Changes in the quantitative and qualitative indicators of blood in athletes training speed, endurance or strength performance

S. M. Malakhova, V. V. Syvola, M. S. Potapenko

Zaporizhzhia State Medical University, Ukraine

The vast majority of researches have focused on the study of an association between the body physical capabilities and quantitative, qualitative indicators and the rheological properties of blood depending on the level of physical activity or physical performance. However, the influence of performance (strength, endurance, speed), which is mainly trained by athletes, on the quantitative and qualitative blood indicators have not been studied enough.

The aim of the work – to study the association between the quantitative and qualitative blood indicators with the characteristics of strength, endurance or speed, that are mainly trained by athletes in different sports.

Materials and methods. A total of 72 athletes (52 men and 20 women) qualified from Candidate Master of Sports (CMS) to Master of Sports of International Class (MSIC) (mean age 21.75 ± 3.32 years) were examined. Depending on the physical performance mainly trained by athletes, three groups were formed: the first group – 48 athletes who mainly trained endurance performance (triathlon, swimming, long-distance running, rowing), the second group – 16 athletes who mainly trained speed performance (sprint running), the third group – 8 athletes who mainly trained strength performance (weightlifting, powerlifting, kettlebell lifting). Among them, there were MSIC – 2, masters of sports (MS) – 25, CMS – 45. Blood parameters were determined in the capillary blood of the athletes, using an automatic hematology analyzer “Abacus junior” (Diatron Messtechnik GmbH, Austria).

Results. Groups of athletes who mainly trained endurance or strength performance did not differ from each other in many blood indicators. However, athletes who mainly trained strength performance had a more pronounced anisocytosis, as evidenced by a 5.8 % (P = 0.008) increase in erythrocyte distribution width (RDWc, %), than athletes who trained endurance performance, as well as by a 15.4 % (P = 0.033) higher mean platelet volume.

Athletes who predominantly trained speed performance had an increased erythrocyte mean corpuscular volume (MCV) by 4.6 % (P = 0.0062), absolute (MID) and relative (MI) mixed number of monocytes, eosinophils and basophils by 172.9 % (P = 0.0004) and 158.3 % (P = 0.0002), respectively, than athletes who trained endurance performance. In athletes who trained strength performance, in contrast to athletes who trained speed performance, significantly higher red blood cell indicators were detected: absolute number of erythrocytes by 7.6 % (P = 0.040); haemoglobin content by 8.0 % (P = 0.032); mean corpuscular hemoglobin concentration by 6.4 % (P = 0.025); RDWc by 5.7 % (P = 0.006) with a decrease of 5.9 % (P = 0.001) in MCV.

Conclusions. Mobilization of the blood oxygen transport function in response to physical activity in athletes, who mainly trained strength performance, was accomplished through the increasing erythrocyte count, hemoglobin content and mean corpuscular hemoglobin concentration with the decreasing erythrocyte mean corpuscular volume. Athletes who predominantly trained speed performance showed the downward changes in erythrocyte count, hemoglobin content, mean corpuscular hemoglobin concentration (within the reference values) and increased erythrocyte mean corpuscular volume. In athletes who mainly trained endurance performance, the erythrocyte population was medium – sized with medium level of mean corpuscular hemoglobin.

Ключові слова: спортсмени, фізичні якості витривалості, швидкості, сили.
Изменения количественных и качественных показателей крови у спортсменов, развивающих качества быстроты, выносливости или силы

С. Н. Малахова, В. В. Сыволап, М. С. Потапенко

В фокусе большинство исследований было изучение ассоциации возможностей организма с количественными, качественными показателями и реологическими свойствами крови в зависимости от уровня двигательной активности или физической работоспособности. Однако влияние качеств (силы, выносливости, скорости), которые преимущественно развиваются атлетами, на количественные и качественные показатели крови изучено недостаточно.

Цель работы - изучение ассоциации количественных и качественных показателей крови с качествами силы, выносливости или скорости, которые преимущественно развиваются спортсмены разных видов спорта.

Материалы и методы. Обследованы 72 спортсмена (52 мужчины и 20 женщин) уровня мастерства от КМС до МСМК, средний возраст – 21,75 ± 3,32 года. В зависимости от физических качеств, которые преимущественно развивали спортсмены, сформированы три группы: первая группа – 48 спортсменов, которые развивали преимущественно качество выносливости (триатлон, плавание, бег на длинные дистанции, академическая гребля), вторая группа – 16 спортсменов, которые развивали преимущественно качество силы (триатлон, плавание, бег на длинные дистанции, академическая гребля), третья группа – 8 спортсменов, которые развивали преимущественно качество скорости (спринтерский бег).

