Assessment of blood morphology, electrolyte level as well as kidney and liver function before and after exiting the water in winter swimmer during the entire winter swimming season – a case study

Ocena morfologii krwi, poziomu elektrolitów we krwi oraz pracy nerek i wątroby u „Morsa" przed i po wyjściu z wody podczas całego sezonu morsowego – studium pojedynczego przypadku

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Key words
blood morphology, electrolytes, kidney, liver, winter swimming, winter baths

Abstract
Study aim: The aim of the study was to assess blood morphology, electrolyte level as well as indices of kidney function and the activity of selected liver enzymes determining liver function before and after exiting the water in a winter swimmer ("Walrus") from the "Kaloryfer" ("Radiator") Krakow Winter Swimming Club during the whole winter bathing season.
Materials and methods: The subject of research was a winter swimmer from the "Radiator" Krakow Winter Swimming Club – a 53-year-old male. Blood was collected from the subject: at the beginning of the winter swimming season, during (five times) and at the end of the season (each time before and after getting out of the water); time maintaining in water: 10 minutes.
Results: Analysing the average values of the indices before and after exiting the water, statistically significant increases were noted in AST [U/L] by 6.4% and LDH [U/L] by 2.45%, as well as a decrease in Na^+ [mmol/l] by 1.14%, Cl^- [mmol/l] by 1.78% and urea [mmol/l] by 3.64%.
Conclusions: Regular baths taken by the winter swimmers in cold water did not affect blood morphology indices and did not cause pathological changes in kidney profile. Furthermore, slight fluctuations regarding the concentration of electrolytes in the blood serum and changes in the hepatic profile additionally "externalised" health problems, which appeared prior to winter swimming.

Słowa kluczowe
morfologia krwi, elektrolity, nerki, wątroba, morsowanie, zimowe kąpiele

Streszczenie
Cel badań: Celem pracy była ocena morfologii krwi, poziomu elektrolitów we krwi, wskaźników pozwalających zbadać pracę nerek i aktywności wybranych enzymów wątrobowych określających funkcję wątroby u „Morsa" z Krakowskiego Klubu Morsów „Kaloryfer" przed i po wyjściu z wody podczas całego sezonu zimowych kąpieli.

The individual division of this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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Materiał i metodyka: Obiektem badań był „Mors" z Krakowskiego Klubu Morsów „Kaloryfer" – 53-letni mężczyzna. Krew od badanego pobrano: na początku sezonu morsowego, w trakcie sezonu morsowego (pięć razy) i pod koniec sezonu (każdorazowo przed i po wyjściu z wody); czas przebywania „Morsa" w wodzie: 10 minut.
Wyniki: Analizując średnie wartości wskaźników przed i po wyjściu z wody wykazano statystycznie istotne zwiększenie AST [U/l] o 6,4 % i LDH [U/l] o 2,45 % oraz zmniejszenie stężenia Na^+ [mmol/l] o 1,14 %, Cl^- [mmol/l] o 1,78 % i mocznika [mmol/l] o 3,64 %.
Wnioski: Regularne kąpiele „Morsa" w zimnej wodzie nie wpłynęły na wskaźniki morfologii krwi i nie wywołały patologicznych zmian w profilu nerkowym. Niewielkie wahania zaobserwowano w stężeniu elektrolitów w surowicy krwi, a zmiany w profilu wątrobowym dodatkowo „uzewnętrzniły" problemy ze zdrowiem, które pojawiły się przed morsowaniem.

INTRODUCTION

Exposure to cold, especially in an aquatic environment, is one of the most stressful stimuli, causing a number of significant physiological reactions, which is a challenge for the thermoregulatory mechanisms of the body[1,2].

The biological effects of cold mainly depend on temperature, the rate of tissue cooling, the time of exposure to cold, as well as the individual sensitivity of the body. The decrease in body temperature in water takes place 2-3 times faster than in the air[1,3].

The whole-body effect of cold on the body is associated with the phenomenon of ischemia and reperfusion, which occurs in two stages. In the first one (ischemia), narrowing of the blood vessels takes place as well as a decrease in blood supply to the skin, which results in its fading. Vasoconstriction causes an increase in heat production and a reduction in its loss. Then, the temperature of the skin, joints and muscles, slowly decreases. The metabolism in the core and the nerve conduction become reduced. The pain threshold is higher, the skeletal muscle tone and the vascular wall increase, which further increases arterial and venous pressure. After the temperature lowers, the muscles become stiff, blood viscosity increases, which limits the perfusion. This can lead to disturbances in consciousness. The second phase – reperfusion – begins after 3-5 minutes from the action of cold. Then, vasodilation takes place; blood supply to the skin increases, resulting in visible erythema and an increase in skin warming. The temperature of tissues and metabolism in the core part also slowly increase. Skeletal muscle tone and the walls of blood vessels, as well as arterial and venous pressure, become reduced. This effect lasts for about 15 minutes until the vessels become narrowed again. Phased flow of blood occurs, referred to by Lewis as waves, which is responsible for protecting the peripheral parts of the body against frostbite[3-5].

