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EFFECT OF SPIRULINA FOOD SUPPLEMENT ON BLOOD MORPHOLOGICAL PARAMETERS, BIOCHEMICAL COMPOSITION AND ON THE IMMUNE FUNCTION OF SPORTSMEN

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Abstract. Of highest biological value are natural concentrates of optimally combined substances produced by nature. One of food supplements of this kind is dietary Spirulina produced by the Tianshi firm (China). It is a most rationally balanced food supplement of a high biological value; it satisfies the needs of the whole body, including its immune system. The aim of the current work was to assess the effect of the multicomponent natural food supplement Spirulina on the physical development, blood morphological, biochemical picture and immune function of sportsmen. Materials and Methods: The study cohort comprised 12 high performance sportsmen (age 20-22 years). They were using tablets of Spirulina, a dietary product for 14 days. Physical development was determined with the aid of standard methods. The general blood picture was analyzed with the aid of a Micros-60 hematological analyzer (company ABX DIAGNOSTICS, France). Lymphocytes and their subsets were analysed by flow cytometery (FACSCalibur, Becton Dickinson Immunocytometry Systems (BDIS, USA) and the absolute and percentage values were calculated. To evaluate immune function lymphocyte blasttransformation response to mitogens was studied. Results: Investigations carried out on endurance-training sportsmen showed that a 14-d administration of Spirulina exerted a positive effect on blood morphological composition indices and its biochemical changes. The results of our study confirm the positive effect of Spirulina food supplement on the quantitative parameters of immune system. Part of the study cohort after weeks showed a tendency of normalizing $CD3^+$, $CD3^+CD4^+$lympocite count: positive changes were still present two weeks following the interruption of Spirulina intake.

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Key words: Sportsmen - Food supplements - Spirulina - Blood biochemical and immune parameters

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Introduction

Great physical loads and their intensity impose strict demands on sportsmen's nutrition. It must be well balanced, highly efficient and meet the bodily demands. Therefore more and more popular in sports practice become highly efficient products, best of them being natural, optimally balanced concentrates of biologically active substances [6,15]. They act as adaptogens by improving bodily response to unfavorable external stimuli (both physical and emotional), raising physical capacity, stimulating the immune system and the functioning of the endocrine glands. However, there is a shortage of information on which products should be used as biologically active food supplements and which functional systems of the body are influenced by their effect in sportsmen. Earlier we have published a series of papers on the use of various food supplements in sportsmen's nutrition [18,19,20].

Over the recent years, many new dietary supplements have appeared on the market and are used by sportsmen. The products of the Chinese firm Tianshi are gaining popularity in their nutrition. These products, such as Spirulina, Cordiceps are being produced following the millennium-long traditions of Chinese medicine. Spirulina *(Spirulina maxima)* was known also in Aztecs medicine. They may be used in higher doses than the homeopathic and lower than pharmacological preparations [29].

Spirulina is an alga containing a valuable combination of substances, including those practically absent in common food. Energetic value of 10 g dried Spirulina powder – 29 kcal: fat – 0.7 g, protein – 5.7 g, carbohydrate – 2.4 g, vitamin A – 57 IU, vitamin B_1 – 0.24 mg (thiamine), B_2 (riboflavin) – 0.38 mg, B_3 (nicotinamide) – 1.3 mg, B_6 (pyridoxine) – 0.4 mg, B_9 (folic acid) – 9.4 mg, vitamin C – 1 mg, vitamin E –0.5 mg, natrium – 104 mg, potassium – 136 mg, calcium – 12 mg, magnesium – 20 mg, iron – 2.8 mg, zinc – 0.2 mg [25]. Dry Spirulina has 60-70 % protein, 10-20 % carbohydrate, 9-14 % fat, 4 % nucleic acid, 4-6 % minerals. Spirulina is a source of β-carotene and iron [12]. Research shows it to stimulate the immune system, build both red and white blood cells and assist detoxification [14]. Spirulina also is a best balanced highly efficient dietary supplement, which satisfies the demands of all systems of the organism and, what is most important, improves the condition of its immune system and is a source of easily available iron [4,5,8]. The literature data show that Spirulina enhances the haemopoietic system and increases resistance to hypoxia [9,21,22]. M. Maranesi et al [17], who were studying *Spirulina platensis* for 20 years, in their publications calls it superfood, an especially efficient concentrate of a perfect composition. The World

Health Organization prognosticates that in the 21st century *Spirulina* will become one of the most important curative and prophylactic components of nutrition and recommends it also in children's nutrition [1,6]. However, despite of a rather high popularity of this product, there is a lack of more or less comprehensive studies to analyze the effect of Spirulina dietary supplement on the sportsmen's adaptation to physical loads.