Результаты. Группы спортсменов, которые преимущественно развивали качество выносливости или силы, не отличались между собой по многим показателям крови. Однако спортсмены, развивающие преимущественно качество силы, имели более выраженный анизоцитоз (о чем свидетельствует большая на 5,8 % (р = 0,008) величина распределения эритроцитов (RDWc, %), чем спортсмены, развивающие качество выносливости, а также больший на 15,4 % (р = 0,033) объем крови, занимаемый тромбоцитами.

Спортсмены, преимущественно развивающие качество скорости, имели больший на 4,6 % (р = 0,0082) средний объем эритроцитов (MCV), на 172,9 % (р = 0,0004) – абсолютное (MID) и на 158,3 % (р = 0,0002) – относительное (MI) содержание смеся моноцитов, базофилов, лейкоцитов, чем спортсмены, развивающие качество выносливости. У спортсменов, которые развивали качество силы, в отличие от спортсменов, развивающих качество скорости, зафиксированы достоверно большие показатели красной крови: абсолютного количества эритроцитов на 7,6 % (р = 0,040), концентрации гемоглобина в цельной крови на 8,0 % (р = 0,032), средней концентрации гемоглобина в эритроцитарной массе на 6,4 % (р = 0,025), относительной величины распределения эритроцитов по объему на 5,7 % (р = 0,006) в условиях меньшего среднего объема эритроцитов на 5,9 % (р = 0,001).

Выводы. Мобилизация кислородтранспортной функции крови к физическим нагрузкам у спортсменов, преимущественно развивающих качество силы, достигается за счет увеличения количества эритроцитов, содержания гемоглобина, средней концентрации гемоглобина в эритроцитарной массе в условиях уменьшения среднего объема эритроцитов.

У атлетов, которые в основном развивали качество скорости, изменения показателей красной крови направлены в сторону уменьшения (в пределах референтных значений) количества эритроцитов, содержания гемоглобина, средней концентрации гемоглобина в эритроцитарной массе и увеличения среднего объема эритроцитов. У спортсменов, преимущественно развивающих качество выносливости, популяция эритроцитов характеризуется средними размерами и средним уровнем внутрителизационной концентрации гемоглобина.

The most important physiological systems that determine body's ability to adapt to physical exercises are the cardiore- spiratory system and red blood cells, which provide oxygen transport to tissues [2]. The vast majority of researches have focused on the study of an association between the body's physical capabilities and quantitative (erythrocyte number), qualitative indicators (erythrocyte mean corpuscular volume, mean corpuscular hemoglobin) and the rheological properties of blood depending on the level of physical activity or physical performance [4,8,10,11,16].
However, the influence of performance (strength, endurance, speed) that athletes trained on the quantitative and qualitative indicators of blood has not been studied enough.

**Aim**

Thus, the aim of this work was to study the association between the quantitative and qualitative indicators of blood and strength, endurance or speed performance that athletes train in various kinds of sport.

**Materials and methods**

After signing an informed consent to participate in the study, 72 athletes (52 men and 20 women) qualified from Candidate Master of Sports (CMS) to Master of Sports of International Class (MSIC) were included. The mean age of subjects was 21.75 ± 3.32 years. Depending on the physical performance mainly trained by athletes, three groups were formed. The first group – 48 athletes who mainly trained endurance performance (triathletes, swimmers, long distance runners, rowers), the second group – 16 athletes who mainly trained speed performance (sprinters), the third group – 8 athletes who mainly trained strength performance (weightlifters, powerlifters, kettlebell lifters). Among them, there were MSIC – 2 athletes, masters of sports (MS) – 25, CMS – 45.

Red blood cell (RBC) number, hematocrit (HCT), mean corpuscular hemoglobin (Hb) concentration (MCHC), mean corpuscular hemoglobin (MCH), erythrocyte mean corpuscular volume (MCV), RBC distribution width (RDWc), white blood cell (WBC) count and differential counts of three WBC subpopulations – lymphocytes (LYM), granulocytes (GRA) – eosinophils (EO), basophils (BA) and mixed number of monocytes, eosinophils and basophils (MID), monocytes (MO); the percentage of lymphocytes (LY, %), granulocytes (GR, %), monocytes and eosinophils (MI, %), platelet count (PLT), plateletcrit (PCT), platelet distribution width (PDWc), mean platelet volume (MPV), erythrocyte sedimentation rate (ESR) were determined in the capillary blood of athletes using an automatic hematology analyzer “Abacus junior” (Diatron Messtechnik GmbH, Austria).

