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ANALYSIS OF BLOOD PARAMETERS IN ATHLETES TAKING INTO ACCOUNT HEMATOCRIT LEVELS

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Introduction. Assessment of hematological parameters in professional athletes requires a special approach. This includes analysis of hematocrit levels, which can be quite high due to their significant oscillations during intense muscular activity and under conditions of relative rest.
Objective. Study of the additional influence of various hematocrit levels on morphological and biochemical blood parameters, determined within the framework of the comprehensive medical examination (CME) of athletes.
Materials and methods. A retrospective study was conducted using data from athletes' medical records. A total of 26,413 hematological parameters obtained during the CME of athletes from Russian national teams were analyzed. Hematocrit was calculated using an automatic Mindray BC-6200 analyzer as the ratio of red blood cell volume to total blood volume. Nonparametric reference intervals for hematocrit, hemoglobin, red blood cell count, and mean corpuscular volume were constructed according to the CLSI EP28-A3c standard. Associations between hematocrit and blood parameters (lipid and protein profiles, glucose, oxygen transport system, sodium, potassium, magnesium, and platelets) were assessed using Spearman's rank correlations within extreme sub-samples (≤ *p*25 and ≥ *p*75 of hematocrit). Only correlations with Spearman's coefficient above 0.5 were considered significant. Comparisons of parameter distributions between percentile groups of hematocrit were performed pairwise using the nonparametric Wilcoxon test with an FDR correction.
Results. Irrespective of sex, within the normal hematocrit range (25–75 percentiles), a strong positive correlation is observed with hemoglobin levels (r_s = 0.836) and red blood cell count (r_s = 0.631). For hematocrit values above the 75th percentile, a strong positive correlation is maintained with hemoglobin concentration (r_s = 0.801) and red blood cell count (r_s = 0.603). Regarding hematocrit values below the 25th percentile, a near-significant correlation was identified with red blood cell count (r_s = 0.437), as well as a strong positive correlation with hemoglobin (r_s = 0.839).
Conclusions. Across different percentile ranges of hematocrit, significant differences in numerous blood biochemical parameters were identified. Thus, the higher the hematocrit level, the higher the concentrations of the recorded parameters in the blood serum. This underscores the importance of taking into account, inter alia, the possible influence of the hematocrit level when evaluating hematological parameters in athletes.

Keywords: professional athletes; morphological and biochemical blood composition; percentile gradations; hematocrit; comprehensive medical examination; high-performance sport

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АНАЛИЗ ПОКАЗАТЕЛЕЙ КРОВИ У СПОРТСМЕНОВ С УЧЕТОМ УРОВНЯ ГЕМАТОКРИТА

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Введение. Оценка гематологических параметров у профессиональных спортсменов требует особого подхода, в том числе к анализу уровня гематокрита, который может быть достаточно высоким, с учетом его осцилляции при напряженной мышечной деятельности и в условиях относительного покоя.
Цель. Изучение дополнительного влияния различных уровней гематокрита на показатели морфологического и биохимического состава крови, определяемые в рамках углубленного медицинского обследования (УМО) спортсменов.
Материалы и методы. Проведено ретроспективное исследование по данным медицинских карт спортсменов. Проанализировано 26 413 гематологических показателей, полученных при проведении УМО спортсменов сборных команд России. Гематокрит рассчитывался на автоматическом анализаторе Mindray BC-6200 как отношение объема эритроцитов к объему крови. Для гематокрита, гемоглобина, количества эритроцитов и среднего объема эритроцитов были построены непараметрические референсные интервалы по стандарту CLSI EP28-A3c. Ассоциации между гематокритом и показателями крови (липидный и белковый профиль, глюкоза, кислородтранспортная система, натрий, калий, магний, тромбоциты) оценивались ранговыми корреляциями Спирмена в крайних подвыборках (≤*p*25 и ≥*p*75 гематокрита). Значимыми считались только корреляции при значениях коэффициента

