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Original Article

Utilizing hemogram indicators and coagulation homeostasis as key markers for precision dosing of physical exertion

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Abstract
Problem statement. To ensure the accurate prescription of physical exertion in sports, physical education, and rehabilitation, it is crucial to employ criteria of adequacythat signify the compatibility of physical exertion with the body's functional capabilities. **Objective**. This study aimed to establish criteria for assessing the adequacy of physical activity, utilizing hemogram indicators and coagulation homeostasis parameters in the context of extreme physical activity. **Materials and methods**. The research involved two groups of 46 male sprinters aged 18–20 years. The first group (GI) comprised highly skilled athletes (Category I - MS, n = 21), while the second group (GII) included less skilled athletes (Categories II-III, n = 25). Additionally, a control group (CG) comprised healthy volunteers of the corresponding age and sex who were not engaged in sports (n = 12).Changes ofthe complete blood count and separate indicators of coagulation homeostasis at rest, under conditions of maximum physical load "to failure" and during recovery were studied. **The results**. It was established that some indicators of hemogram and indicators of coagulation homeostasis changed differently in low- and high-skilledathletes during extreme physical load and during recovery. Athletes of different qualifications differed in the dynamics of the following hemogram indicators (markers): hemoglobin concentration, red blood cell count,erythrocyte sedimentation rate, white blood cell count total, number of segmented neutrophils, leukocyte intoxication index. These parameters were higher in low- than in high-skilled athletes. The low-skilled athletes also had greater changes of indicators that characterize the tendency to hypercoagulation. Close correlations between these marker indicators and parameters of coagulation homeostasis were also established. **Discussion**. The marker indicators changed more in low- than in high-skilled athletes, because these athleteshad less developed mechanisms of regulation of adaptive and compensatory states in conditions of physical exertion "to failure". An increase in marker indicators signaled unfavorable changes in the body of low-skilled athletes when physically overworked. This was confirmed by an increase in the tendency to hypercoagulation with its known pathogenetic effect on the body. **Conclusions.** The obtained data confirm that the hemogram indicators and the indicators of coagulation homeostasis can be markers of the functional state for assessing adaptive reactions of athletes to intensive physical work. They can also be used as markers when dosing exercises in physical education and rehabilitation.
Key words: hemogram, coagulation, marker, adaptation, runners-athletes, extreme physical exertion.

Introduction

It is known that physical activity has a positive effect on the human body. Physical exercises have a positive effect in various areas: sports, physical education and physical rehabilitation of patients with a wide variety of pathologies (Korytko Z.I., 2020). It is also known that regular physical exercises increase the body's functional reserves and its adaptation potential. They increase the body's resistance to adverse and extreme factors. Physical exercise also reduces morbidity, mortality and the risk of sudden death from cardiovascular disease (Villeneuve, P. J. et al, 1998; Polianska O. S., 2018). At the same time, physical loads have a positive effect on the body only when they are adequate in volume and intensity to the body's functional capabilities (Leskiv I.Ya. et al, 2013; Mazur V.A. & Skavronsky O. P., 2016). Physical loads of great intensity can result in a state of overtraining and failure of adaptation (Elloumi M.et al., 2005; Kreher J. B., & Schwartz J. B., 2012).

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Inadequate physical loads result in the emergence of pre-pathological or pathological conditions and disease progression with people who have a reduced level of health (Waltz X. &Connes P., 2014; Chernozub A.et al., 2018).

Numerous papers focus on methods of dosing the amount of physical exertion at various types of activity (Wasfy M. M., & Baggish A. L., 2016; Korytko Z.I., 2020; Gallardo-Gómez D. et al., 2023). Scientists constantly search for markers based on the indicators of various systems that can signal the appropriate amount of physical exertion.

