Impact of vigorous effort on blood morphological indicators in triathletes participating in the XTERRA Poland 2017 competition

Wpływ intensywnego wysiłku na wskaźniki morfologiczne krwi u triathlonistów startujących w zawodach XTERRA POLAND 2017

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Key words
triathlon, morphology blood

Abstract
Purpose: The aim of the study was to determine the influence of participation in the XTERRA Poland 2017 triathlon on blood morphology indicators.

Material and methods: The study was performed in a group among 10 triathletes aged 30-40 years. Blood was collected 24 hours before, immediately after, and 16 hours after the competition. Blood morphological indicators were evaluated using the ABX Micros60 60 analyser.

Results: Comparison of the results among the first (24 hours before the competition), second (immediately after the competition), and third assessment (16 hours after the competition) revealed statistically significant changes for WBC [10⁹/L], RBC [10¹²/L], HGB [g/L], HCT [L/L], MCV [fL] and PLT [10⁹/L].

Conclusions: The intensity of effort in the XTERRA Poland 2017 triathlon competitors was confirmed in the results of blood morphology. Blood counts in those practicing triathlon well characterise the actual scope and direction of exercise changes and allow for the diagnosis of transient adaptive effects. The results of the research confirmed that vigorous physical effort during the triathlon increased leukocyte and platelet counts, but 16 hours after completing the competition, their value was close to baseline level. Most likely, this phenomenon was caused by the intense effort, stress or even eating a large meal before the competition. Analysing the red blood cell system showed a tendency towards decrease in the number of red blood cells, HGB and HCT both after the competition and 16 hours after its completion, which results from increased post-exercise haemolysis or the risk of anaemia.

Słowa kluczowe
triathlon, morfologia krwi

Abstract
Cel: Celem pracy jest uzyskanie odpowiedzi w jaki sposób udział w triathlonie XTERRA POLAND 2017 wpłynął na wskaźniki morfologiczne krwi.

Material i metody: Badanie przeprowadzono w grupie 10 triathlonistów w wieku 30-40 lat. Krew pobrano 24 godziny przed zawodami, bezpośrednio po zawodach oraz 16 godzin po zakończeniu zawodów. Wykonano oznaczenia wskaźników morfologicznych krwi u triathlonistów w aparacie ABX MICRO 60.

Wynik: Analizując wyniki pomiędzy pierwszym pomiarem (24 godzin przed zawodami) a pomiarem drugim (bezpośrednio po zawodach) i trzecim pomiarem (16 godzin po) zaobserwowano zmiany istotne statystycznie dla: WBC [10⁹/L], RBC [10¹²/L], HGB [g/L], HCT [L/L], MCV [fL], PLT [10⁹/L].
INTRODUCTION

The triathlon is a very demanding discipline. This sport requires high endurance and physical condition of the body from athletes, which is associated with long-term training. Due to the specificity of this discipline, comprehensive preparation is required. Competitors must demonstrate high efficiency in each of the triathlon events (swimming, cycling, running). Preparation for the triathlon is individual in the case of each competitor. Diet, lifestyle and cooperation with a physician are important. A doctor examines parameters such as pulmonary ventilation per minute, blood pressure, cardiac volume per minute, heart rate and stroke volume. Haematology also plays an important role in sports medicine. It is used for diagnosis, treatment and prevention. Constant monitoring of haematological indices allows assessment of physical performance, which is of great significance in endurance sports such as the triathlon. The results of all these tests help in choosing an individual training programme for each athlete. Physical effort is of great importance to the processes taking place in the body. It also influences changes in blood morphotic parameters. During activity, blood volume is reduced by up to 15% after just a few minutes of training. Physical training causes increased blood flow to the muscles and decreased blood flow to the internal organs. Blood pressure drops after exercise. The loss of water in the athlete’s body is also significant. This affects the composition of the blood. Vigorous exercise causes an initial reduction in the amount of blood plasma, which only returns to the norm following exercise. Changes in blood counts also depend on the training and shape of the athletes. The less they are trained, the greater the changes can be observed.