The immune protection of the organism is multicomponent and capable of adapting to environmental factors. The functional status of the immune cells circulating in the blood, the amount and character of secreted substances are markers of changes taking place in the organism. Immune cells are activated upon getting into an inflammatory focus and regional lymphatic organs; the substances secreted post activation (interleukines, interferones, growth factors) not only modulate the local immune response, but also get into circulation. Here they act on both immune cells and other systems, e.g., stimulate hepatocytes for acute phase protein secretion, bone marrow cell proliferation, increase endothelial permeability. Thus, blood cells signify the character and intensity of immune responses. In their turn, immune system cells are exposed to the effect of the molecules produced by other organ systems [7,9].

Under conditions of strenuous work the cells secrete stress hormones, among them cortisol; therefore in peripheral blood neutrophilia, lymphocytopenia become pronounced, the production of oxidative oxygen radicals in neutrophils is down regulated, the nasociliary clearance and secretory IgA (sIgA) secretion are impeded, the functional activity of natural killers and the lymphocyte prolipherative response to stimulation decrease, etc. [2,11]. This response can be modified by the effect of special food supplements; for instance, enhanced carbohydrate intake exerts a positive effect on glucose level control and mitigates the stressogenic response of cortisol and growth hormones, thus changes of immune responses become less pronounced [13,21,22,26].

It is obvious that the functioning of immune cells greatly depends on nutritional habits. Deficiency or excess of proteins and microelements (iron, zinc, vitamins A, E, B_6 and B_{12}) as well as fat excess are factors of immune cell functional deficiency [3].

Spirulina abounds in antioxidants, vitamins, microelements and other nutritive substances. It is known as a potent inductor of gamma-interferon and a somewhat weaker stimulation of interleukin 4 and influence on 1β production. Thus, Spirulina is expected to upregulate the cellular immune response directed against intracellular microorganisms, rather than the humoral link of immune response [6,7], though changes of the immune indices in individuals from different

immunodeficiency groups, induced by the intake of natural food supplements such as Spirulina, have not yet been given exhaustive studies [11].

The aim of the present work was to assess the effect of the multicomponent natural food supplement Spirulina on the sportsmen's physical development and blood composition and on their immune function.

Materials and Methods

The study cohort comprised 12 high performance sportsmen (age 20-22 years), who combined studies with endurance training. After the first investigation, when the physical development, blood morphological and biochemical composition were determined, the study subjects were using tablets of Spirulina, a dietary product of the firm Tianshi, based on dry powder of the alga *Spirulina platensis*, fermented *Cordiceps sinensis* mycelium and β-carotene. One tablet contained 250 mg of Spirulina. Three tablets were consumed by each participant of the study three times a day between the meals with ample water for 14 days. Their nutritive regime was determined by the methods of questioning and questionnaires. Examinations were performed before Spirulina supplementation, immediately following the supplementation, and two weeks after the supplementation had been interrupted.

Physical development was determined with the aid of standard methods by measuring the study subjects' height, body mass, muscle and fat mass and index, lung vital volume [24].

Venous blood was sampled from an antecubital vein and the samples were collected into sterile vacutainers. The general blood picture was analyzed with the aid of a Micros-60 hematological analyzer (ABX DIAGNOSTICS, France). We used it to measure red blood corpuscles (RBC), haemoglobin (HB), haematocrit (HCT), mean red corpuscle volume (MCV), erythrocyte sedimentation rate (ESR), red corpuscle distribution area (RDA), white blood corpuscle (WBC) count, lymphocyte (LYM), monocyte (MON), granulocyte (GRA) count and percentage. A Reflatron-IV express-analyzer was employed to measure blood biochemical indices, such as creatinekinase (CK), creatinine (Crea), cholesterol (Chol), triglycerides (Tg), bilirubin (Bil), urea (Urea) and uric acid (Ua).