References provide data on markers of the body's adaptation to physical exertion based on various parameters. The studied marker indicators based on changes in various body systems, which signal the impact of physical exertion on the body of athletes. Data of markers based on biochemical changes in the body during exercise have been presented (Arakawa K. et al, 2016; Lee E.C. et al, 2017; Sybil M. et al, 2018). Indicators of hemodynamic reactions were studied, including indicators of central hemodynamics and heart rate variability under conditions of significant physical exertion (Korytko Z.I. et al., 2020; Mykhalyuk E.L. et al., 2021). Changes of indicators of energy exchange at the maximum loads with athletes of various qualifications were studied (KorytkoZ.I., 2011). Data of changes of blood parameters during exercise have been presented (Patelis N. et al, 2016; Akinci B. et al, 2019), etc. Changes of the hematological parameters of the body during systematic physical exercises draw special attention. It is known that changes of blood provide information about the level of health, signal the progression of the disease or the recovery of the patient, as well as the susceptibility to various diseases. (Filipyuk, A., & Radchenko, O., 2017; Korytko Z.et al, 2019; Ivanov I., 2022). Therefore, it became necessary to identify a composition of hematological indicators that would most accurately signal the impact of physical exertion on the physical condition and performance capacity of athletes, as well as on the health of people of different ages and sexes in the process of physical education, and patients in the process of physical rehabilitation.

In our opinion, the search for criteria for the adequacy of physical exertion to the functional capabilities of the body based on the indicators of various systems is possible when comparing the deployment of adaptive and compensatory reactions under the conditions of extreme physical work "to failure" with athletes of different qualifications. Comparing indicators of high-skilled athletes, who are perfectly adapted to physical overloads, and low-skilled athletes, who are less adapted, will make it possible to mark the parameters that change differently under conditions of extreme physical exertion. These parameters will indicate the mechanisms of adaptation to stress (Korytko Z.I., 2013).

The aim of the study is to establish criteria for assessing the adequacy of physical activity, utilizing hemogram indicators and coagulation homeostasis parameters in the context of extreme physical activity.

Materials & methods

The research involved two groups of 46 male sprinters aged 18–20 years. The first group (GI) included highly skilled athletes (Category I - MS, n = 21), while the second group (GII) included less skilled athletes (Categories II-III, n = 25). Additionally, a control group (CG) was comprised of healthy volunteers of the corresponding age and sex who were not engaged in sports (n = 12). All participants agreed to the study and signed the informed consent.

Indicators were measured in three states: at rest, after extreme physical load "to failure" and after 30 minutes of recovery. Limit physical load was modeled with the Conconi bicycle ergometric test (Conconi F., et al. 1982). Athletes performed physical load of increasing power "to failure".

The complete blood count (CBC) and separate parameters of coagulation homeostasis in high- and low-skilled athletes were studied. All indicators of hemogram and parameters of coagulation homeostasis were obtained with the help of a non-invasive diagnostic method to determine the blood formula and biochemical regulatory indicators of metabolism and blood circulation of Malikhin-Pulavsky using the hardware and software complex and the "Success" program. This device and measurement method has several patents and is allowed to be sold in Ukraine and many other countries (Malykhin A.V., 2007).

Analyzed indicators of the CBC were as follows: red blood cell count (RBC, x 10^{12}/L), hemoglobin (HGB, g/L) and color index (CI), erythrocyte sedimentation rate (ESR, mm/hr), white blood cell count total (WBC, x 10^9/L) and differential. The leukogram indicators were analyzed in detail. The number and types of white blood cells were studied. The total and absolute differential WBC counts of lymphocytes (Lym), monocytes (Mon), eosinophils (Eos), basophils (Ba) and neutrophils (Neu) were studied. Based on leukogram indicators, the following leukocyte indices were calculated: adaptation index (AI) (Garkavi L.Kh. et al, 1979) and leukocyte intoxication index (LII) of Kalf-Kalif (Torguev A.P., 2008), which characterizes the degree of inflammation, destruction, intoxication. The adaptation index value determined the type of adaptation reaction. The following types of adaptation reaction are distinguished: "stress" (0.3 and <); "orientation" (0.31 - 0.5); "calm adaptation" (0.51 - 0.7); "overactivation" (0.71 - 0.9) and "increased activation" (0.9 and >).

Moreover, the following separate indicators of the blood coagulation system were also analyzed: the Lee-White clotting time (the time of the beginning and the time of ending of blood clotting, s), hematocrit (HT, %), platelet count (PLT x 10^9/L), prothrombin index (%), fibrinogen (g/L).

Before and after the exercise, a quantitative immunological analysis of D-dimers was done using the Roche Diagnostics cobas h232 system (Dempfle C.E., 2006).

The data were statistically processed using Excel and SPSS 11.5 statistical programs. A significant difference was determined by the Student, Wilcoxon, and Mann-Whitney tests, and relations were identified using the Pearson correlation coefficient and factor analysis.

Results

As shown in **Table 1**, no indicators differed among themselves in a state of rest with athletes of low and high qualification (P > 0.05). These indicators were within the normal range of reference values for healthy people and did not differ from the indicators of the control group.