Спирмена выше 0,5. Сравнение распределений показателей между центильными группами гематокрита проводилось попарно непараметрическим критерием Вилкоксона с FDR-поправкой.
Результаты. Независимо от пола в нормальном диапазоне показателя гематокрита (25–75 процентилей) наблюдается его тесная положительная взаимосвязь с показателями гемоглобина (r_s = 0,836) и количеством эритроцитов (r_s = 0,631). При значениях гематокрита выше 75 процентиля тесную положительную взаимосвязь с ним проявляет концентрация гемоглобина (r_s = 0,801) и количество эритроцитов (r_s = 0,603). Что же касается значений показателя гематокрита ниже 25 процентиля, то здесь была выявлена его близкая к достоверной взаимосвязь с количеством эритроцитов (r_s = 0,437), а также сильная положительная взаимосвязь с гемоглобином (r_s = 0,839).
Выводы. В разных процентильных диапазонах гематокрита выявлены достоверные различия многих биохимических показателей крови: чем выше гематокрит, тем выше концентрации регистрируемых параметров в сыворотке крови. Это обусловливает необходимость при анализе и оценке гематологических показателей у спортсменов учитывать, помимо целого ряда других факторов, возможное дополнительное влияние величины гематокрита.

Ключевые слова: профессиональные спортсмены; морфологический и биохимический состав крови; процентильные градации; гематокрит; углубленное медицинское обследование; спорт высших достижений

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Финансирование: исследование выполнено без спонсорской поддержки.

Соответствие принципам этики: авторы заявляют, что одобрение комитетом по этике не требовалось, поскольку были проанализированы обезличенные данные медицинских карт (архивные материалы) и люди непосредственно не участвовали в исследовании.

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INTRODUCTION

The issues concerning the necessity of a special approach to the analysis and evaluation of hematological parameters in professional athletes, in particular with additional consideration of the hematocrit level, remain poorly studied [1–5]. The values of the vast majority of hematological parameters reflect their concentration in blood serum, the volume of which decreases during hypohydration. As a result, the concentration of substances contained therein increases accordingly [1, 6]. Hypohydration in athletes can arise from unreplenished fluid deficiency, hyponatremia, or hypoalbuminemia, which determine the osmotic and oncotic pressure of the blood [1].

According to Petibois et al. [7], when analyzing biochemical parameters in athletes, the phenomenon of plasma volume changes induced by physical exercise should be taken into account. Cooling, psychological stress, nutrition, hydration, as well as prolonged and intense exercise can significantly alter hemoconcentration during physical exertion, challenging comparison of data obtained by different studies. In order to address this problem in the future, the factor of hemoconcentration must be taking into account. Indeed, substantial biochemical shifts may be observed after correction for exercise-induced plasma volume changes.

Baranovskaya et al. demonstrated that in a homogeneous group of male athletes during a delayed post-exercise period, specifically 40 h after the last training session, distinct differences in the values of certain blood biochemical parameters were established, which were significantly associated with different levels of hematocrit [8]. In a study by Jacob et al., an attempt was made to analyze the influence of the hematocrit parameter on biochemical and morphological blood parameters [9].

Currently, there exist at least four methods for determining hematocrit in laboratory settings, each with its own advantages and disadvantages [10]. This must be taken into account when conducting a comparative analysis of research results, especially when different methods for determining hematocrit are used (in venous or capillary blood, under conditions of relative rest or during intense muscular activity, etc.).

In this study, our aim was to investigate the influence of various hematocrit levels on the parameters of morphological and biochemical blood composition determined within the framework of the comprehensive medical examination (CME) of athletes.

To achieve this aim, the following tasks were set:

- to calculate percentile gradations of the hematocrit parameter in male and female athletes and to identify the relationship of its various percentile ranges with parameters of the morphological and biochemical blood composition;
- to determine the significance of differences in the analyzed set of parameters of morphological and biochemical blood composition across different percentile ranges of the hematocrit parameter.

MATERIALS AND METHODS

A retrospective study of medical record data of athletes was conducted. A total of 26,413 hematological results from the CME of athletes from Russian national teams were analyzed (49% female, 51% male; mean age — 20 ± 3 years). The following parameters were taken into account: hematological (hemoglobin, hematocrit, mean

corpuscular volume, red blood cell count, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, platelets, mean platelet volume) and biochemical (levels of sodium, potassium, magnesium, iron in blood serum; concentrations of cholesterol, high-density and low-density lipoproteins, albumin, total protein, glucose, total cholesterol).

Descriptive characteristics were presented as median and interquartile range. Non-parametric reference intervals (2.5–97.5 percentile) for hematocrit, hemoglobin, red blood cell count, and mean corpuscular volume were constructed according to the CLSI EP28-A3c standard, with preliminary diagnostics and exclusion of outliers based on Cook's distance (using the reference intervals package) [11, 12].