Investigation of the immune state of the sportsmen included determination of lymphocyte subtypes, as $CD3^+$ (T lymphocytes), $CD3^+CD4^+$ (T lymphocytes helpers/inductors), $CD3^+CD8^+$ (T cytotoxic/suppressor lymphocytes), $CD3^-$ $CD16^+/56$ (NK cells), $CD19^+$ (B lymphocytes) and evaluation of lymphocyte blasttransformation response to mitogens. Immunophenotyping of lymphocyte subsets was performed by two-color direct immunofluorescence technique using

mouse monoclonal antibodies (Becton Dickinson Immunocytometry Systems (BDIS), USA). Analysis was performed on FACSCalibur flow cytometer (BDIS, USA) using SimulSET software. Lymphocytes were electronically gated on the basis of their forward scatter versus 90^o scatter criteria as well as with the aid of Simultest LeucoGATE (CD45FITC/CD14PE) monoclonal antibodies. Irrelevant mouse IgG antibodies of the same isotype (IgG_1FITC/IgG_{2a}PE) and concentration were used as controls to set fluorescence markers between negatively and positively stained lymphocyte clusters and to detect the presence of non-specific staining. The obtained data were compared with the normative elaborated in a multicenter study [11].

The functional response of lymphocytes to stimulation was studied *in vitro* by the lymphocyte blasttransformation reaction: lymphocytes isolated in a sterile way by density gradient centrifugation were stimulated with mitogens – phytohemagglutinin, lectin from *Phaseolus vulgaris* (PHA-P, Sigma) and Phytolacca Americana, pokeweed mitogen (PWM, Sigma). The cells were incubated for 72 h at 37^oC in RPMI-1640 medium containing 1-glutamine, antibiotics and 20% of foetal calf serum. The number of blast cells (responding to stimulation) and nonblast cells (not responding to stimulation) was assessed by the morphological method [21].

The obtained data were processed by methods of mathematical statistics. The arithmetical mean $\bar{x}$, error $S\bar{x}$, standard deviation *S* were calculated. To evaluate differences among the mean indices of different stages of the study, Student's t criterion was applied to related sets. The Kolmogorov-Smirnov test was used to evaluate the correspondence of the distribution of indices to the standard level.

Discussion

In the test subjects, the indices of physical development (height, body mass) changed but little over the experimental period (Table 1). Body mass over this period decreased on average from 75.99±2.37 to 75.03±2.24 kg. Lung capacity showed an insignificant increase (from the average of 5.53±0.19 L to 5.61±0.22 L, but the increase was statistically not reliable). The most important information on the physical development of the sportsmen is derived from the ratio between muscle and fat mass. With decreasing body mass, over the study period also fat mass decreased from 9.03±0.77 kg at the beginning of the experiment to 8.89±0.74 kg at its end, and after 2 weeks it decreased to 8.55±0.70 kg.

The role of blood morphological composition in the sportsmen's body is very significant. Blood supports the vitality of the bodily systems and organs by

performing various functions, supplying organs with oxygen and nutritive substances, eliminating the products of metabolism, protecting the body against infections, regulating the hormone level, etc.

Table 1
Dynamics of the sportsmen's physical development indices over the experimental period

Indices	Height cm	Body mass (kg)	Body mass index (kg/m^2)	Lung vital volume (L)	Fat mass (kg)	Muscle mass (kg)	Muscle and fat mass index
			Before the use				
$\overline{X}$	182.25	75.99	22.90	5.53	9.03	40.58	4.89
$S\overline{x}$	2.29	2.37	0.50	0.19	0.77	1.26	0.49
S	7.93	8.19	1.70	0.65	2.68	4.37	1.68
			After a 2-week use				
$\overline{X}$	182.25	75.57	22.74	5.53	8.89	40.60	4.95
$S\overline{x}$	2.29	2.17	0.43	0.21	0.74	1.15	0.51
S	7.93	7.52	1.50	0.73	2.57	3.97	1.77
			2 weeks after the use				
$\overline{X}$	182.25	75.03	22.60	5.61	8.55	40.90	5.21
$S\overline{x}$	2.29	2.24	0.45	0.22	0.70	1.17	0.56
S	7.93	7.75	1.56	0.75	2.41	4.06	1.93
			t				
I-II	0	0.13	0.30	-0.03	0.12	-0.02	-0.08
I-III	0	0.30	0.50	-0.29	0.46	-0.19	-0.44
II-III	0	0.17	0.23	-0.25	0.34	-0.18	-0.36