STUDY AIM

The aim of the study was to assess changes in blood counts in triathlon competitors. The following research questions were posed:
1. How do the blood counts in people practising triathlon characterise the actual scope and direction of exercise changes and allow for the diagnosis of transient adaptive effects?
2. How does participation in the XTERRA POLAND 2017 triathlon influence blood counts (WBC [10^9/L], RBC [10^12/L], HGB, HCT [L], MCV [L], MCH [mmol/L], MCHC [mmol/L], PLT [10^9/L]) before the triathlon, immediately after the competition and after a 16-hour interval?

MATERIAL AND METHODOLOGY

Characteristics of the studied competitors

The study group comprised men (n = 10) aged 32.8 ± 3.1 years from the Active Side of Life Association (in PL: Stowarzyszenie Aktywna Strona Życia) in Kraków, regularly practising the triathlon with an average training experience of 10 ± 4.2 years. The sports level of the participants corresponded to sports class 1 and 2 (national level competitors).

The training of triathletes was divided into 3 phases: base, specialisation and direct sports preparation. The triathlon season in Poland begins in May and ends in September. Getting the participants in shape for the competition is associated with the appropriate distribution of training over time. October is the period of de-training. From November to January inclusive, it is time to build the base. The period from February to April regards specialist preparation of athletes. After this specialist preparation, depending on the date of the competition, triathletes begin their direct competition preparation. The first stage of preparation, the base, is mainly work on strengthening the deep muscles and stabilising one’s figure, as well as motor preparation. The athletes work to improve technique and motor coordination. Workouts are aerobic, at a moderate intensity level. The second stage of training is specialisation. The main goal of this stage is to improve the athlete’s capabilities during exercise in the mixed zone and to prepare for subsequent subliminal work. The main training elements of this stage are perfecting runs and cycling. The specialisation stage introduces interval training with emphasis on the pace of running and cycling. The third stage is working on swimming technique. Interval workouts and running intervals are continued at a subliminal level. The training in the third stage is mostly focused on starting in the competition.

2017 XTERRA POLAND Competition

The athletes participated in the XTERRA POLAND triathlon. The competition took place on August 13, 2017 at Zakrzówek Lake. The competitors covered the following distances: 1.5 kilometres (km) of swimming in the Zakrzówek reservoir, 36 km of cycling along the Bielański-Tyniecki Landscape Park route and 10 km of running in the Zakrzówek area. The mean (range) temperature during the sports competition was 31.2 ± 3.1 C (25-33°C), relative humid-
ity 69 ±8% (60-71%), and the dew point was 21 ±3°C (18-25°C). The swimming part was performed in a water tank with a water temperature of 20 ±1°C. At this stage of the race, all participants were equipped with wetsuits. During cycling, the competitors participating in the competition used bicycles with carbon or aluminium frames.

Before the start, the competitors were not instructed on the amount of fluids or energy products to be consumed during the competition in order to avoid the influence of these factors on the final result. However, after the competition, each participant was asked to estimate the amount of fluid consumed at each nutrition point. The average fluid intake of the competitors during the competition was 0.7 ±0.3 l of water and 1.5 ±0.5 l of isotonic drinks.

### Measurement of morphological indices

Participants had their blood collected the day before the competition on August 12, 2017, on the day of the competition, immediately after completing the competition in Kraków and at the site of the competition (Zakrzówek – Krakow) immediately after the end of the competition (Measurement 2). The collected material was analysed at the Blood Physiology Laboratory of the University of Physical Education in Kraków. The study was approved by the Ethical Committee at the Regional Medical Chamber in Kraków (approval No.: 17/KBL/OIL/2015).

Basic haematological indicators were measured with the HORIBA ABX Micros 60 blood analyser (Laboratory of Blood Physiology, University of Physical Education in Kraków).

The following indices were determined:
1. WBC [10⁹/L] – white blood cells;
2. RBC [10¹²/L] – red blood cells;
3. HGB [g/L] – haemoglobin;
4. HCT [L/L] – haematocrit;
5. MCV [fL] – mean cell volume;
6. MCH [fmol] – mean haemoglobin mass in red blood cell;
7. MCHC [mmol/L] – mean concentration of haemoglobin in red blood cell;
8. PLT [10⁹/L] – platelet count.