Differences in some indicators were found only with high-skilled athletes. They had a tendency to increase the total number of leukocytes (11.05 ± 3.3 x 10^9/L, P > 0.05) and a decrease in the absolute number of monocytes (0.21 ± 0.04 x 10^9/ L, P < 0.05). They also had an increased leukocyte intoxication index (19.33 ± 4.15, P < 0.01).

Table 1. Features of the hemogram indicators with runners of different qualifications at rest (M ± m)

Indexes	Investigated groups			P between GII and GI
	CG (n = 12)	GI (n =21)	GII (n = 25)	
HGB (g/L)	152.67 ± 7.03	152.67 ± 7.03	153.84 ± 11.84	P > 0.05
RBC (x 10^{12}/L)	5.11 ± 0.13	5.11 ± 0.13	4.93 ± 0.24	P > 0.05
WBC (x10^9/L)	7.12 ± 0.43	11.05 ± 3.30	5.95 ± 1.47	P > 0.05
Lymphocytes (%)	29.1 ± 1.46	30.25 ± 0.89	30.20 ± 1.19	P > 0.05
Lymphocytes (x10^9/L)	2.04 ± 0.11	3.29 ± 0.99	1.71 ± 0.16	P > 0.05
Monocytes (%)	6.1 ± 0.86	4.84 ± 1.94	9.26 ± 1.50*	P < 0.05
Monocytes (x10^9/L)	0.49 ± 0.09	0.21 ± 0.05*	0.57 ± 0.07	P < 0.01
Eosinophils (%)	2.3 ± 0.36	4.86 ± 0.04*	4.59 ± 0.23*	P > 0.05
Eosinophils (x10^9/L)	0.16 ± 0.04	0.54 ± 0.18*	0.27 ± 0.03*	P > 0.05
Bands neutrophils (%)	6.2 ± 0.8	5.24 ± 1.25	7.9 ± 1.19	P > 0.05
Bands neutrophils (x10^9/L)	0.44 ± 0.06	0.30 ± 0.07	0.50 ± 0.12	P > 0.05
Segmented neutrophils (%)	54.8 ± 1.51	55.17 ± 2.32	48.72 ± 2.48	P < 0.05
Segmented neutrophils (x10^9/L)	3.53 ± 0.32	6.57 ± 1.86	2.90 ± 0.23	P > 0.05
ESR (mm/hr)	10.71 ± 2.84	10.71 ± 2.84	14.64 ± 4.01	P > 0.05
Color indicator	0.89 ± 0.03	0.89 ± 0.03	0.92 ± 0.03	P > 0.05

Note: * - P < 0.05; ** - P < 0.01 – probability between GI, GII and CG

At the same time, as can be seen from the **Table 2**, the adaptation index was within the normal range (0.54 - 0.61) both with athletes of high and low qualification, and in representatives of the control group. This indicated the type of adaptive response "quiet adaptation".

Only highly-qualified athletes had an elevated leukocyte intoxication index. This index was higher for them than for low-skilled athletes and the control group.

Table 2. Adaptation index and leukocyte intoxication index with runners of different qualifications and in the control group at rest (M ± m)

Indexes	Investigated groups			P between GII and GI
	CG (n = 12)	GI (n =21)	GII (n = 25)	
AI	0.54 ± 0.03	0.55 ± 0.01	0.61 ± 0.02*	P > 0.05
ЛІІ	2.22 ± 0.43	3.01 ± 0.32	2.18 ± 0.19	P < 0.05

Note: * - P < 0.05; ** - P < 0.01 – probability between GI, GII and CG

As can be seen from the **Table 3**, the studied groups of high- and low-skilled athletes almost did not differ in the chief parameters of coagulation homeostasis at rest. There were differences only between the groups of athletes (G1 and G2) and the control group (CG) (P < 0.01).

Athletes of both groups, in contrast to the control group, had reduced the time of beginning and the time of ending of blood clotting. There were also differences in the platelet count, in the value of the prothrombin index and in the value of the hematocrit.