Better tolerance of cold has been noted in winter swimmers[6]. In addition, the immune system is more active in these people, thus, taking regular winter baths prevents diseases and toughens the body[3,6,7]. Winter baths activate the sympathetic nervous system and cause norepinephrine to increase, making them a pain-reducing factor. In addition, this form of recreation positively affects state of mind and well-being[8].

Research has shown that winter swimming stimulates metabolism. By decreasing the diffusion of lactate in the blood, people regularly bathing in cold water are characterised by better adaptation to physical exercise[9].

Blood is a version of connective tissue, and its fluid nature is ensured by the presence of plasma, a pale yellow liquid, consisting of about 92% of water and about 7% of proteins. The rest of the plasma is composed of salts and substances transported through the blood (e.g. hormones, dissolved gases, metabolic products and nutrients). Apart from plasma, the blood also contains morphotic elements (red and white blood cells and platelets) that are suspended in it. The importance of blood in the human body is demonstrated by the multitude of its functions, starting from the transport of substances, participation in immune processes, coagulation and thermoregulation, to providing homeostasis[10-13].

Components of kidney profile are urine and blood tests that allow the assessment of kidney function, both during diagnosis and treatment, as well as early detection of pathologies and precise location of their occurrence[14,15].

Diagnostic tests used in the evaluation of kidney function: urinalysis, electrolytes: Na, K; urea, creatinine, uric acid, total protein, keratin kinase, GFR – glomerular filtration rate. Creatinine determination is one of the basic tests that initially evaluates kidney function. Increased concentration is revealed only after significant damage to the nephrons and is indicative of renal failure. For the diagnosis of early stages of renal failure, a more sensitive and accurate test is the assessment of glomerular filtration rate (GFR), i.e. the ratio of creatinine concentration to urinary flow rate[16-18].

Elevated levels of urea occur with chronic nephritis, tubular necrosis or glomerulonephritis[18]. Increased levels of uric acid can be observed in the case of kidney or cardiovascular disease, metabolic disorders, diabetes or hypertension[19,20]. Determination of the level of creatine kinase activity is used in the diagnosis and treatment of tissue damage, mainly related to muscles. Thus, its elevated level may be a sign of injury, cerebrovascular disease or myocardial infarction[21-23].

Liver function tests[24,25] are an effective method of detecting and monitoring liver function disturbances.

Commonly used liver indices: total bilirubin, ALT – alanine aminotransferase, AST – aspartate aminotransferase, GGT – gamma-glutamyltransferase, LDH – lactate dehydrogenase, proteinogram, ALP – alkaline phosphatase, anti-HCV antibodies, HBs antigen.

Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) are enzymes present in various body tissues, including the liver, the skeletal and cardiac muscles and kidneys. During hepatocyte damage, serum levels of these enzymes increase, however, ALT is more sensitive and specific in liver diseases, while elevated AST is characteristic of myocardial infarction. Increased levels of ALT and AST are observed in chronic hepatitis B and C, hepatic steatosis, autoimmune hepatitis or can be induced by toxic substances[26-29].

Gamma-glutamyltransferase (GGT), as the indicator with the highest sensitivity, is used to diagnose liver and bile duct diseases. It also allows to detect alcoholism or stroke. Increased bilirubin, or hyperbilirubinaemia, occurs in diseases of liver parenchyma or biliary obstruction. The increase in lactate dehydrogenase (LDH) activity is indicative of diseases involving tissue necrosis. Elevated levels are found in anaemia, acute myocardial, skeletal muscle, lung, kidney or skin damage[24,26,30,31].

STUDY AIM

The aim of the study was to assess blood count, blood electrolyte levels, indicators evaluating the kidneys and activity of selected liver enzymes determining liver function during the whole winter bathing season in a "Walrus" from the Krakow "Radiator" Winter Swimming Club before and after exiting the water, and to answer the following questions:

1. Do the low water and air temperatures influence the selected blood counts, i.e. RBC, Hct, Hgb, MCV, MCH, MCHC, WBC, PLT during winter baths taken by the "Walrus" from the Krakow "Radiator" Winter Swimming Club?
2. Do the low water and air temperatures affect the blood electrolytes, i.e. Na^+, K^+, Cl^- during winter baths taken by the "Walrus" from the Krakow "Radiator" Winter Swimming Club?
3. Do the low water and air temperatures influence selected biochemical parameters of kidney profile, i.e. urea, creatinine, uric acid as well as hepatic profile, i.e. bilirubin, AST, ALT, GGT, LDH during winter baths taken by the "Walrus" from the "Radiator" Winter Swimming Club in Krakow?

RESEARCH MATERIAL AND METHODOLOGY

The research object was a "Walrus" from the Krakow Winter Swimming Club – a 53-year-old man who has regularly taken winter baths at Kryspinów Lagoon 3-4 times a week for 11 years. Good adaptive conditions, resistance to low water and air temperatures caused the selection of this particular "Walrus".