### Statistical analysis

Data are presented as mean values and standard deviation. Normality of distributions was verified on the basis of the Shapiro-Wilk test. The assumption of sphericity was assessed using the Mauchley test. Differences in the parameters examined before and after the triathlon were evaluated using analysis of variance (ANOVA) for repeated variables or, if the assumptions were not met, the ANOVA test for Friedman’s ranks was applied. Tukey’s test or, respectively, the post hoc test for Friedman’s ANOVA, being part of the Statistica Medical Kit software, were used for post-hoc evaluation. The significance level of α=0.05 was adopted in the analyses, which were performed using the Statistica 12 package (StatSoft®, USA).

### RESULTS

Measurement 1 was performed 24 h before the triathlon, Measurement 2 - immediately after completing the triathlon, and Measurement 3 - 16 hours following the end of the triathlon.

The mean values and standard deviation (SD) of the obtained results are presented in Table 1.

### Analysis of results between Measurement 1 (24 h before competition) and 2 (immediately after the competition)

Analysis of the results between Measurement 1 (24 hours before the competition) and 2 (immediately after its completion) is presented in Table 1 and Figure 1.

Statistically significant changes were found. An increase in the number of WBC by as much as 56% was observed. The number of PLTs also

### Table 1

| Index          | Measurement 1 | Measurement 2 | Measurement 3 | p     | p 1/2 | p 2/3 | p 1/3 |
|----------------|---------------|---------------|---------------|-------|-------|-------|-------|
| WBC [10⁹/L]   | 6.25 ±2.16    | 14.53 ±3.73   | 7.50 ±1.66    | <0.000001* | <0.001* | <0.001* | 0.634 |
| RBC [10¹²/L]  | 5.18 ±0.23    | 4.89 ±0.20    | 4.40 ±0.18    | <0.000001* | 0.008*  | <0.001* | <0.001* |
| HGB [g/L]     | 15.45 ±0.81   | 14.54 ±1.01   | 12.96 ±0.87   | <0.000001* | 0.012*  | <0.001* | <0.001* |
| HCT [L/L]     | 44.60 ±1.89   | 41.71 ±3.03   | 37.70 ±2.25   | <0.000001* | <0.001* | <0.001* | <0.001* |
| MCV [fL]      | 86.21 ±3.18   | 85.16 ±3.50   | 85.70 ±2.23   | 0.008*  | 0.007* | 0.104  | 0.328 |
| MCH [fmol]    | 29.67 ±1.11   | 29.71 ±1.11   | 29.47 ±1.51   | 0.849   | ≥0.05  | ≥0.05  | ≥0.05  |
| MCHC [mmol/L] | 34.44 ±0.91   | 34.89 ±0.91   | 34.42 ±1.68   | 0.723   | ≥0.05  | ≥0.05  | ≥0.05  |
| PLT [10⁹/L]   | 248.50 ±44.64 | 269.63 ±54.94 | 214.50 ±43.81 | <0.000001* | 0.032*  | <0.001* | <0.001* |

* statistically significant differences (p<0.05)
increased by 7.8%. Analysis of the results also demonstrated a reduction in RBC by 5.6% and HGB by 5.9%, as well as a decrease in HCT by 6.5% and MCV by 1.2%.

Analysis of results between Measurement 2 (immediately after the competition) and 3 (16 h after the competition)

Analysis of the results between the Measurement 2 (immediately after the competition) and 3 (16 hours after the competition) is presented in Table 1 and Figure 2. Statistically significant changes were noted.

The number of WBCs decreased by 48.8%, while the number of PLTs also dropped by 20.5%. The number of RBCs fell again by 5.6%. Analysis of the results also showed a decrease in HGB by 10.9%, and HCT by 9.6%. In the analysis of the remaining indices, no statistically significant changes were observed.

Analysis of results between Measurement 1 (24 h before the competition) and 3 (16 h after the competition)

Analysis of the results between Measurement 1 (24 hours before the competition) and 3 (16 hours after the competition) is presented in Table 1 and Figure 3.

A decrease in the value of the majority of examined indices was observed. RBC decreased by 15.1%, HGB value by 16.1%, and HCT by 15.5%. The number of PLTs decreased by 13.7%. Analysis of the remaining indices did not show any statistically significant changes.