Table 3. Features of separate parameters of coagulation homeostasis with runners of different qualifications at rest (M ± m)

Indexes	Investigated groups			P between GII and GI
	CG (n = 12)	GI (n =15)	GII (n = 15)	
Beginning of blood clotting (s)	118.5 ± 5.06	91.2 ±7.24**	80.0 ± 4.84**	P < 0.05
Ending of blood clotting (s)	208.3 ± 4.72	150.8 ± 11.26**	135.4 ± 7.08**	P > 0.05
PLT (x 10^9/L)	261.8 ± 12.19	171.65 ± 11.15**	165.4 ± 15.7**	P > 0.05
Fibrinogen (g/L)	3.22 ± 0.04	3.14 ± 0.04	3.12 ± 0.04*	P > 0.05
Prothrombin index (%)	76.12 ± 0.51	76.45 ± 0.37*	77.32 ± 0.49	P > 0.05
HT (%)	43.31 ± 1.44	44.22 ± 2.81	38.88 ± 2.25*	P > 0.05

Note: * - P < 0.05; ** - P < 0.01 – probability between GI, GII and CG

The Hemogram indicators and parameters of coagulation homeostasis changed differently for high- and low-skilled athletes after physical load "to failure" and during recovery (**Figures 1, 2**). This reflected different ways of adaptation of the body under the influence of regular physical exertion. The differences between the indicators of high- and low-skilled athletes allowed us to single out the marker indicators of the adequacy of response to physical exertion.

Low-skilled athletes had less suppression of red blood cells than high-skilled athletes. The first had only a tendency to decrease the number of erythrocytes and hemoglobin was noted (P > 0.05), and high-skilled athletes there was a sharp decrease in the number of erythrocytes (by 19.2%, P < 0.01). The number of red blood cells continued to decrease during recovery in both groups of athletes.

The number of erythrocytes in both groups athletes (HS and LS athletes) turned out to be very low (by 16.8% in HS and by 18.5% in LS athletes, P < 0.01) at 30 minutes of recovery (**Figure 1**).

Figure 1. Dynamics of red blood indicators of high-skilled athletes (G1) and low-skilled athletes (G2) after physical load "to failure" and after 30 minutes of recovery (%)

The indicators of white blood responded very sensitively to extreme physical exertion. However, changes in white blood counts had a different trend than in red blood counts. The total number of leukocytes increased largely in low-skilled athletes than in high-skilled athletes. (**Figure 2**).

After physical load "to failure" with low-skilled athletes, the total number of leukocytes increased by more than two times (by 108.6%, P < 0.001), but began to decrease during the recovery period. Moreover, the total number of leukocytes of high-skilled athletes increased by only 15.9% (P < 0.05) after exercise, but continued to increase during the recovery period (by 200%, P < 0.001).

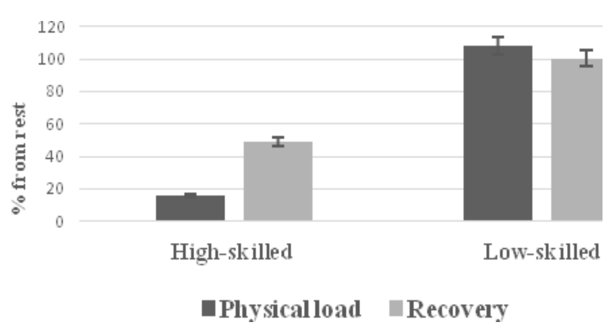

Figure 2. Changes of the total number of leukocytes of high- and low-skilled athletes after physical load "to failure" and after 30 minutes of recovery (%)

The Leukogram parameters changed a lot after the physical load and during the recovery period. These changes were greater for high- than for low-skilled athletes.

After physical load, the number of lymphocytes decreased (by 14.0%, $P < 0.05$), and the number of eosinophils decreased almost to zero for low-skilled athletes. Before physical load, the number of eosinophils with them was 4.59 ± 0.23% (0.27 ± 0.03 x 10^9/l), and after exercise the number of eosinophils was 0.7 ± 0.02% (0.09 ± 0.04 x 10^9/l), $P < 0.01$). At the same time, there was an increase in the number of monocytes and neutrophils ($P < 0.05$). The number of segmented neutrophils increased with a shift of the blood formula to the left, which is characterized by a pronounced tendency to increase bands neutrophils (bNt, $P > 0.05$). The amount of bNt after physical load increased to 17.58 ± 1.93% (1.88 ± 0.52 x 10^9/l) with low-skilled athletes. Percentage changes in leukogram parameters were more pronounced with high-skilled qualified athletes (**Figure 3**).