Statistical analysis of the study results was performed using a software package Statistica for Windows 13 (StatSoft Inc., № JPZ804382130ARCH10-J). The Shapiro–Wilk test was used to determine the normality of quantitative indicators distribution. Quantitative indicators were presented in the form of arithmetic mean and standard deviation taking into account the normality of the data; qualitative indicators – in the form of absolute and relative frequency.

Comparison of quantitative indicators in independent groups was determined by the method of parametric statistics using the two-sample Student’s t-test with the two-sided test index for a statistical significance value. A difference in qualitative characteristics between independent groups was assessed using the Pearson’s chi-square test with Yates’ correction and Fisher’s exact test. Differences were considered statistically significant at the level of P < 0.05.

**Results**

Comparison of blood parameters in athletes who mainly trained endurance or strength performance revealed a significant predominance of erythrocyte heterogeneity (RDWc) (12.70 ± 0.61 vs. 13.44 ± 0.92 %) by 5.8 % (P = 0.008) and PCT (0.13 ± 0.03 vs. 0.15 ± 0.04 %) by 10.3 % (P = 0.003) in athletes, who trained strength trained (Table 1). That is, athletes who trained strength performance had a greater RDWc and MPV.

The MID showed a 35 % (P = 0.056) increasing trend in athletes who trained strength performance. Thus, athletes who mainly trained strength performance had a more pronounced anisocytosis, as evidenced by a 5.8 % (P = 0.008) increase in RDWc than athletes who trained endurance performance, as well as by a 15.4 % (P = 0.033) higher MPV (Table 2). There were no other differences in blood counts between groups of athletes who mainly trained endurance or strength performance.

Comparative analysis of blood counts in endurance-trained and speed-trained athletes found a significant predominance of the following indicators in the latter: MID by 172.9 % (0.37 ± 0.36 vs. 1.01 ± 0.40 10⁹/l, P = 0.0004), MI by 158.3 % (5.83 ± 4.32 ± 15.06 ± 5.18 %, P = 0.0002), MCV by 4.6 % (89.15 ± 4.49 vs. 93.25 ± 2.12 fl, P = 0.0082). PCT showed a trend of being higher in speed-trained athletes in contrast to endurance-trained ones (P = 0.0804).

A higher MCHC was noticeable in endurance-trained athletes in contrast to athletes who trained speed performance, but this difference did not have a statistical significance (P = 0.0810).

Thus, athletes who predominantly trained speed performance had higher MCV by 4.6 % (P = 0.0082), MID – by 172.9 % (P = 0.0004) and MI – by 158.3 % (P = 0.0002) than endurance-trained athletes.

Comparison of hematochemical parameters in strength-trained and speed-trained athletes demonstrates that the latter had significantly higher MID by 77.2 % (0.57 ± 0.63