DISCUSSION

The aim of this study is to demonstrate the changes taking place in the morphotic elements of the blood among triathletes participating in the 2017 XTERRA POLAND competition before the start, immediately after and 16 hours after the competition. Based on the available literature and research published to date, there are not many studies in relation to the above-mentioned objective. The majority of morphological indices have been tested for runners and cyclists. According to Che-Hung Liu et al., the haematological indices: RBC, HGB, HCT and plasma were analysed in 19 runners taking part in the Ultramarathon in Taipei. No statistically significant changes were observed. In turn, according to Konstam et al., an increase in the number of RBCs was demonstrated for the whole group of cyclists participating in training. The number of
RBCs decreased 20 minutes after the end of training, but did not drop to baseline level. However, in the group of 20 cyclists who participated in interval training, blood was collected before and immediately after training session, and the results indicated an increase in the number of WBC, RBC and PLT, as well as an increase in HGB and HCT. Huskens et al. tested 92 healthy volunteers taking part in an amateur cycling race who experienced a post-exercise increase in the number of PLT, where the effect was more intense in men than in women. Most likely, this phenomenon was due to the increased reactivity of pro- and anti-inflammatory processes. Natale et al. conducted a study among a group of 14 men competing in a 100-km race. The results of this study before and immediately after the competition were compared, and an increase in the number of WBC was found. The authors suggest that such a change may be caused by muscle damage. Wells et al. described a group of 6 men and 4 women running a marathon. The participants had their blood drawn 1 week before and immediately after the race, as well as 4, 8 and 24 hours after the competition. Several hours after the race, no changes in HCT, HGB concentration or RBC count were observed. The sample taken immediately after exercise showed an increase in the number of WBCs. In addition, immediately after the competition, the plasma volume was reduced by 8% in women and 13% in men. According to Davidson et al., in a group of 90 men and 25 women who ran a marathon, blood was drawn before and after the start, and the majority of the marathon runners experienced an increase in platelet counts as well as MCH and MCHC following the run. According to the authors, the probable cause of these changes was loss of water from the body. Other authors described research carried out among a group of 90 teenagers running a marathon. Their blood was collected before, immediately after and 24 hours after the competition. There was a slight increase in the number of WBCs and a slight decrease in HGB and HCT immediately after the competition. The authors suggest that proper training of the athletes resulted in slight changes regarding morphotic elements of the blood.

When analysing all the studied groups of triathletes (between Measurements 1, 2 and 3), a decrease in the RBC number was found, i.e. between Measurement 1 (24 hours before the competition) and 3 (immediately after the competition) by 5.6%, between Measurement 2 (immediately after the competition) and 3 (taken 16 hours after the competition), a decrease in the RBC by 5.5%; and between Measurement 1 (24 hours before the competition) and 3 (16 hours after the competition), a reduction in the RBC amount by 15.1% was noted. For HGB, between Measurement 1 (24 hours before the competition) and 2 (immediately after the competition) there was a decrease by 5.9%, between Measurement 2 (immediately after the competition) and 3 (16 hours after the competition) a decrease by 10.9% was found, and between Measurement 1 (24 hours before the competition) and 3 (16 hours after the competition), there was a reduction by 16.1%.

For HCT, between Measurement 1 (24 hours before the competition) and 2 (immediately after the competition), a reduction of 6.5% was shown, between Measurement 2 (immediately after the competition) and 3 (16 hours after the competition), there was a decrease by 15.5%, and between Measurement 1 (24 hours before the competition) and 3 (16 hours after the competition), a reduction by 15.5% was noted.

For MCV, between Measurement 1 (24 hours before the competition) and 2 (immediately after the competition), there was a decrease by 6.5%, between Measurement 2 (immediately after the competition) and 3 (16 hours after the competition), a decrease by 15.5% was observed, and between the Measurement 1 (24 hours before the competition) and 3 (16 hours after the competition), there was a reduction by 15.5%.
iron loss may also be associated with excessive neutrophils among the studied triathletes. Reduction in the number of erythrocytes caused by not consuming enough carbohydrates before strenuous exercise. Reduction in the number of erythrocytes among the studied triathletes may also be associated with excessive iron loss. Currently, there are no established levels of iron requirements for athletes performing any specific disciplines. In people who train, iron resources are mainly excreted in urine and, to a lesser extent, in sweat. Dietary mistakes and even mechanical injuries should also be taken into account, which, through regular and prolonged foot-strike haemolysis on the ground, causes the destruction of red blood cells contained in the blood vessels of the lower limbs. The etiology of this intravascular haemolysis has been linked to associated mechanical injuries running, hence the synonym “foot-strike haemolysis”. Others have postulated that haemolysis may also be associated with other non-traumatic factors. Researchers suggest that the decrease in haemoglobin may be due to haemolysis, which is a mechanism for destroying red blood cells during and after physical activity. In addition, the decrease in haemoglobin may be due to haemodilution, which is associated with endurance training and occurs in athletes due to the increase in plasma volume. In the research by scientists from Pavia Medical School, it has been proven that HCT reduction may occur in the case of high physical activity immediately after a long break from training.