At the beginning of the study, blood structural indices of the involved sportsmen were within the normal levels. After two weeks of Spirulina administration these indices showed a positive effect of this dietary product on the haemopoietic system (Table 2). Erythrocyte count in the sportsmen's blood over the study period showed no significant changes; nevertheless, immediately following Spirulina administration it showed an increasing tendency (on average $0.06x10^{12}$/L). Analysis of RBC counts in the first and second stages of the experiment revealed a more significant increase of this index in the sportsmen whose initial RBC levels had been low. The average erythrocyte volume (MCV)

following 14 days of Spirulina administration showed no changes and after 2 weeks of Spirulina intake decreased. The RDW (red corpuscle distribution area) index at the beginning of the study approached the lower limit of the recommended level, but following Spirulina administration it showed a statistically reliable increase. The literature data [3,10] indicate that such shift should be regarded as a good bodily response in assimilating iron.

Table 2
Dynamics of the sportsmen's general blood picture over the experimental period

Indices	RBC 10^{12}/L	HGB g/L	HCT %	MCV fL	RDW %	ESR mm/h
Physiological marks	3.8-5.8	110-165	35-50	80-97	10.0-15.0	110
Before the use						
$\overline{X}$	4.94	146.33	44.00	88.00	11.42	5.17
$S\overline{x}$	0.13	3.09	0.96	0.78	0.15	2.11
S	0.46	10.71	3.34	2.70	0.50	7.32
After a 2-week use						
$\overline{X}$	5.00	147.17	43.91	88.00	11.22	3.58
$S\overline{x}$	0.10	1.99	0.66	0.69	0.11	0.58
S	0.35	6.90	2.28	2.37	0.40	2.02
2 weeks after the use						
$\overline{X}$	4.98	147.75	42.83	86.08	11.68	4.58
$S\overline{x}$	0.07	1.53	0.43	0.68	0.13	1.08
S	0.24	5.29	1.50	2.35	0.46	3.73
t						
I-II	-0.37	-0.23	0.08	0.00	1.08	0.72
I-III	-0.27	-0.41	1.11	1.86	-1.36	0.25
II-III	0.17	-0.23	1.37	1.99	-2.67*	-0.82

*P<0.05

Similar changes were revealed also in the haemoglobin level of the sportsmen's blood. During the first stage of the study this index increased not very significantly (by 0.84 g/L), and the increase was more significant (by 1.42 g/L) in the second stage.

Another important index of blood composition, haematocrit, throughout the study period kept decreasing but showed no statistically reliable changes. A higher erythrocyte count and a higher haemoglobin level at a lower mean volume and a higher mean haemoglobin content in them and a decreased haematocrit percentage are the desirable phenomena for the sportsmen whose activities require particularly high endurance.

White blood corpuscles (WBC) perform various protective functions, participate in cellular and humoral immunity. In the leucograms of the sportsmen – participants of our study, after 2 weeks of Spirulina administration the leukocyte class percentage was within the recommended normative levels. In the third stage (2 weeks following the interruption of Spirulina intake), an increasing tendency of leukocyte count and positive shifts in the leukocyte formula were observed. In the leucogram, the percent ratio of agranulocytes (lymphocytes and monocytes) and granulocytes (neutrophils, basophils, eosinophils) was smoothened (Table 3).

Throughout the whole period of study the mean values of blood biochemical indices were within the recommended limits (Table 4). The mean creatine kinase indices were nearly the same, however, the difference between their maximal and minimal parameters was very high. Two persons stood out for their creatinekinase levels, which were above norm. It is worth noting than these sportsmen before study had been taking several dietary supplements. In 7 persons of 12, for whom blood creatine kinase in the first trial reached the average level (from 24.4 to 194 u/L), immediately following Spirulina intake increased from 39.8 to 244 u/L Blood creatinine level throughout the study period decreased on average from 93.99±2.84 to 90.45±4.05 μmol/L, and this difference can be regarded as a positive phenomenon.