### Table 1. Blood counts in athletes who mainly trained endurance or strength performance, M ± SD

| Value, units of measure | Performance (n = 48) | Strength (n = 16) | P-level | % |
|------------------------|---------------------|------------------|---------|---|
| WBC, 10⁹/l            | 5.91 ± 1.41         | 7.14 ± 2.57      | 0.149   |   |
| LYM, 10⁹/l            | 2.28 ± 1.42         | 2.46 ± 1.36      | 0.889   |   |
| MID, 10⁹/l            | 0.37 ± 0.38         | 0.57 ± 0.63      | 0.056   | 35% |
| GRA, 10⁹/l            | 3.47 ± 1.00         | 4.11 ± 2.03      | 0.381   |   |
| LY, %                  | 35.58 ± 7.70        | 36.66 ± 10.79    | 0.665   |   |
| Ml, %                  | 5.63 ± 4.32         | 7.68 ± 6.49      | 0.306   |   |
| GR, %                  | 58.60 ± 7.77        | 57.56 ± 12.21    | 0.622   |   |
| RBC, 10⁹/l            | 4.38 ± 0.46         | 4.50 ± 0.43      | 0.340   |   |
| HGB, g/l              | 148.92 ± 11.76      | 154.38 ± 12.44   | 0.110   |   |
| HCT, %                | 38.94 ± 3.74        | 39.63 ± 3.96     | 0.466   |   |
| MCV, fl               | 89.15 ± 4.49        | 88.06 ± 3.30     | 0.194   |   |
| MCH, pg               | 34.25 ± 3.22        | 34.44 ± 2.22     | 0.398   |   |
| MCHC, g/l             | 383.92 ± 28.69      | 390.75 ± 26.05   | 0.264   |   |
| RDWc, %               | 12.70 ± 0.61        | 13.44 ± 0.92     | 0.008   | 5.8% |
| PLT, 10⁹/l            | 170.49 ± 37.70      | 183.06 ± 48.54   | 0.153   |   |
| PCT, %                | 0.13 ± 0.03         | 0.15 ± 0.04      | 0.033   | 15.4%|
| MPV, fl               | 7.87 ± 0.81         | 8.12 ± 0.57      | 0.155   |   |
| PDWc, %               | 37.66 ± 2.23        | 38.58 ± 1.55     | 0.116   |   |
| ESR, mm/h             | 6.26 ± 1.83         | 7.17 ± 1.94      | 0.245   |   |
Blood counts in athletes who mainly trained endurance or speed performance, M ± SD

| Value, units of measure | Performance | P-level | ±% |
|-------------------------|-------------|---------|----|
|                         | Endurance (n = 48) | Speed (n = 8) |     |
| WBC, 10^9/l             | 5.91 ± 1.41 | 6.67 ± 1.80 | 0.2814 |
| LYM, 10^9/l             | 2.28 ± 1.42 | 2.23 ± 1.18 | 0.3673 |
| MID, 10^9/l             | 0.37 ± 0.36 | 1.01 ± 0.40 | 0.0004 172.9 % |
| GRA, 10^9/l             | 3.47 ± 1.00 | 3.42 ± 0.76 | 0.9533 |
| LY, %                   | 35.58 ± 7.70 | 31.88 ± 14.15 | 0.9813 |
| MI, %                   | 5.83 ± 4.32 | 1506 ± 5.18 | 0.0002 158.3 % |
| GR, %                   | 56.60 ± 7.77 | 53.05 ± 11.46 | 0.1087 |
| RBC, 10^12/l            | 4.38 ± 0.46 | 4.16 ± 0.23 | 0.1061 |
| HGB, g/l                | 148.92 ± 11.76 | 142.00 ± 12.80 | 0.1975 |
| HCT, %                  | 38.94 ± 3.74 | 38.73 ± 2.46 | 0.9254 |
| MCV, fl                 | 89.15 ± 4.49 | 93.25 ± 2.12 | 0.0082 4.6 % |
| MCH, pg                 | 34.25 ± 3.22 | 34.09 ± 1.61 | 0.8330 |
| MCHC, g/l               | 383.92 ± 28.69 | 365.88 ± 11.41 | 0.0810 |
| RDWc, %                 | 12.70 ± 0.81 | 12.68 ± 0.44 | 0.3965 |
| PLT, 10^12/l            | 170.49 ± 37.70 | 188.38 ± 22.58 | 0.1178 |
| PCT, %                  | 0.13 ± 0.03 | 0.15 ± 0.02 | 0.0804 |
| MPV, fl                 | 7.87 ± 0.81 | 7.90 ± 0.81 | 0.7561 |
| PDWc, %                 | 37.66 ± 2.23 | 38.16 ± 2.21 | 0.4372 |
| ESR, mm/h               | 6.26 ± 1.83 | 5.88 ± 1.25 | 0.3995 |