During recovery (after 30 minutes), the total number of leukocytes continued to increase ($P < 0.05$) with a pronounced shift of the leukogram to the left. The number of bands neutrophils increased sharply ($P < 0.05$). However, all other populations of leukocytes were restored to the initial level, with the exception of lymphocytes, the number of which continued to decrease ($P < 0.05$) (**Figure 3**).

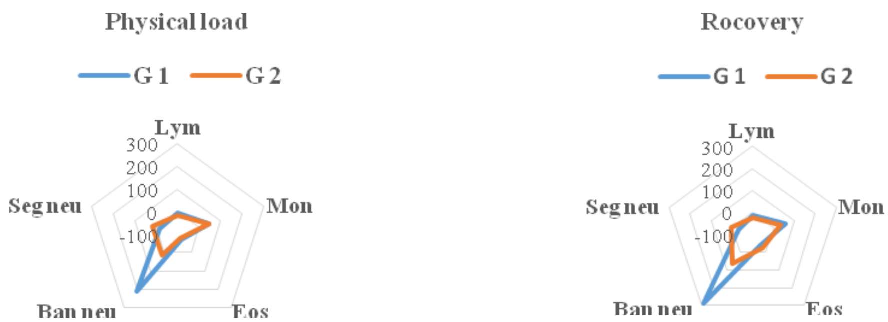

Figure 3. Dynamics of leukogram parameters of high-skilled athletes (G1) and low-skilled athletes (G2) after physical load "to failure" and after 30 minutes of recovery (%)

One-vector changes of parameters characterizing coagulation homeostasis were observed with all runners after physical load. The time of the beginning of blood clotting decreased ($P < 0.05$). The time of the ending of blood clotting did not significantly change ($P > 0.05$). The number of platelets increased significantly ($P < 0.01$). At the same time, fibrinogen concentration, prothrombin index value and hematocrit value were increased ($P < 0.05$) with low-skilled athletes. They also had a significantly increased concentration of D-dimers (by 15%, $P < 0.05$). However, among high-skilled athletes, only a tendency to increase these indicators was observed ($P > 0.05$). The changes of the blood coagulation system during adaptation to physical load "to failure" were more pronounced with low-skilled athletes after the physical test. They had a reduction of the time of the beginning of blood clotting (by 11%, $P < 0.01$), while with high-skilled athletes this time was reduced only by 7.1% ($P < 0.05$). The number of platelets increased more than two times (by 122%, $P < 0.01$) with low-skilled athletes, and with high-skilled athletes, the number of platelets increased only by 52.7% ($P < 0.05$). Value of the hematocrit increased significantly (by 24.6%, $P < 0.01$) with low-skilled athletes, and with high-skilled athletes, the value of the hematocrit did not change significantly ($P > 0.05$). That is, with highly qualified athletes, changes in the blood coagulation system were much less pronounced (**Figure 4**).

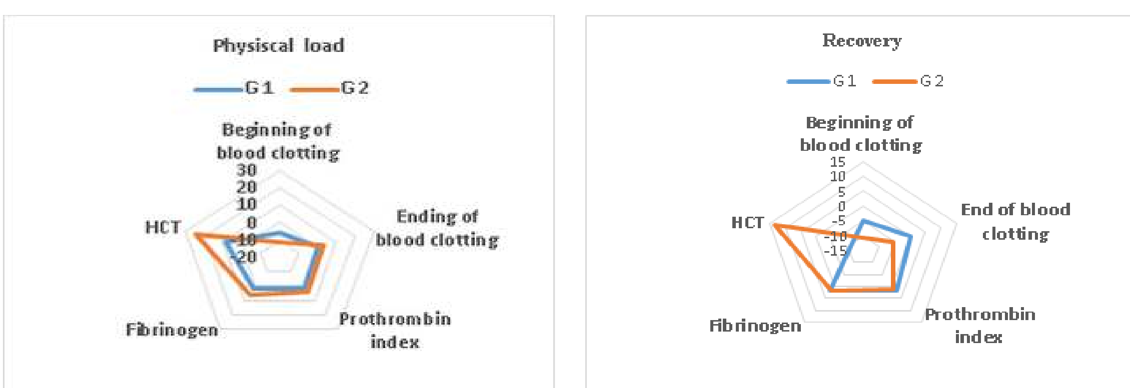

Figure 4. Changes of separate indicators of coagulation homeostasis of high-skilled athletes (G1) and low-skilled athletes (G2) after physical load "to failure" and after 30 min of recovery (%)

After 30 minutes of recovery, the number of platelets was almost restored ($P > 0.05$) in both groups of athletes, but indicators of the time of the beginning of blood clotting and indicators of time of end of blood clotting continued to decrease ($P < 0.05$).

