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Original research

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

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

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 = 0.0082), 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.

Key words: athletes, physical performance in endurance, speed, strengt.

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Зміни кількісних та якісних показників крові у спортсменів, які розвивають якості швидкості, витривалості або сили

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У фокусі переважної більшості досліджень – вивчення асоціації фізичних можливостей організму з кількісними, якісними показниками та реологічними властивостями крові залежно від рівня рухової активності або фізичної працездатності. Проте вплив якостей (сили, витривалості, швидкості), що переважно розвивають атлети, на кількісні та якісні показники крові вивчений недостатньо.

Мета роботи – вивчити асоціації кількісних та якісних показників крові з якостями сили, витривалості або швидкості, що переважно розвивають спортсмени різних видів спорту.

Матеріали та методи. Обстежили 72 спортсмени (52 чоловіки та 20 жінок) рівня майстерності від КМС до МСМК, середній вік – 21,75 ± 3,32 року. Залежно від фізичних якостей, котрі здебільшого розвивали спортсмени, сформували три групи: перша – 48 спортсменів, які переважно розвивали якість витривалості (тріатлон, плавання, біг на довгі дистанції, академічна гребля), друга група – 16 спортсменів, які передусім розвивали якість швидкості (спринтерський біг), третя група – 8 спортсменів, які переважно розвивали якість сили (важка атлетика, пауерліфтинг, гирьовий спорт). Майстрів спорту міжнародного класу (МСМК) – 2, майстрів спорту (МС) – 25, кандидатів у майстри спорту – 45. Показники крові визначали в капілярній крові спортсменів за допомогою автоматичного гематологічного аналізатора «Abacus junior» (Diatron Messtechnik GmbH, Австрія).

Результати. Групи спортсменів, які переважно розвивали якості витривалості або сили, не відрізнялися між собою за багатьма показниками крові. Але спортсмени, які переважно розвивали якість сили, мали більш виражений анізоцитоз (про

Ключові слова: спортсмени, фізичні якості витривалості, швидкості, сили.

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що свідчить більша на 5,8 % (p = 0,008) величина розподілу еритроцитів (RDWc, %), ніж спортсмени, які розвивали якість витривалості, а також більший на 15,4 % (p = 0,033) об'єм крові, що становлять тромбоцити.

Спортсмени, які переважно розвивали якість швидкості, мали більший на 4,6 % (p = 0,0082) середній об'єм еритроцитів (MCV), на 172,9 % (p = 0,0004) – абсолютний (MID) та на 158,3 % (p = 0,0002) – відносний (MI) вміст суміші моноцитів, базофілів, еозинофілів, ніж спортсмени, які розвивали якість витривалості. У спортсменів, які розвивали якість сили на відміну від спортсменів, які розвивали якість швидкості, зафіксовані вірогідно більші показники червоної крові: абсолютної кількості еритроцитів на 7,6 % (p = 0,040); концентрації гемоглобіну в цільній крові на 8,0 % (p = 0,032); середньої концентрації гемоглобіну в еритроцитарній масі на 6,4 % (p = 0,025); відносної ширини розподілення еритроцитів по об'єму на 5,7 % (p = 0,006) за умов меншого середнього об'єму еритроцитів на 5,9 % (p = 0,001).

Висновки. Мобілізація кисневотранспортної функції крові до фізичних навантажень у спортсменів, які переважно розвивали якість сили, досягається шляхом збільшення кількості еритроцитів, вмісту гемоглобіну, середньої концентрації гемоглобіну в еритроцитарній масі за умов зменшення середнього об'єму еритроцитів. У атлетів, які переважно розвивали якість швидкості, зміни показників червоної крові спрямовані в бік зменшення (в межах референтних значень) кількості еритроцитів, вмісту гемоглобіну, середньої концентрації гемоглобіну в еритроцитарній масі та збільшення середнього об'єму еритроцитів. У спортсменів, які переважно розвивали якість витривалості, популяція еритроцитів характеризувалася середніми розмірами та середнім рівнем внутрішньоклітинної концентрації гемоглобіну.

Ключевые слова: спортсмены, физические качества выносливости, скорости, силы.