Blood counts in athletes who mainly trained strength performance, M ± SD

| Value, units of measure | Performance | P-level | ±% |
|-------------------------|-------------|---------|----|
|                         | Strength (n = 16) | Speed (n = 8) |     |
| WBC, 10^9/l             | 7.14 ± 2.57 | 6.67 ± 1.80 | 0.903 |
| LYM, 10^9/l             | 2.46 ± 1.38 | 2.23 ± 1.18 | 0.668 |
| MID, 10^9/l             | 0.57 ± 0.83 | 1.01 ± 0.40 | 0.022 77.2 % |
| GRA, 10^9/l             | 4.11 ± 2.03 | 3.42 ± 0.76 | 0.713 |
| LY, %                   | 36.66 ± 10.79 | 31.88 ± 14.15 | 0.854 |
| MI, %                   | 7.68 ± 6.49 | 15.06 ± 5.18 | 0.008 98.1 % |
| GR, %                   | 57.56 ± 12.21 | 53.05 ± 11.46 | 0.298 |
| RBC, 10^12/l            | 4.50 ± 0.43 | 4.16 ± 0.23 | 0.040 7.8 % |
| HGB, g/l                | 154.39 ± 12.44 | 142.00 ± 12.80 | 0.032 8.0 % |
| HCT, %                  | 39.63 ± 3.96 | 38.73 ± 2.46 | 0.624 |
| MCV, fl                 | 88.06 ± 3.30 | 93.25 ± 2.12 | 0.001 5.9 % |
| MCH, pg                 | 34.44 ± 2.22 | 34.09 ± 1.61 | 0.540 |
| MCHC, g/l               | 390.75 ± 26.05 | 365.88 ± 11.41 | 0.025 6.4 % |
| RDWc, %                 | 13.44 ± 0.92 | 12.68 ± 0.44 | 0.006 5.7 % |
| PLT, 10^12/l            | 183.06 ± 48.54 | 188.38 ± 22.58 | 0.806 |
| PCT, %                  | 0.15 ± 0.04 | 0.15 ± 0.02 | 0.758 |
| MPV, fl                 | 8.12 ± 0.57 | 7.90 ± 0.81 | 0.602 |
| PDWc, %                 | 38.58 ± 1.55 | 38.16 ± 2.21 | 0.783 |
| ESR, mm/h               | 7.17 ± 1.94 | 5.88 ± 1.25 | 0.144 |

Discussion

According to I. Z. Khazipova and V. G. Shamratova (2012), the heart functional reserve is mainly responsible to ensure the endurance, while the state of microcirculation influence is less relevant [15]. Meanwhile, it is well known that the body’s oxygen transport capacity depends on the blood volume and the HGB in it. Decrease in the quantitative and qualitative parameters of red blood cells in anemia conditions significantly reduces the adaptive capacity of the cardiovascular system and whole human body. Mobilization of the oxygen transport function of blood is provided through, first of all, augmenting the total oxygen-carrying capacity of RBC, that is by increase in number and/or size of erythrocytes.

Herewith, the quantitative pattern contributes to the development of adverse hemorheological shifts [7], such as reduced whole blood flow with increasing HCT, which causes a resistance to blood flow, that in its turn, reduces the oxygen transport capacity of blood [14]. Under such conditions, the self-regulation mechanism is activated, namely RBCs display a less aggregation activity, aimed at improving the microrheological properties along with the negative changes in the macrorheological indicators and vice versa [9].

The study results of V. G. Shamratova and I. R. Khazipova (2011) indicated that the adrenaline-induced rheological response of RBC is influenced by their MCV and cytoplasmic viscosity, the change in cell size in the erythrocyte population and the severity of anisocytosis [16]. The correlations were complex and nonlinear. Thus, with an increase in proportion of microcytes or macrocytes in the erythrocyte population, the authors reported a decrease in erythrocyte adrenoreactivity and altered blood rheological properties [16]. The best rheological properties of blood, according to V. G. Shamratova and I. R. Khazipova coincided with the maximum adrenoreactivity of RBCs being consistent with average values of HCT and MCV (44.5 % and 88 fl, respectively); while the physiological optimum was in the range of RBC size predominantly represented by mature cells [16].

So, strength-trained athletes, in contrast to speed-trained athletes, showed significantly higher RBC parameters:

- the absolute number of erythrocytes by 7.6 % (P = 0.040);
- hemoglobin content (HGB) by 8.0 % (P = 0.032);
- MCHC by 6.4 % (P = 0.025);
- RDWc by 5.7 % (P = 0.006) with a 5.9 % (P = 0.001) decrease in MCV.

There was a clear correlation between RBC parameters and the athletic performance trained (Fig. 1–4). The highest indicators of RBC count, HGB, MCHC were observed in strength-trained athletes and the lowest ones in athletes who trained speed performance.

The values of RBC, HGB, MCHC were intermediate in endurance-trained athletes.

At the same time, strength-trained athletes had the lowest MCV, which was the highest in speed-trained athletes. The mean RBC was intermediate in athletes who trained endurance performance.