By analysing all the studied groups of triathletes (between Measurements 1, 2 and 3) for WBC, an increase by as much as 56% was shown between Measurement 1 (24 hours before the competition) and 2 (immediately after the competition), and between Measurement 2 (immediately after the competition) and 3 (16 hours after the competition), a decrease by 48.8% was indicated. The authors of studies conducted so far in athletes have noted that fluctuations in the number of white blood cells in the blood may be dependent on various factors. The increase in WBC counts is most often explained by a decrease in plasma volume during increased activity. Scientists suggest that the number of white blood cells may also be affected by the consumption of a large meal before training, the vigorous effort itself, and even stress before the start or during the competition, which is manifested by an increase in adrenaline, noradrenaline or cortisol. This is confirmed in the research by Tota et al. According to Maron et al., increasing the number of leukocytes in the body confirms the principle that training improves the immunity of athletes. However, in a 4-year study on Spanish triathletes, it has been demonstrated that white blood cell counts are within the normal limits during both the pre-competitive and competitive periods. However, 16% of triathletes in the Australian Institute of Sport study were neutropenic, while 5% showed signs of monocytopenia, respectively. According to Philip et al., neutropenic individuals are generally more susceptible to bacterial infections that can occur after inappropriate treatment or the occurrence of injuries to the skin. The cause of neutropenia is unclear. This may be due to the exercise-induced apoptosis of the neutrophil and the consequent shorter lifespan of the neutrophils.

When analysing all the studied groups of triathletes (between Measurements 1, 2 and 3), an increase in the number of PLTs was found, i.e. between Measurement 1 (24 hours before the competition) and 2 (immediately after the competition) by 7.8%, between Measurement 2 (directly after the competition) and 3 (16 hours after the competition), the number of PLTs decreased by 20.5%, and between Measurement 1 (24 hours before the competition) and 3 (16 hours after the competition) the number of PLTs decreased by 13.7%. One of the possible reasons for the increase in platelet count after vigorous training may be the loss of plasma in the blood after such exercise, and the decrease in PLT (within normal limits) in triathletes after competition as a return to baseline values. Vigorous exercise increases the activity of platelets and clotting factors, which ensures blood fluidity. Górski mentions an increase in the number of platelets after a single effort, but immediately states that the reason for this is difficult to explain. In other studies it has been shown that vigorous training increases blood clotting activity. The triathlon has even been described as a high-risk sport, predisposing the athlete’s body to blood clots. In yet other studies on this subject, it has been demonstrated that vigorous exercise during a triathlon does not affect the risk mentioned here.

CONCLUSIONS

The results obtained in the course of this research allow formulation of the following conclusions:

1. Blood counts in athletes practicing the triathlon well-characterise the actual scope and direction of exercise changes and allow for the diagnosis of temporary adaptive effects.

2. The results of the research confirmed that vigorous physical exercise during the triathlon increased leukocyte and platelet counts, however, 16 hours after the end of the competition, their values were similar to those obtained at baseline.
Most likely, this phenomenon was caused by the vigorous effort, stress or even consuming a large meal prior to the competition.

3. Analysis of the red blood cell system showed a tendency towards a decrease in the number of red blood cells, HGB and HCT, both immediately after and 16 hours following the end of the competition, which results from increased post-exercise haemolysis or the risk of anaemia.