The threshold values of the 25th and 75th percentiles of hematocrit were used to stratify the sample into three groups: ≤ *p*25, *p*25–*p*75, and ≥ *p*75. All calculations were performed in R 4.x using dplyr, tidyr, broom, purrr, ggplot2, and flextable. The statistical significance level was two-sided ($\alpha = 0.05$). Multiple testing was controlled using the Benjamini–Hochberg method within each test family. Missing values were handled on a complete-case basis in each specific model/comparison; variables with zero variability were excluded.

Associations between hematocrit and blood parameters were assessed using Spearman's rank correlations in the extreme subsamples (≤ *p*25 and ≥ *p*75 of hematocrit) between hematocrit and each quantitative indicator (separately in each subsample). The calculation required at least three observations and non-zero variance for both variables; in cases where these conditions were not met, the correlation for that pair was not calculated. Only correlation coefficients with a critical Spearman's rank correlation coefficient (r_s) value of above 0.5 were considered significant [13].

Comparison of parameter distributions between hematocrit groups (≤ *p*25, *p*25–*p*75, ≥ *p*75) was performed pairwise using the nonparametric Wilcoxon test with a FDR correction within the panel of biochemical/hematological markers [14]. Correlations for the central range (*p*25–*p*75) and the results of one-factor models on the full sample were used as a reference for comparison with estimates in the extreme quartiles and for calculating standardization coefficients.

RESULTS AND DISCUSSION

At the first stage, percentile gradations of red blood cell parameters were calculated. The data obtained are presented in Table 1. The interrelationships of hematocrit within its different percentile ranges with the other studied morphological and biochemical blood parameters were identified (Table 2).

Borderline health conditions in athletes begin to develop before the onset of clinical manifestations and before blood parameters begin to exceed the reference interval [6, 15, 16]. This explains the currency of the percentile approach to the analysis and assessment of blood parameters in professional athletes in sports

Table 1. Percentile gradations of hematocrit, hemoglobin, mean corpuscular volume, and red blood cell count in professional athletes

Parameter	*n*	Sex	Percentiles							
			*p*5	*p*10	*p*25	*p*50	*p*75	*p*85	*p*90	*p*95
Hematocrit, %	8757	F	35.74	38.65	39.47	40.25	41.15	43.01	43.86	44.0
	10,410	M	41.29	41.84	42.90	44.20	45.90	46.68	47.64	48.6
Hemoglobin, g/L	8757	F	115.00	118.80	125.0	130.8	136.40	139.3	141.5	144.30
	10,410	M	133.00	137.00	143.0	149.0	155.00	158.7	160.7	164.30
Red blood cell count, $\times 10^{12}$/L	8757	F	3.99	4.10	4.27	4.47	4.68	4.80	4.88	5.00
	10,410	M	4.54	4.66	4.85	5.06	5.28	5.40	5.49	5.62
Mean corpuscular volume, fL	8757	F	80.70	82.80	85.56	88.32	90.92	92.30	93.20	94.50
	10,410	M	81.29	83.07	85.40	87.78	90.03	91.39	92.20	93.50
Mean corpuscular HGB, pg	8757	F	26.01	27.00	28.20	29.30	30.30	30.80	31.15	31.65
	10,410	M	27.00	27.70	28.60	29.50	30.40	30.84	31.18	31.64
Mean corpuscular HGB concentration, g/dL	8757	F	31.50	31.80	32.50	33.19	33.73	34.03	34.24	34.51
	10,410	M	32.20	32.50	33.04	33.60	34.11	34.40	34.60	34.90

Table compiled by the authors based on their own data

Note: *n* — number of athletes; F — females; M — males; HGB — hemoglobin.

Table 2. Correlative relationships of the hematocrit parameter in different percentile ranges with the studied morphological and biochemical blood parameters