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Изменения количественных и качественных показателей крови у спортсменов, развивающих качества быстроты, выносливости или силы

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В фокусе большинства 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 развивают атлеты, 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 развивают 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 скорости (спринтерский бег), третья группа – 8 спортсменов, которые развивали преимущественно качество силы (тяжелая атлетика, пауэрлифтинг, гиревой спорт). Мастеров спорта международного класса (МСМК) – 2, мастеров спорта (МС) – 25, кандидатов в мастера спорта – 45. Показатели крови определяли в капиллярной крови спортсменов с помощью автоматического гематологического анализатора «Abacus junior» (Diatron Messtechnik GmbH, Австрия).

Результаты. Группы спортсменов, которые преимущественно развивали качества 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 % (p = 0,008) величина распределения эритроцитов (RDWc, %), чем спортсмены, развивающие качество выносливости, а также больший на 15,4 % (p = 0,033) объем крови, занимаемый тромбоцитами.

Спортсмены, преимущественно развивающие качество скорости, имели больший на 4,6 % (p = 0,0082) средний объем эритроцитов (MCV), на 172,9 % (p = 0,0004) – абсолютное (MID) и на 158,3 % (p = 0,0002) – относительное (MI) содержание смеси моноцитов, базофилов, эозинофилов, 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 % (p = 0,040), концентрации гемоглобина в цельной крови на 8,0 % (p = 0,032), средней концентрации гемоглобина в эритроцитарной массе на 6,4 % (p = 0,025), относительной ширины распределения эритроцитов по объему на 5,7 % (p = 0,006) в условиях меньшего среднего объема эритроцитов на 5,9 % (p = 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 внутриклеточной концентрации гемоглобина.

The most important physiological systems that determine body's ability to adapt to physical exercises are the cardiorespiratory 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 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), plateletocrit (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., № JPZ804I382130ARCN10-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 $P < 0.05$.

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

Value, units of measure	Performance		P-level	Δ%
	Endurance (n = 48)	Strength (n = 16)		
WBC, 10^9/l	5.91 ± 1.41	7.14 ± 2.57	0.149	
LYM, 10^9/l	2.28 ± 1.42	2.46 ± 1.36	0.889	
MID, 10^9/l	0.37 ± 0.36	0. 57 ± 0.63	0.056	35 %
GRA, 10^9/l	3.47 ± 1.00	4.11 ± 2.03	0.381	
LY, %	35.58 ± 7.70	36.66 ± 10.79	0.865	
MI, %	5.83 ± 4.32	7.68 ± 6.49	0.306	
GR, %	58.60 ± 7.77	57.56 ± 12.21	0.822	
RBC, 10^{12}/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, 10^9/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	

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 15.4 % (P = 0.033) 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 10^9/l, P = 0.0004), MI by 158.3 % (5.83 ± 4.32 vs. 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 hematological parameters in strength-trained and speed-trained athletes demonstrates that the latter had significantly higher MID by 77.2 % (0.57 ± 0.63

Table 2. 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	15.06 ± 5.18	0.0002	158.3 %
GR, %	58.60 ± 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 ± 0.61	12.68 ± 0.44	0.3965	
PLT, 10^9/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	

Table 3. Blood counts in athletes, who mainly trained strength or speed 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 ± 1.36	2,23 ± 1.18	0.668	
MID, 10^9/l	0.57 ± 0.63	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	96.1 %
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	7.6 %
HGB, g/l	154.38 ± 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, 10^9/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	

vs. 1.01 ± 0.40 10^9/l, P = 0.022), MI – by 96.1 % (7.68 ± 6.49 vs. 15.06 ± 5.18 %, P = 0.008), MCV by 5.9 % (88.06 ± 3.30 vs. 93.25 ± 2.12 fl, P = 0 001) in contrast to athletes who trained strength performance *(Table 3)*.

Nevertheless, strength–trained athletes showed a significantly higher RBC by 7.6 % (4.50 ± 0.43 vs. 4.16 ± 0.23 10^{12}/l, P = 0.040), HGB – by 8.0 % (154.38 ± 12.44 vs. 142.00 ± 12.80 g/l, P = 0.032), MCHC – by 6.4 % (390.75 ± 26.05 vs. 365.88 ± 11.41 g/l, P = 0.025) and RDWc – by 5.7 % (13.44 ± 0.92 vs. 12.68 ± 0.44 %, P = 0.006) as compared to athletes who trained speed performance.