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References
1. Trew S. Mój pierwszy triathlon Buk Rower, Warszawa 2012: 10-20.
2. Klettaenthous M. Triatlon ad A do Z. Wydawnic-

3. Dąbrowski Z. Fizjologia krwi. Wybrane zagadnienia. Wydawnictwo Naukowe PWN, Warszawa 1998: 15-47.
4. Ziółko E. Podstawy fiziologii człowieka. Oficynia Wydawnicza PWSZ w Nysie, Nysa 2006: 19-28.
5. Telegów A. Diagnostyka hematologiczna - podstawowe badanie: morfologia krwi. [In:] Telegów A (ed.). Diagnostyka laboratoryjna i obrazowa dla potrzeb fizjoterapii i kosmetologii. AWF Kraków, Kraków 2020: 212-221.
6. Che-Hung L., Yen-Fong T., Iuon-I., Yin-Quan Ch., Shih-Hao W., Wei-Fong K., et al. The changes of red blood cell viscoelasticity and sports anemia in male 24-hr ultra-maratho-
7. Konstam M.D., Tu-meh S., Wynne J., Beck J.R., Kozlowski J., Holman B.L. Effect of exercise on erythrocyte count and blood ac-
tivity concentration after technetium-99m in vivo red blood cell labeling. Circulation 1982: 66: 638-642.
8. Bashaftah H., Afzalpour M.I., Fatahi A.A., Nazar S., Ilbeigi S. The effects of acute in-
terval cycling and blood flow restriction on hematologic factors of beginner cyclists. Turk J Sports Exerc 2017; 19: 70-76.
9. Hjusken D., Roest H., Heming J.A., Konigst J., Kremers R.M.W., Bloem-men S. Strenuous exercise induces a hyperreactive rebalanced haemostatic state that is more pronounced in men. Thromb Haemost 2016, 115(6): 1109-1119.
10. Natale V.M., Bremer I.K., Moldeovanu A.I., Vissi-lou P., Skok P., Shephard R.J. Effects of three different types of exercise on blood le-
uocyte count during and following exercise. Sao Paulo Med J 2003; 121: 9-14.
11. Galun E., Burstein R., Assia E., Tut-Kaspa I., Roslen-bum J., Epshtein Y. Changes of white blood cell count during prolonged exercise. Int J Sports Med 1987; 8: 253-255.
12. Wells C.L., Stern J.R., Hecht L.H. Hemato-

16. Spodaryk K., Kopeć A. Iron stores in ma-
thletes throughout the sport season. JSEP, Adv Exerc Sports Physiol 2004; 18(1): 3-9.
17. Wijk R., Wouter W.S. The energy-less red

cell phenotype of elite Olympic triathletes: A three-year follow-up. Int J Sports Med 2002: 23: 391-396.
18. Spodaryk K., Kopeć A. Iron stores in mar-
thletes throughout the sport season. JSEP, Adv Exerc Sports Physiol 2004; 18(1): 3-9.
19. Szyguła M. Fizjologia krwi. Wybrane za-
gadnienia. Oficyna Wydawnicza PWSZ w Nysie, Nysa 2006: 19-28.
20. Böning D., Klarholz C., Himmelsbach B., Özcan S., Ilbeigi S. The effects of acute in-
uivo red blood cell labeling. Circulation 1982; 66: 638-642.
21. Francisco Javier O., Manuel R., Manuel R.R. Exercise training induces low peripheral CD34+ stem cells. Br J Haematol 2003; 120: 914-915.
22. Labriola L.T., Friberg T.R., Hein A. Marathon runner’s retinophaty. Semin Ophthalmol 2009; 24: 247-250.
23. Górski J. Podstawy fiziologii wysiłku. PZWL, Warszawa, 2011: 3-9.
24. Prisco D., Francalanci I., Filippini M., Hagi M.I. Physical exercise and hemostasis, Int J Clin Lab Res 1994: 24: 125-131.
25. Hanke A.A., Staib A., Görlinger K., Penrey M., Dirkman M. Kienbaum P. Whole blood coagulation and platelet activation in the athlete: a comparison of marathon, triathlon and long distance cycling Eur J Med Res 2010; 15: 59-65.
26. Ahmedzaid S., El-Sayed M.S., MacLaren D.P. Effects of time of day and acute resis-
tance exercise on platelet activation and function. Clin Hemorheol Microcirc 2010; 45: 391-399.