Parameter	Hematocrit values below the 25th percentile			Hematocrit values within 25–75 percentiles			Hematocrit values above the 75th percentile		
	n	r_s	*p*	*n*	r_s	*p*	*n*	r_s	*p*
Sodium, mmol/L	4653	0.044	0.003	9483	0.054	0.000	4735	-0.004	0.794
Hemoglobin, g/L	4788	0.839	0.000	9591	0.836	0.000	4788	0.801	0.000
HDL cholesterol, mmol/L	4651	0.046	0.002	9472	-0.154	0.000	4731	-0.069	0.000
Red blood cell count, $\times 10^{12}$/L	4788	0.437	0.000	9591	0.631	0.000	4788	0.603	0.000
Mean corpuscular volume, fL	4788	0.270	0.000	9591	-0.007	0.514	4788	0.076	0.000
Mean corpuscular HGB, pg	4798	0.179	0.000	9572	0.061	0.000	4797	0.041	0.005
Mean corpuscular HGB concentration, g/dL	4798	0.078	0.000	9572	0.137	0.000	4797	-0.040	0.005
Potassium, mmol/L	4656	0.089	0.000	9486	0.089	0.000	4737	-0.008	0.596
Magnesium, mmol/L	4652	0.080	0.000	9475	0.039	0.000	4729	0.004	0.769
Albumin, g/L	4648	0.076	0.000	9474	0.099	0.000	4731	0.001	0.962
Total protein, g/L	4665	0.104	0.000	9488	0.061	0.000	4740	0.048	0.001
Glucose, mmol/L	4658	0.026	0.077	9492	0.082	0.000	4743	-0.032	0.028
Total cholesterol, mmol/L	4652	0.112	0.000	9473	-0.093	0.000	4735	0.046	0.002
LDL cholesterol, mmol/L	4650	0.092	0.000	9471	0.000	0.985	4731	0.066	0.000
Iron, μmol/L	4727	0.216	0.000	9512	0.109	0.000	4747	0.084	0.000
Platelets, $\times 10^9$/L	4788	-0.095	0.000	9591	-0.132	0.000	4788	-0.004	0.800
Mean platelet volume, fL	4787	0.015	0.308	9589	0.016	0.107	4788	0.053	0.000

Table compiled by the authors based on their own data

Note: *n* — number of athletes; r_s — Spearman's correlation coefficient; HGB — hemoglobin; HDL — high-density lipoproteins.; LDL — low-density lipoproteins.; *p* — statistical significance level ($p \leq 0.05$).

medicine [6, 15, 16]. It is assumed that the optimal values of blood parameters in athletes, ensuring their optimal performance, fall within the 25–75 percentile range (Table 1) [15, 16].

During the research, statistically significant correlations were obtained between different percentile ranges of hematocrit and the blood parameters studied (Table 2). Independent of sex and under the normal hematocrit range (25–75 percentiles), a strong positive direct correlation was found with hemoglobin levels ($r_s = 0.836$; $p = 0.000$) and a moderate correlation with red blood cell count ($r_s = 0.631$; $p = 0.000$). For hematocrit values above the 75th percentile, a strong positive direct correlation was noted with hemoglobin concentration ($r_s = 0.801$; $p = 0.000$) and a moderate correlation with red blood cell count ($r_s = 0.603$; $p = 0.000$). Regarding hematocrit values below the 25th percentile, a statistically significant moderate positive correlation was found with red blood cell count ($r_s = 0.437$; $p = 0.000$), as well as a strong positive correlation with hemoglobin ($r_s = 0.839$; $p = 0.000$).

The strong association of hematocrit values across all its percentile ranges with hemoglobin concentration and red blood cell count indicates that these parameters should always be recorded together. When distinct discrepancies arise between the percentile intervals of hematocrit, hemoglobin, and red blood cell count, blood tests should be rechecked. In this regard, the World Anti-Doping Agency includes both hemoglobin concentration and hematocrit level among other indirect parameters of erythropoiesis in doping control screening procedures, without attempting to separate these parameters [17].

Interpretation of red blood cell parameters, particularly hematocrit, in athletes requires consideration of dynamic shifts in plasma volume. Two opposing processes — hemoconcentration and hemodilution — significantly influence blood rheology and oxygen transport

Table 3. Pairwise comparisons of the studied blood parameters between groups of athletes with hematocrit values below the 25th percentile, within 25th–75th percentiles, and above the 75th percentile