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.

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 microreological properties along with the negative changes in the macroreological 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].

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/m^2), 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. Khazipova (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 adrenaline-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].

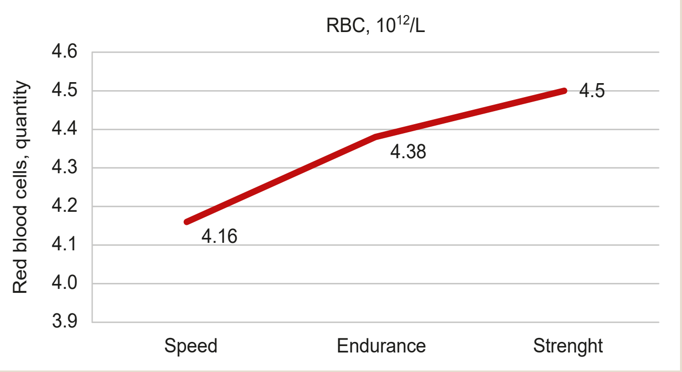

Fig. 1. Correlation between RBC count and speed, endurance or strength performance in trained athletes.

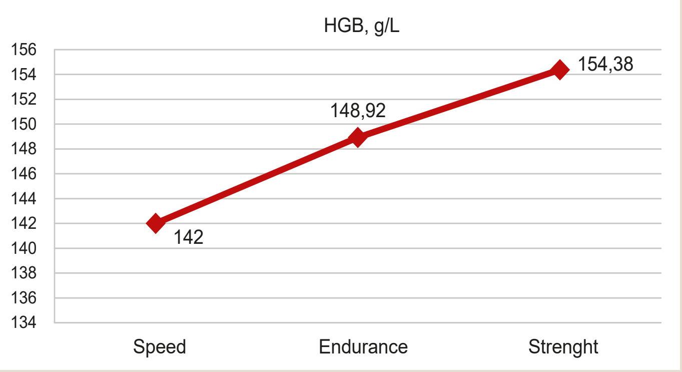

Fig. 2. Correlation between HGB and speed, endurance or strength performance in trained athletes.

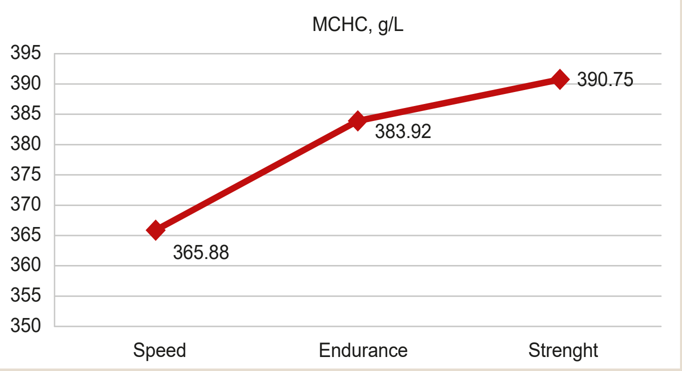

Fig. 3. Correlation between MCHC and speed, endurance or strength performance in trained athletes.

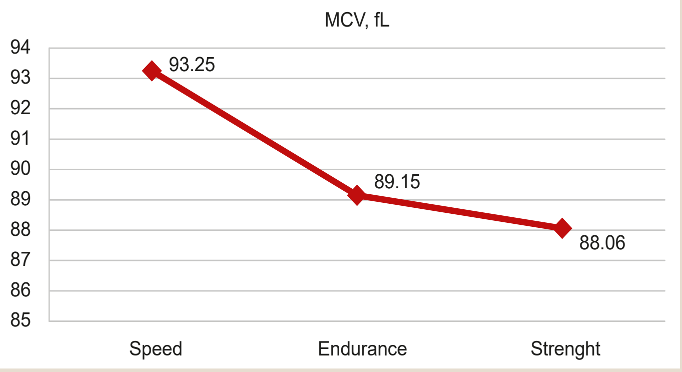

Fig. 4. Correlation between MCV and speed, endurance or strength performance in trained athletes.

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, Kovelska A. V. and co-authors revealed a direct correlation between VO_2max ml/min^{-1} and both HGB ($r = 032$; $P < 0.05$) 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.

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