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References
1. Trew S. Mój pierwszy triathlon Buk Rower, Warszawa 2012: 10-20.
2. Klettaenthous M. Triatlon ad A do Z. Wydawnic-

3. Dąbrowski Z. Fizjologia krwi. Wybrane zagadnienia. Wydawnictwo Naukowe PWN, Warszawa 1998: 15-47.
4. Ziółko E. Podstawy fiziologii człowieka. Oficyna Wydawnicza PWSZ w Nysie, Nysa 2006: 19-28.
5. Telegów A. Diagnostyka hematologiczna - podstawowe badanie: morfologia krwi. [In:] Telegów A (ed.). Diagnostyka laboratoryjna i obrazowa dla potrzeb fizjoterapii i kosmetologii. AWF Kraków, Kraków 2020: 212-221.
6. Che-Hung L., Yen-Fong T., Iuon-I., Yin-Quan Ch., Shih-Hao W., Wei-Fong K., et al. The changes of red blood cell viscoelasticity and sports anemia in male 24-hr ultra-maratho-
7. Konstam M.D., Tu-meh S., Wynne J., Beck J.R., Kozlowski J., Holman B.L. Effect of exercise on erythrocyte count and blood ac-
tivity concentration after technetium-99m in vivo red blood cell labeling. Circulation 1982: 66: 638-642.
8. Bashaftah H., Afzalpour M.I., Fatahi A.A., Nazar S., Ilbeigi S. The effects of acute in-
terval cycling and blood flow restriction on hematologic factors of beginner cyclists. Turk J Sports Exerc 2017; 19: 70-76.
9. Hjusken D., Roest H., Heming J.A., Konigst J., Kremers R.M.W., Bloem-men S. Strenuous exercise induces a hyperreactive rebalanced haemostatic state that is more pronounced in men. Thromb Haemost 2016, 115(6): 1109-1119.
10. Natale V.M., Bremer I.K., Moldeovanu A.I., Vissi-lou P., Skok P., Shephard R.J. Effects of three different types of exercise on blood le-
uocyte count during and following exercise. Sao Paulo Med J 2003; 121: 9-14.
11. Galun E., Burstein R., Assia E., Tut-Kaspa I., Roslen-bum J., Epshtein Y. Changes of white blood cell count during prolonged exercise. Int J Sports Med 1987; 8: 253-255.
12. Wells C.L., Stern J.R., Hecht L.H. Hemato-

16. Spodaryk K., Kopeć A. Iron stores in mar-
thletes throughout the sport season. JSEP, Adv Exerc Sports Physiol 2004; 18(1): 3-9.
17. Wijk R., Wouter W.S. The energy-less red

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18. Spodaryk K., Kopeć A. Iron stores in mar-
thletes throughout the sport season. JSEP, Adv Exerc Sports Physiol 2004; 18(1): 3-9.
19. Szyguła M. Fizjologia krwi. Wybrane za-
gadnienia. Oficyna Wydawnicza PWSZ w Nysie, Nysa 2006: 19-28.
20. Böning D., Klarholz C., Himmelsbach B., Özcan S., Ilbeigi S. The effects of acute in-
uivo red blood cell labeling. Circulation 1982; 66: 638-642.
21. Francisco Javier O., Manuel R., Manuel R.R. Exercise training induces low peripheral CD34+ stem cells. Br J Haematol 2003; 120: 914-915.
22. Labriola L.T., Friberg T.R., Hein A. Marathon runner’s retinophaty. Semin Ophthalmol 2009; 24: 247-250.
23. Górski J. Podstawy fiziologii wysiłku. PZWL, Warszawa, 2011: 3-9.
24. Prisco D., Francalanci I., Filippini M., Hagi M.I. Physical exercise and hemostasis, Int J Clin Lab Res 1994: 24: 125-131.
25. Hanke A.A., Staib A., Görlinger K., Penrey M., Dirkman M. Kienbaum P. Whole blood coagulation and platelet activation in the athlete: a comparison of marathon, triathlon and long distance cycling Eur J Med Res 2010; 15: 59-65.
26. Ahmedzaid S., El-Sayed M.S., MacLaren D.P. Effects of time of day and acute resist-
tance exercise on platelet activation and function. Clin Hemorheol Microcirc 2010; 45: 391-399.