Parameter	Percentiles						Statistical significance level		
	< 25		25–75		> 75				
	n	*M* [95% CI]	*n*	*M* (95% CI)	*n*	*M* (95% CI)	p_1	p_2	p_3
Albumin, g/L	4648	43.09 [42.99;43.19]	9474	43.96 [43.89; 44.04]	6719	44.69 [44.59; 44.79]	≤0.001	≤0.001	≤0.001
Total protein, g/L	4665	69.86 [69.74; 69.99]	9488	70.96 [70.88; 71.05]	6731	72.09 [71.98; 72.19]	≤0.001	≤0.001	≤0.001
Hemoglobin, g/L	4788	124.09 [123.88; 124.29]	9591	140.68 [140.55; 140.82	4797	156.41 [156.24; 156.59]	≤0.001	≤0.001	≤0.001
Red blood cell count, $\times 10^{12}$/L	4788	4.33 [4.32;4.33]	9591	4.79 [4.79; 4.80]	4797	5.29 [5.28; 5.30]	≤0.001	≤0.001	≤0.001
Iron, μmol/L	4727	14.61 [14.40; 14.82]	9512	17.59 [17.45; 17.73]	6846	19.49 [19.32; 19.67]	≤0.001	≤0.001	≤0.001
Mean corpuscular volume, fL	4788	86.94 [86.80; 87.08]	9591	88.05 [87.97; 88.12]	4797	88.27 [88.17; 88.37]	≤0.001	0.4	≤0.001
Mean corpuscular hemoglobin, pg	4798	28.77 [28.71; 28.83]	9572	29.40 [29.37; 29.43]	4797	29.60 [29.57; 29.64]	≤0.001	≤0.001	≤0.001
Mean corpuscular hemoglobin concentration, g/dL	4798	33.08 [33.05; 33.11]	9572	33.40 [33.38; 33.41]	4797	33.54 [33.52; 33.56]	≤0.001	≤0.001	≤0.001
Potassium, mmol/L	4656	4.08 [4.07; 4.09]	9486	4.16 [4.16; 4.17]	6730	4.17 [4.16; 4.17]	≤0.001	≤0.001	0.4
Magnesium, mmol/L	4652	0.83 [0.83; 0.83]	9475	0.84 [0.84; 0.84]	6716	0.84 [0.84; 0.85]	≤0.001	≤0.001	≤0.001
Sodium, mmol/L	4653	139.12 [139.06; 139.18]	9483	139.47 [139.43; 139.51]	6725	139.46 [139.41; 139.50]	≤0.001	≤0.001	0.8
Glucose, mmol/L	4658	4.89 [4.88; 4.91]	9492	4.98 [4.97; 4.99	6753	4.94 [4.93; 4.96]	≤0.001	≤0.001	≤0.001
Mean platelet volume, fL	4787	8.88 [8.85; 8.91]	9589	8.89 [8.87; 8.91]	4797	8.98 [8.95; 9.01]	≤0.001	≤0.001	≤0.001
Platelets, $\times 10^9$/L	4788	258.34 [256.86; 259.83]	9591	247.40 [246.37; 248.43]	4797	237.61 [236.29; 238.92]	≤0.001	≤0.001	≤0.001
HDL cholesterol, mmol/L	4651	1.74 [1.72; 1.75]	9472	1.60 [1.59; 1.61]	6718	1.10 [1.08; 1.11]	≤0.001	≤0.001	≤0.001
LDL cholesterol, mmol/L	4650	2.21 [2.19; 2.23]	9471	2.28 [2.27; 2.30]	6717	2.39 [2.37; 2.40]	≤0.001	≤0.001	≤0.001
Cholesterol, mmol/L	4652	4.37 [4.34; 4.39]	9473	4.34 [4.33; 4.36	6730	4.31 [4.29; 4.33]	≤0.001	0.034	0.005

Table compiled by the authors based on their own data

Note: *n* — number of athletes; CI — confidence interval of the mean; *p* — significance of differences in blood parameters depending on hematocrit percentiles (p_1 — <25, >75; p_2 — <25, 25–75; p_3 — 25–75, >75).

function and must be considered key factors in evaluating data from laboratory monitoring.

Hemoconcentration is characterized by an increased concentration of cellular elements per unit volume of blood due to a decrease in plasma volume. This leads to an apparent or false elevation of hematocrit and hemoglobin concentrations. The main mechanisms underlying this phenomenon in athletes are dehydration due to sweating [18]; fluid shift into the interstitial space; "stress" hemoconcentration involving the release of catecholamines and cortisol in response to physical exertion that causes a transient reduction in plasma volume, possibly due to increased vascular tone and changes in permeability.

At the same time, hemodilution is the process of increasing blood plasma volume, leading to a decrease in the relative concentration of red blood cells and hemoglobin. This is the process of physiological adaptation, particularly pronounced in endurance-training athletes. The main mechanisms include adaptive hypervolemia (athletic hypervolemia), where the key roles are played by the activation of the renin–angiotensin–aldosterone system and increased vasopressin secretion in response to exercise [19]; expansion of plasma volume after a single bout of exercise.

