using data on morphological changes of peripheral blood erythrocytes, we propose to create an erythrocyte profile of patients to predict the risk of developing complications associated with chronic fatigue syndrome, in which the main indicators should be the level of exercise tolerance based on physical load, which is closely correlated with

Prospects for further research

Further research may be aimed at finding ways to improve the system of cardiohemodynamic control of people with chronic fatigue syndrome, and find measures to prevent and reduce the impact of the main factors of CFS in people of all ages.

Limitation

The study was conducted among older teachers, so the data obtained relate only to the studied contingent. Additional research is needed to disseminate the data among people of other ages and social groups, as well as among representatives of other specialties.

Conclusions

1. The study of the quantitative composition of erythrocytes of peripheral blood and hemoglobin, as well as their ratio (color index) in patients with chronic fatigue syndrome on the background of low tolerance to physical fatigue revealed a decrease in erythrocytes and hemoglobin by 42% and 25%, respectively. the presence of anemic hypoxia.

2. In conditions of chronic fatigue there is a decrease in osmotic resistance of erythrocytes, as evidenced by a decrease in the number of osmotically stable erythrocytes with a gradual decrease in the concentration of NaCl solution (3.0%; 0.5%; 0.46%; 0.3%).

3. With chronic fatigue there is a deterioration of membranes in erythrocytes of peripheral blood, as evidenced by a decrease in their osmotic stability and increase in the number of irreversibly altered forms of erythrocytes of peripheral blood, as well as a decrease in erythrocytes of peripheral blood, which is closely correlated with

It should be noted that in different risk groups of chronic fatigue syndrome differ leading factors, as well as major comorbid chronic diseases.

1. In the high-risk group, the main factors are hypokinesia, overweight, hypertension, hereditary factors; along with diseases of the cardiovascular system in this risk group revealed chronic fatigue syndrome associated with chronic diseases of the endocrine, musculoskeletal and respiratory systems, which corresponds to the data of other authors.

2. In the group of medium risk the main factors are: hypokinesia, overweight, nervous and emotional overload; chronic diseases of the cardiovascular, nervous system, musculoskeletal system and senses, combined with a decrease in disc-shaped erythrocytes of peripheral blood by 35%.

3. Patients in the low-risk group have virtually no pathogenetic factors in the development of chronic diseases. Exceptions are only patients with severe hypokinesia and nervous and emotional overload, as well as diseases of the digestive system.

Acknowledgment

The authors are very grateful to all the teachers who took part in the experiment.

Conflict of interest

The authors declare that there is no conflict of interest.

References


stability of erythrocytes]. DGU VPO GRMU, 2016; 16.
15. Toropchin V.I. Vplyv kombinatsiyi enerlivy ta nukuleksa na pokaznyky perekysseny lipidiv u khvorykh na nealkohoľny steatohepatyt, spoluchenyy z syndromom kronichnoy vitomy [The effect of the combination of energy and nuclei on lipid peroxidation in patients with non-alcoholic steatohepatitis associated with chronic fatigue syndrome]. Ukrainy morphological almanach. 2011:1(9)124-128. [in Ukrainian]
Sergii L. Popel

popelsergij@gmail.com

https://orcid.org/0000-0001-9019-3966

Department physical culture and sport Vasil Stefanyk Precarpatian University,
Shevchenko str., 57, 76025, Ivano-Frankivsk, Ukraine

Ivan V. Melnic

imelnik_64@ukr.net

https://orcid.org/0000-0002-2585-6134

Department of Dental Surgery,
Ivano-Frankivsk National Medical University,
Ivano-Frankivsk Hetman Mazepa Street 11 \ 14, Ukraine

Ihor K. Churpiy

ch.igor.if@gmail.com

https://orcid.org/0000-00003-1735-9418

Ivano-Frankivsk National Medical University,
Halyska str. 2, 76000, Department of Physical Rehabilitation,
Ergotherapy with a course of physical education, Ivano-Frankivsk City, Ukraine

Przemek Bejga

bejbej@o2.pl

https://orcid.org/0000-0003-4871-4689

Geriatric rehabilitation center, Elena Gura, Poland;
ul. Szprotawska 21 Kożuchów 67-120, Zielona Góra, Polska

Zbigniew Śliwiński

popelsergij@gmail.com

https://orcid.org/0000-00003-4871-4689

Faculty of Medicine and Health Sciences, Department of Pharmakology and Toxicology,
University of Zielona Góra, Polska
Zespół opieki zdrowotnej w Zgorzelcu, Stacjonarny Osrodek Rehabilitacji Chorob Naradu Ruchu dla Dorosłych I dzieci Im. Prof. Degi w Zgorzelcu, Polska

Інформація про авторів

Сергій Л. Попель

popelsergij@gmail.com

https://orcid.org/0000-0001-9019-3966

Прикарпатський національний університет імені Василя Стефаника
Вул. Шевченка, 57, Івано-Франківськ, 76025, Україна

Іван В. Мельник

imelnik_64@ukr.net

https://orcid.org/0000-0002-2585-6134

Івано-Франківський національний медичний університет,
Івано-Франківськ, вулиця гетьмана Мазепи 11 \ 14, Україна

Ігор К. Чурпій

ch.igor.if@gmail.com

https://orcid.org/0000-00003-1735-9418

Івано-Франківський національний медичний університет,
Галицька вул. 2, 76000, відділення фізичної реабілітації,
Ерготерапія з курсом фізкультури, м. Івано-Франківськ, Україна

Пшемек Бейга

bejbej@o2.pl

https://orcid.org/0000-00003-4871-4689

Центр геріатричної реабілітації, Олена Гура, Польща;
вулиця Шпротау 21 Кошуць 67-120, Zielona Góra, Polska

Збігнєв Слівінський

popelsergij@gmail.com
Информация об авторах

Сергей Л. Попель
popelsergij@gmail.com
https://orcid.org/0000-0001-9019-3966
Прикарпатский национальный университет имени Василия Стефанька
ул. Шевченка, 57, Ивано-Франковск, 76025, Украина

Иван В. Мельник
imelnik_64@ukr.net
https://orcid.org/0000-0002-2585-6134
Ивано-Франковский национальный медицинский университет,
Ивано-Франковск, улица Гетмана Мазепы 11\14, Украина

Игорь К. Чурний
ch.igor.if@gmail.com
https://orcid.org/0000-0003-1735-9418
Ивано-Франковский национальный медицинский университет,
ул. Галицкая. 2, 76000, отделение физической реабилитации,
Эротерапия с курсом физкультуры, г. Ивано-Франковск, Украина

Пшемек Бейга
bejbej@o2.pl
https://orcid.org/0000-0003-4871-4689
гернитический реабилитационный центр, Елена Гура, Польша;
ул. Szprotawska 21 Kożuchów 67-120, Зелена-Гура, Польша

Збигнев Сливинский
popelsergij@gmail.com
https://orcid.org/0000-0003-4871-4689
Факультет медицины и здравоохранения, кафедра фармакологии и токсикологии,
Университет Зелена-Гура, Польша

This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0)

Received: 2022-02-12  Accepted: 2022-03-10  Published: 2022-06-25