Discussion

Thus, in the initial state (at rest), the main indicators of the hemocytogram of athlete-runners (EG1 and EG 2) were the same as those of their peers who did not play sports (CG). Features were only among high-skilled athletes. The separate leukogram indicators of these athletes differed from the control group because high-skilled athletes performed heavy training loads. This was, obviously, a sign of overtraining.

This state of overtraining of high-skilled athletes was confirmed by a significantly increased leukocyte intoxication index (19.33 ± 4.15, $P < 0.01$) compared to the CG and the group of low-skilled athletes. An increased index proved the presence of inflammation, destruction, and intoxication phenomena (Radchenko O. et al, 2019).

At the same time, the adaptation index of all athletes and representatives of the control group was within the normal range (0.54 - 0.61) in a state of rest. This type of adaptation reaction is defined as "quiet adaptation" and characterized by high resistance and high adaptation potential of all participants.

The differences between the two groups of athletes from the control group were only in separate indicators of blood coagulation. High-skilled athletes had a lower number of platelets. They had also a shortened indicator of the time of the beginning and of the time of the ending of blood clotting. All this also obviously indicated that high-skilled athletes had a state of under-recovery from large previous training loads, as it was established on the basis of factor analysis that the parameters of blood coagulation and hemocytograms are very closely related.

After physical load "to failure", a slight suppression of erythrocytes was observed with low-skilled athletes. A sharp decrease of the number of erythrocytes (by 19.2%, $P<0.01$) was observed only with high-skilled athletes. Apparently, this was due to the fact that high-skilled athletes had a greater physical load in the physical test "to failure", and it is known that erythrocytes react sensitively to excessive physical load (Malakhova S.M. et al, 2020).

At the same time, the values of indicators that characterize the morpho-functional state of white blood varied greatly. These changes were very significant with low-skilled athletes. They had an almost classical second phase of leukocytosis (I neutrophilic) immediately after physical exertion. This phase occurs as the result of heavy physical load. This phase is characterized by a doubling of the total number of leukocytes ($P < 0.05$), lymphocytopenia ($P < 0.05$). This is accompanied by significant monocytosis; a drop in the number of eosinophils, almost to zero ($P < 0.01$); an increase in the number of segmented neutrophils. At the same time, there is a shift of the blood formula to the left, which is characterized by a significant increase in bands neutrophils ($P < 0.05$) (Korytko Z.I., 2020; Korytko Z.I. et al, 2021).

High-skilled athletes had even greater changes of leukogram parameters in percentage. This, obviously, was due to the fact that they performed the limit cycle ergometric physical load of much higher power.

The second phase of leukocytosis with a transition to the third phase (II neutrophilic) was expressed in the blood of high-skilled athletes. Leukocytosis continued to increase in comparison with the Ineutrophilic phase ($P < 0.05$). This phase is characterized by lymphocytopenia and significant monocytosis ($P < 0.05$). A drop in the number of eosinophils, almost to zero ($P < 0.05$), neutrophilia and shift of the blood formula to the left (significant increase in the number of bands neutrophils, $P < 0.05$) have been documented.

Analysis of the dynamics of hematological indices (especially LII) of two groups of athletes showed that after the physical test, greater changes were observed in the group of low-skilled athletes. This proved greater severity of destructive processes with these athletes (Torguev A.P., 2008; Korytko Z., 2021).

The leukocyte intoxication index underwent the greatest changes. This index includes the number of eosinophils. Eosinophils are known to be the source of a number of cytokines. Some of the cytokines are involved in maintaining homeostasis. At the same time, other cytokines perform a pro-inflammatory function and secrete pro-inflammatory mediators (factor that activates platelets, pro-inflammatory prostaglandins). They are cells involved in tissue damage. Eosinophils secrete a transforming growth factor, participate in the development of reactions caused by T-lymphocytes. Eosinophils can modulate hypersensitivity reactions of the immediate type, inactivating mediators that release mast cells (histamine, leukotrienes, lysophospholipids and heparin) (Melo R. C.et al., 2013; Radchenko O. et al, 2019). Under conditions of great physical exertion, the number of eosinophils decreased sharply (almost to zero), as the hematological index LII increased the most ($P < 0.01$). Therefore, the reaction of low-skilled athletes to physical load "to failure" proved less perfect mechanisms of regulation of the blood system of these athletes. The imbalance in the ratio of separate indicators of the hemocytogram was greater, which indicated their less adequate adaptation to the action of extreme loads.