Hemodilution improves the rheological properties of blood (reduces viscosity), facilitates cardiac output, and enhances cutaneous blood flow for thermoregulation. However, this underlies the phenomenon of "sports pseudoaemia", when an adapted athlete with a normal total red blood cell mass and absolute hemoglobin content shows hematocrit and hemoglobin values per unit volume of blood at the lower limit of norm or slightly below. This condition is adaptive and does not require treatment [20]. It is critically important to differentiate this condition from true iron deficiency states.

The second stage of the work involved pairwise comparisons of the studied blood parameters among groups of athletes with hematocrit values below the 25th percentile, between the 25th–75th percentiles, and above the 75th percentile (Table 3). According to the obtained results, the parameters of protein, lipid, and carbohydrate metabolism differ statistically significantly across different percentile ranges of hematocrit. This illustrates the necessity of additionally considering the influence of hematocrit on biochemical blood parameters when carrying out their assessment in athletes.

Only the differences in mean corpuscular volume and mean platelet volume were found to be non-significant in the hematocrit range below the 25th percentile and between the 25th–75th percentiles. For hematocrit values between the 25th–75th percentiles and above the 75th percentile, the differences in blood sodium and potassium content parameters were non-significant.

During the differential analysis of the influence of hematocrit values on the biochemical composition of blood (Table 3), significant differences were established in the designated ranges of the hematocrit parameter, as well as in hemoglobin and red blood cell concentrations. At the same time, an increase in serum iron levels in the setting of consistently high hematocrit has an important differential diagnostic significance. The most probable cause of such a combination is polycythemia vera, where clonal proliferation of erythroid cells is accompanied by ineffective erythropoiesis, altered hepcidin regulation, and intense iron turnover. This distinguishes polycythemia vera from secondary hypoxic erythrocytoses, which are characterized by normal or decreased iron levels due to its active utilization [21].

Furthermore, in cases of blood thickening due to dehydration, a simultaneous increase in the concentration of all plasma components, including iron, occurs. This is the state of relative hyperferremia, rather than a true increase in the total amount of iron in the body.

In addition, a small but statistically significant increase in total protein and albumin content at a hematocrit level above the 75th percentile is most likely associated with a decrease in the volume of the blood's liquid part. However, it cannot be ruled out that this also confirms the influence of the body's protein potential on hematopoiesis [1, 22]. A combined increase in hematocrit, total protein, and albumin under a normal or elevated sodium level is a classic sign of dehydration.

In our opinion, it is interesting that hemoconcentration is accompanied by worsening of lipid metabolism indicators (increased LDL levels and decreased HDL levels), while simultaneously showing a tendency to reduce the risk of thrombus formation due to decreased platelet content in the blood. During dehydration, plasma volume decreases, leading to a false (relative) increase in the concentration of all plasma components, including LDL. HDL levels may also falsely increase, although this effect is less pronounced. The combined alteration of the lipid profile (increase in low-density lipoproteins — LDL and decrease in high-density lipoproteins — HDL) and a reduction in platelet count (thrombocytopenia) in the setting of elevated hematocrit is a complex pathophysiological phenomenon characteristic of a number of conditions, primarily associated with chronic hypoxia [23, 24].

Thus, when analyzing and assessing the concentration of key biochemical blood composition indicators in athletes, it is necessary to additionally account for the hematocrit level and the possibility of associated shifts in the analyzed parameters, even within their normal ranges.

CONCLUSION

Interpretation of red blood cell parameters, particularly hematocrit, in athletes requires consideration of dynamic shifts in plasma volume. Two opposing processes — hemoconcentration and hemodilution — significantly affect blood rheology and oxygen transport function and should be considered key factors in evaluating laboratory monitoring data.

In professional athletes aged 17–23 years under relative rest conditions, the hematocrit level of venous blood, when measured using a Mindray BC-6200 analyzer, shows a strong positive correlation primarily with hemoglobin concentration and red blood cell count, regardless of sex. To avoid measurement errors, these indicators should be determined simultaneously. In cases where distinct discrepancies are found in the percentile intervals of hematocrit, hemoglobin, and red blood cell count, they must be rechecked.

Statistically significant differences found between the values of individual blood parameters at different hematocrit levels justify the necessity of additionally considering this factor when analyzing and evaluating hematological indicators in athletes.

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