Table 2. Blood counts in athletes who mainly trained endurance or speed performance, M ± SD

Table 3. Blood counts in athletes, who mainly trained strength or speed performance, M ± SD
It has been proved, that adrenergic aggregation activity is enhanced by a significant decrease or increase in erythrocyte volume and intracellular viscosity. The MCH determines cytoplasmic viscosity and depends on erythrocyte life span [12]. Optimal rheological parameters are typical predominantly for mature erythrocytes [16].

The study results of G.-F. von Tempelhoff et al. (2016), based on an examination of 286 healthy women (age 46.5 ± 17.6 years; BMI 25.5 ± 5.2 kg/m²), showed an association between erythrocyte deformability, MCV and MCHC depending on age but not on BMI in middle-aged women with normal weight or moderately overweight. The authors found that erythrocyte aging was accompanied by a decrease in MCV and an increase in their stiffness. The significant influence of MCV and MCHC on the RBC deformability in apparently healthy middle-aged women was revealed, namely low MCHC and high MCV were associated with increased deformability, and high MCHC and low MCV correlated with increased RBC stiffness [5]. Bosch F. H. et al. [1] also observed a decreased RBC deformability with an increased MCHC and a decreased MCV. Rheological changes in the blood showed an increase in blood viscosity in women with age. Nevertheless, MCV, MCHC or MCH did not affect RBC aggregation in middle-aged women [1].

However, the works of V. G. Shamratova and I. R. Kha- zipova (2011) concluded that the blood rheological properties (viscosity) were largely dependent on HCT values. An increase in HCT, especially exceeding the mean value, was matched by a drop in erythrocyte adrenoreactivity and resulted in altered rheological properties not only of whole blood, but also RBCs. In contrast, a decrease in blood viscosity due to a decrease in HCT was associated with an increase in adenine-induced RBC aggregation [16].

An increase in the proportion of circulating macrocytes also worsened the rheological properties of blood [16].

That is, an increase in the number of RBC and HGB is an extremely important pre-condition for improving oxygen transport function of blood, especially when adapting to significant physical activity, although it is associated with alterations in the rheological properties of blood.

Kostova V. et al. (2012) found a linear correlation between dynamic viscosity and hematocrit in patients with type 2 diabetes mellitus. The relationship demonstrated an increase in viscosity causing an increase in hemorheological parameters (HCT, RBC count and fibrinogen) [3].

The data obtained suggested that people, who practice sports professionally and train certain physical performances, may have changes in the quantitative and qualitative parameters of red blood, which simultaneously support an enhancement of oxygen transport function and improvements in the rheological properties of blood by reducing the MCV. According to our data, such changes occurred in strength-trained athletes.

Kovelska A. V. and co-authors (2017) found a link between basic indicators of physical performance and some hematological parameters, including HGB and MCV. The authors revealed a statistically significant correlation $r = -0.27, P < 0.05$ between training experience and MCV [10]. Decreased MCV is known to be an indicator of increased body adaptability to exercise, as it is inversely related to tissue oxygen supply [6].
Our data indicated that the athletes who mainly trained endurance performance had medium-sized RBC and average MCH that may have promoted athletic excellence in such sports as triathlon, marathon running and others. Athletes should have a higher level of aerobic capacity during long-term training, which requires general endurance. Blood volume and RBC count are important factors for maximum aerobic capacity and physical performance. Regular physical exercise increases blood volume on the sidelines of improvements in maximum aerobic capacity and physical performance owing to RBC count. In analyzing the relationship between the main indicators of physical performance and hematological parameters in athletes, Kovalska A. V. and co-authors revealed a direct correlation between VO₂max ml/min⁻¹ and both HGB (r = 0.32; P < 0.05) and MCH (r = 0.37; P < 0.05) [10].

Our findings demonstrate a need for further study of the changes in blood parameters in athletes who mainly trained speed performance. The advantages of increased MCV along with reduced MCH in order to train high-speed sports performance are not well understood. Perhaps the changes in RBC size towards its increase were caused by cell swelling due to ionic imbalance.

The decrease in HCT, in the minds of Kovelska A. V., may be favorable for physical performance through the influence on circulation, which can be seen in reducing peripheral vascular resistance and increasing blood volume. With increasing training experience, there was a downward trend (P > 0.05) in the levels of HGB and HCT. Based on the results obtained, the researchers suggested that these differences were driven by the presence of one possible mechanism of the blood system adaptation to training loads, involving increase in the volume of circulating blood mainly due to its plasma component [10]. The parameters of RBCs either did not change or showed a tendency to decrease with an increase in circulating plasma volume [13].