The nature of changes of indicators that characterize coagulation homeostasis under conditions of extreme physical load "to failure" indicates a tendency to hypercoagulation. Numerous literature data (Patelis N. et al, 2016; Kupchak B. R. et al, 2017), indicates that hypercoagulation has a pathogenetic effect on the body, because even a slight increase of the amount of fibrinogen is considered a risk factor for cardiovascular diseases (Jiang P. E et al, 2019).

Therefore, tolerance to the physical load "to failure" was higher with representatives of high-skilled athletes group, because they had less pronounced changes of indicators that characterize the blood's tendency to hypercoagulation. These changes were smaller both after the physical test "to failure" and during the recovery process.

Many researchers consider hypercoagulation, which is observed in conditions of high physical and emotional stress against the background of pronounced hyperadrenergy, as a pathogenetic mechanism for the development of various functional and morphological changes in the body (Myshchenko V., 2004; Monastyrsky V. A., 2007; VygovskaYa. I., 2007). Therefore, a factor analysis was performed to identify the relationships between hemocytogram indicators and parameters of coagulation changes. With its help, the closest correlations were established between these indicators.

Based on the factor analysis, it was established that after the physical test, the blood indicators of high-skilled athletes are combined into a factor with a high factor load (14.7). Interrelations between the following parameters were revealed: the time of the beginning of blood clotting, as well as the time of the ending of blood clotting and leukogram indicators are closely related ($r \geq 0.765$-0.890); platelets and fibrinogen with leukogram indicators are connected by feedback links above medium and high strength ($r \geq -0.584$-0.861). The closest relation is observed between indicators characterizing coagulation homeostasis and leukocyte intoxication index ($r = 0.976$).

After physical exertion, the blood indicators of low-skilled athletes combine into a factor with an even greater factor load (16.7) than that of high-skilled athletes. The relations between the following parameters were revealed: the time of the beginning of blood clotting and the time of the ending of blood clotting and leukogram indicators are connected by close direct relationships ($r \geq 0.720$-0.810); platelets and fibrinogen are inversely related to leukogram indicators ($r = -0.710$--0.770). In addition, parameters characterizing the activity of red blood (hemoglobin and erythrocytes, $r = 0.962$) are added with very close connections.

Thus, the results of the conducted studies prove differences in adaptation processes of athletes of different qualifications in the hemocoagulation system. Tolerance to physical exertion "to failure" was higher with high-skilled athletes, as they had a less pronounced propensity of blood to hypercoagulability. At the same time, during the recovery process, significant fluctuations of indicators were also observed with these athletes (especially this was related to the time of the beginning and of the time of the ending of blood clotting), which can be interpreted as the beginning of unfavorable changes in the blood coagulation system.

Conclusions

1. It has been established, that despite the state of under-recovery from previous loads, high-skilled athletes show better tolerance to physical load (practically the same changes of leukogram parameters, better restitution of indicators, as well as a lower degree of activation of the coagulation). Therefore, high-skilled athletes have more sophisticated mechanisms of regulation of adaptive and compensatory states, which may be associated with less activation of hypercoagulation and its pathogenetic influence.
2. A criterion for the depth of overtraining can be a violation of the balance between subpopulations of leukocytes, in particular, the Calf-Kalif leukocyte intoxication index, which characterizes the degree of inflammation, destruction, intoxication, since this balance changes more with low-skilled athletes after physical exertion and increases during recovery as a result of excessive physical exertion.
3. The indicators of the adequacy of adaptation and compensatory reactions can also serve as indicators that characterize the coagulation homeostasis (the time of the beginning and the time of the ending of blood clotting, hematocrit, fibrinogen, D-dimers). These indicators changed less with high-skilled athletes, despite the fact that they performed a greater volume of physical load "to failure".
4. The blood indicators (hemoglobin, red blood cell count, erythrocyte sedimentation rate, the total of white blood cell count, the number of segmented neutrophils) can be criteria for the adequacy of physical exertion. Based on factor analysis it has been established that these indicators are most closely related to blood coagulation indicators, changes in which can characterize the adequacy of adaptation to physical exertion.

Conflicts of interest. Authors report no conflict of interest.

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