Blood cholesterol and triglyceride levels for all study participants were below the lower recommended level. Urea and uric acid levels in their blood over the study period showed no statistically significant changes, however, immediately following Spirulina intake and two weeks later exhibited a pronounced increasing tendency, implying the intensifying effect of this drug on protein metabolism in the body.

Table 5 shows that during the first examination the mean percentage of some lymphocyte subtypes characteristic of immune response ($CD3^+$, $CD3^+CD4^+$) was below the lower age-related standard levels.

Table 3
Dynamics of the sportsmen's leukocyte count and formula over the experimental period

Indices	WBC 10^9/L	#LYM 10^9/L	LYM %	#MON 10^9/L	MON %	#GRA 10^9/L	GRA %
Physiological marks	3.5-10	1.2-3.2	17-48	0.3-0.8	4-10	1.2-6.8	43-76
Before the use							
$\bar{X}$	5.33	1.70	34.08	0.25	6.04	3.38	59.88
$S\bar{x}$	0.31	0.08	2.15	0.03	0.70	0.32	2.52
S	1.07	0.26	7.46	0.10	2.43	1.10	8.71
After a 2-week use							
$\bar{X}$	5.18	1.54	33.28	0.18	4.68	3.45	62.04
$S\bar{x}$	0.48	0.08	2.73	0.02	0.34	0.45	2.84
S	1.67	0.27	9.47	0.07	1.17	1.56	9.85
2 weeks after the use							
$\bar{X}$	5.49	1.62	30.48	0.28	5.92	3.59	63.61
$S\bar{x}$	0.21	0.09	1.56	0.02	0.40	0.18	1.67
S	0.73	0.31	5.41	0.08	1.37	0.64	5.79
t							
I-II	0.28	1.46	0.23	1.88	1.76	-0.12	-0.57
I-III	-0.42	0.71	1.35	-0.89	0.15	-0.57	-1.23
II-III	-0.60	-0.64	0.89	-3.15**	-2.39*	-0.29	-0.47

*P<0.05; **P<0.01

The level of T lymphocytes in 66.7% of the study cohort was below the lower standard level and in 58.3% the percentage of T helpers/inductors was low. In 41.7% the absolute $CD3^+CD4^+$ T lymphocyte count was below the age-related standard, i.e. below 700 cells/mm^3; in 83.3% of cases a low level of specific cytotoxic lymphocytes ($CD3^+CD8^+$) was determined. Low B lymphocyte levels during the first examination were rarer (41.7%). The percentage of natural killers characteristic of nonspecific immune response on the contrary, was often (in 83.3% if individuals) above the upper normal limit (19%). In 41.7% of cases the cell count per milliliter was above 400. The distribution of $CD3^+CD4^+$ cells versus the age-related standard levels is shown in Fig. 1 and of CD $16^+/56^+$ cells in Fig. 2.

Table 4
Dynamics of the sportsmen's blood biochemical indices over the experimental period

Indices	Ck u/L	Crea μmol/L	Chol mmol/L	Tg mmol/L	Bil μmol/L	Urea mmol/L	Ua μmol/L
Physiological marks	24-167	27-115	2.6-5.2	0.5-2.3	3.4-17	1.8-8.3	143-372
Before the use							
$\bar{X}$	92.35	93.99	3.81	1.52	18.14	5.60	307.00
$S\bar{x}$	15.13	2.84	0.23	0.26	2.03	0.46	9.83
S	52.42	9.83	0.81	0.85	7.04	1.60	34.05
After a 2-week use							
$\bar{X}$	97.13	90.45	3.72	0.94	16.40	6.20	321.00
$S\bar{x}$	18.25	4.05	0.22	0.08	2.83	0.33	19.61
S	63.22	14.03	0.75	0.27	9.81	1.15	67.92
2 weeks after the use							
$\bar{X}$	96.83	94.47	3.75	1.14	18.13	6.75	340.42
$S\bar{x}$	16.36	2.71	0.21	0.14	1.87	0.35	17.24
S	56.68	9.40	0.72	0.48	6.49	1.23	59.72
t							
I-II	-0.20	0.72	0.27	1.13	0.50	-1.05	-0.64
I-III	-0.20	-0.12	0.18	1.72	0.00	-1.97	-1.68
II-III	0.01	-0.82	-0.09	-1.27	-0.51	-1.13	-0.74