Thus, the data yielded by the study convincingly demonstrate the correlation between the direction and severity of changes in qualitative and quantitative blood indicators and physical performance, which athletes mainly trained in various sports.

Conclusions

1. Mobilization of the blood oxygen transport function in response to physical activity in athletes, who mainly trained strength performance, was accomplished through the increasing erythrocyte count, hemoglobin content and mean corpuscular hemoglobin concentration with the decreasing erythrocyte mean corpuscular volume.

2. Athletes who predominantly trained speed performance showed the downward changes in erythrocyte count, hemoglobin content, mean corpuscular hemoglobin concentration (within the reference values) and increased erythrocyte mean corpuscular volume.

3. In athletes who mainly trained endurance performance, the erythrocyte population was medium-sized with medium level of mean corpuscular hemoglobin.

Conflict of interest: authors have no conflict of interest to declare. Конфлікт інтересів: відсутній.
in young men with different levels of motor activity]. Zhurnal mediko-
biofizikskikh issledovanii, 7(3), 251-260. https://doi.org/10.17238/
issn2542-1298.2019.7.3.251 [in Russian].

[9] Katukhin, L. N. (2001). Rol’ reologicheskikh determinant entrototsitov
v regulitatsiy struktury krovotoka [The role of rheological determinants
of red blood cells in the regulation of blood flow]. Klinicheskaya labo-
ratornaya diagnostika, (12), 22-24. [in Russian].

[10] Kovel’ska, A. V., Lysenko, O. M., Horenko, Z. A., & Ocheretko B. I.
(2017). hematolohichni pokaznyky krovi u sportsmeniv ta riven fizychnoi
pratsednostnosti [Hematologic indices in athletes and physical work
capacity level]. Sportyvna medytsyna i fiziynna reabilitatsiya, (2),
74-82. [in Ukrainian].

[11] Krivoschekov, S. G., Divert, V. E., Melnikov, V. N., Vodjanitskij, S. N.,
& Girenko, L. A. (2013). Sravnitel’nyi analiz reaktsii gazooobrazen a
i kardiorespiratornoi sistemy plovstov i lyzhnikov na narastayushchuyu
normobaricheskuyu gipoksiyu [Comparative Analysis of Gas Exchange and
Cardiorespiratory Systems Reactions to Increasing Normobaric Hypoxia
and Physical Load of Swimmers and Skiers]. Fiziologiya cheloveka, 39(1),
117-125. https://doi.org/10.7868/
SO131164612060070 [in Russian].

[12] Murav’ev, A. V., & Murav’ev, A. A. (2005). Vne- i vnutrikletcheskie
mekhanizmy izmeneniya agregatsii entrototsitov [Extra- and intracellular
mechanisms of changes in erythrocyte aggregation]. Fiziologiya
cheloveka, 31(4), 108-112. [in Russian].

[13] Nekhvyadovich, A. I., Budko, A. N., Petrova, E. E., & Pasyukevich, A. A.
(2016). Differentsirovanniy podkhod k otsenke izmeneniya kartiny krovi
v protsesse adaptatsii k trenirovochnym nagruzkam po
gimnastike sportivnoi [The differential approach to the assessment of
the variation of the hematological status in the course of adaptation to
the training loads of sportswomen of the artistic gymnastics]. Priklady
nyaya sportyvna nauka, (1), 63-71. [in Russian].

[14] Solov’eva, T. I., & Lukina, E. A. (2006). Mikrohemoreologicheskie
narusheiya: charakteristika i klinicheskoe znachenie [Microhemor-
exological disorders: characteristics and clinical significance]. Terapev-
ticheskii arkhiv, 78(2), 87-91. [in Russian].

[15] Khazipova, I. R., & Shamratova, V. G. (2011). Vzaimosvyazi adreno-
reaktivnosti entrototsitov s nekotorymi makro- i mikroreologicheskimi
parametrami krovi u zdorovykh lyudei [Interrelations of adrenoreactivity
of erythrocytes with some macro- and microhemological parameters in
blood of healthy people]. Vestnik Bashkirskogo universiteta, 16(4),
1219-1222. [in Russian].