As is mentioned in introduction, under the effect of cortisol, whose content, among other factors, increases also under physical strain and stress, T lymphocyte count in peripheral blood is downregulated. This tendency was corroborated also by the results of our study: under conditions of quantitative deficit of T lymphocytes, the B lymphocyte count most often corresponded to the age-related standard levels. The enhanced natural killers count, which is characteristic of viral disease patients, in this case can signify the transmission of cells from the marginal pool into the circulating one, which is a feature of a stress physical load [16,28]. One can see in Fig. 3 that lymphocyte response to mitogen stimulation in the study cohort was rather active; the functional deficiency of lymphocytes was established only in 16.7% and the activation even in 75% of the study subjects.

The second examination of immune indices to assess the early response and the third one to establish the duration of the effect were performed 14 days following the daily intake of Spirulina food supplement (3 tablets 3 times a day).
Table 5 shows a positive tendency of changes in immune indices versus the data of the first examination (changes are statistically not reliable).

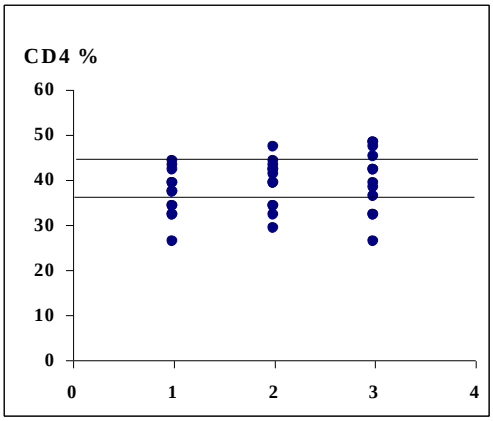

Fig. 1
$CD3^+CD4^+$ cell count versus age-related standard limits

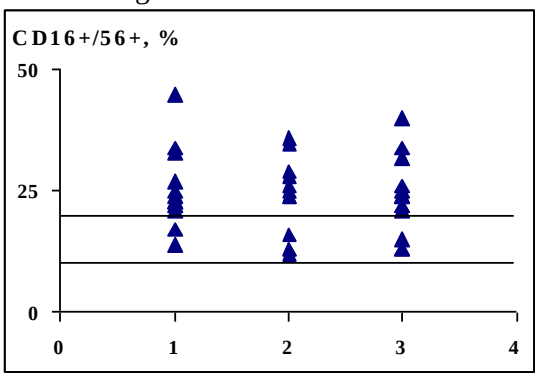

Fig. 2
$CD16^+/56^+$ cell count versus age related standard limits

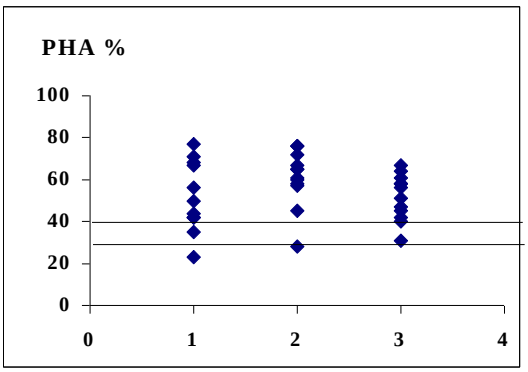

Fig. 3
Lymphocyte response to phytohaemagglutinin stimulation

The second examination, like the first one, revealed a low T lymphocyte percentage in 8 out of 12 subjects, i.e. 66.7% of the study cohort, however, the third examination showed a positive change of this index: T lymphocyte count was low only in 41.7% of study group subjects. The percentage of T helpers/inductors was clearly normalized both in the second and third examination: this index was low in 33.3% versus 58.3% in the first examination (Fig. 1.), whereas the specific cytotoxic lymphocyte count as well as the total T lymphocyte count were increasing slower: this index was low in 83% of the study subjects during the first and second examination and in 75% of cases in the third examination. The percentage of B lymphocytes practically did not change, and the initially increased percentage of natural killers gradually decreased [16] (this index was unregulated in 83.3 %of individuals in the first, 66.7% in the second and 75% in the third examination).

While discussing the results it should be noted that tendency, or inclination to quantitative immunodeficiency can be related not only with physical strain but also with chronic stress [13] evoked by a double strain - that of studying and training. The sooner response of lymphocytes to stimulation may be explained by the fact that the sportsmen's ration contains higher amounts of proteins. On the other hand, literature data show that some of the functional immune indices, such as the cytotoxic activity of natural killers and the proliferative response of lymphocytes under phytohaemagglutinin stimulation, are higher in sportsmen than in subjects not engaged in sports [21,22,23,27].

The results of our study confirm the positive effect of Spirulina food supplement on the quantitative indices of immune system. Part of the study cohort after weeks showed a tendency of normalizing $CD3^+$, $CD3^+CD4^+$ lymphocyte count: positive changes were still present two weeks following the interruption of Spirulina intake.

Table 5
Dynamics of the sportsmen's immune indices over the xperimental period ($\overline{X} \pm S\overline{x}$)

Indices	Physiological marks %	Physiological marks mm^3	Stages	Results %	Results mm^3
Lymphocyte percentage and count	28-39	1600-2400	1	36.0±2.3	2050±99
			2	35.4±3.2	1901±112
			3	36.1±2.6	1960±168
$CD3^+$, T lymphocytes	67-76	1100-1700	1	61.8±2.5	1279±98
			2	64.0±2.6	1223±95
			3	66.5±2.6	1289±102
$CD3^+CD4^+$, T helpers/inductors	38-46	700-1100	1	36.6±1.5	753±53
			2	38.8±1.6	746±63
			3	39.6±2.0	763±62
$CD3^+CD8^+$, T cytotoxic/suppressor	31-48	500-900	1	25.4±2.3	529±60
			2	25.8±2.1	494±53
			3	25.2±2.3	501±66
$CD16^+CD56^+$, natural killers	10-19	200-400	1	25.7±2.4	513±44
			2	23.4±2.4	441±51
			3	24.1±2.4	487±81
$CD19^+$, B lymphocytes	11-16	200-400	1	10.9±1.0	225±24
			2	10.9±0.7	209±21
			3	10.8±1.0	208±24
Lymphocyte blasttransformation to PHA, %	30-40		1	48±6	
			2	61±4	
			3	52±3	
Lymphocyte blasttransformation to PWM, %	8-10		1	10±2	
			2	13±2	
			3	10±2	

Stages: 1. Before the use; 2. After a 2-week use; 3. Two weeks after the use

Conclusions

1. During the two weeks of Spirulina intake, the physical development of the sportsmen showed no statistically significant changes.
2. Immediately following the 14-d period of Spirulina administration, in the sportsmen's blood erythrocyte count and haemoglobin concentration had a tendency to an increase accompanied by a decrease of the mean erythrocyte volume and unchanged blood haematocrit. Leucocyte count also showed an increasing tendency, and the percent ratio of agranulocytes and granulocytes was leveling-off.
3. Spirulina intake caused no violation of the recommended standard levels of blood biochemical indices. The levels of cholesterol, triglycerides, bilirubin in the blood showed a decreasing and of urea and uric acid an increasing tendency.
4. Most of the positively changed morphological and biochemical indices of the sportsmen's blood composition retained similar levels for another two weeks following the withdrawal of Spirulina from their diet.
5. Under higher than medium physical loads, the number of lymphocyte subtypes characteristic of specific immune response, particularly $CD3^+$ (T lymhocytes), $CD3^+CD4^+$ (T helpers/inductors) has a tendency to decrease with increasing the number of $CD16^+CD56^+$ (natural killers). Lymphocyte response to mitogen stimulation is enhanced.
6. The Spirulina food supplement, based on microalgae, exert a positive effect on the quantitative indices of immune response: the number of T helpers/inductors tends to normalize sooner (after 14 days) and that of T cytotoxic/suppressor lymphocytes later (after 28 days).

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