Blood was collected from the subject: at the beginning of the winter swimming season (November), during the season (five times) and at the end of the season (April) – always before and after exiting the water in an amount of 5 ml from the ulnar vein into Vacuette tubes with K3EDTA. The blood was taken by a qualified nurse, under the supervision of a doctor; the duration of maintaining in the water was 10 minutes; blood assays were performed at the Laboratory of Blood Physiology, University of Physical Education in Krakow and at the Department of Analytics and Clinical Biochemistry - Institute of Oncology in Krakow. The testing was approved by the Bioethical Commission at the District Medical Chamber in Krakow.

Weather parameters were as follows:

- 1st bath (November): water temperature 7°C, air temperature 8°C;
- 2nd-6th bath: water temperature about 2-4°C, air temperature about 1-2°C;
- 7th bath (April): water temperature 10°C, air temperature 19°C.

Blood measurements were performed using an ABX MICROS 60 haematology analyser (USA). The following indicators were determined:

- Red blood cell count – RBC [10^{12}/L];
- Haematocrit – Hct [L/L];
- Haemoglobin – Hgb [g/L];
- Average haemoglobin mass in red blood cell– MCH [fmol];
- Average volume of red blood cell – MCV [fL];
- Average hemoglobin concentration in red blood cell – MCHC [mmol/L];
- White blood cell count – WBC [10^9/L];
- Blood platelet count – PLT [10^9/L].

To determine the concentration of electrolytes in the blood serum, the Roche Cobas c501 biochemical analyser was used for the quantitative determination of sodium, potassium and chloride ions, using ion-selective electrodes.

The following indicators were marked:

- Sodium – Na [mmol/l];
- Potassium – K [mmol/l];
- Chlorine – Cl [mmol/l].

Electrolyte concentrations were determined in the blood serum using the method of indirect potentiometry. The ion-selective electrode uses the unique properties of materials to obtain electrical potential for ion measurements in a solution. The full measurement system for a given ion contains an ion-selective electrode, a reference electrode and electrical circuits for measuring and analysing the value of the potential difference in order to obtain the concentration of the studied ion.

Testing selected biochemical blood indicators was performed using the Roche Cobas c311 haematology analyser. Samples were stored at (-15) – (-25)°C. In the case of cloudiness or the presence of precipitates, the samples were centrifuged.

The following indicators were marked:

- Urea [mmol/l];
- Creatinine [mmol/l];
- Uric acid [μmol/l];
- Total bilirubin [μmol/l];
- *Aspartate aminotransferase* – AST [U/l];
- Alanine aminotransferase – ALT [U/l];
- Gamma-glutamyl transpeptidase – GGT [U/l];
- Lactate dehydrogenase - LDH [U / L].

The level of urea in the serum was determined via the kinetic method with urease and glutamate dehydrogenase. The enzymatic method was used to determine creatinine. The enzymatic-colorimetric method with the uricase enzyme in which the uric acid oxidation takes place is used to determine the concentration of uric acid. The determination of bilirubin was carried out with the colorimetric test, where in a very acidic environment and in the presence of a suitable solubilizing agent, total bilirubin is bound to the diazonium ion. The determination of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) was performed according to the recommendations of the IFCC (International Federation of Clinical Chemistry and Laboratory Medicine), modified for better performance and stability. A decrease in the measurement of absorbance was observed[22,23]. The enzymatic and colorimetric method was used to determine gamma-glutamyltransferase (GGT). Determination of lactate dehydrogenase (LDH) was performed using the UV test by means of photometric measurement of the increase in absorbance.

Statistical analysis

Data are presented in the form of raw values, means and standard deviation or median and I and III quartiles, depending on the assessment of the normal distribution. Normality of distribution was verified using the Shapiro-Wilk's test. Differences between the tested parameters before entering and after exiting were assessed using the Student's *t* test for dependent variables or the Wilcoxon test. The significance level of $\alpha = 0.05$ was assumed in the analyses. The analyses were performed using the Statistica 12 package (StatSoft®, USA).

RESULTS

Analysing the mean values of the indicators before and after exiting the water, a statistically significant increase in liver enzymes determining liver function was found: AST [U/L] by 6.4% (Fig. 4) and LDH [U/l] by 2.45% (Fig. 5). In addition, there was a statistically significant reduction in the concentration of indicators used to test renal function: Na^+ [mmol/l] by 1.14% (Fig. 1), Cl^- [mmol/l] by 1.78% (Fig. 2) and urea [mmol/l] by 3.64% (Fig. 3) in the "Walrus" following the winter bathing season. No changes were found for the remaining indicators: RBC [10^{12}/l], HCT [l/l], HGB [g/l], MCH [fmol], MCV [fl], MCHC [mmol/l], WBC [10^9/l], PLT [10^9/l], K^+ [mmol/l], creatinine [mmol/l], uric acid [μmol/l], total bilirubin [μmol/l], ALT [U/l], GGT [U/l] (Tab. 1).

reservoirs during the winter season (in Poland from November to April), which guarantees that the water temperature does not exceed 4°C while the temperature falls below 0°C[32-34].

Many fanatics (enthusiasts, supporters, hobbyists, lovers) of this sport believe that regular bathing in cold waters provides better immunity of the body, thanks to which these

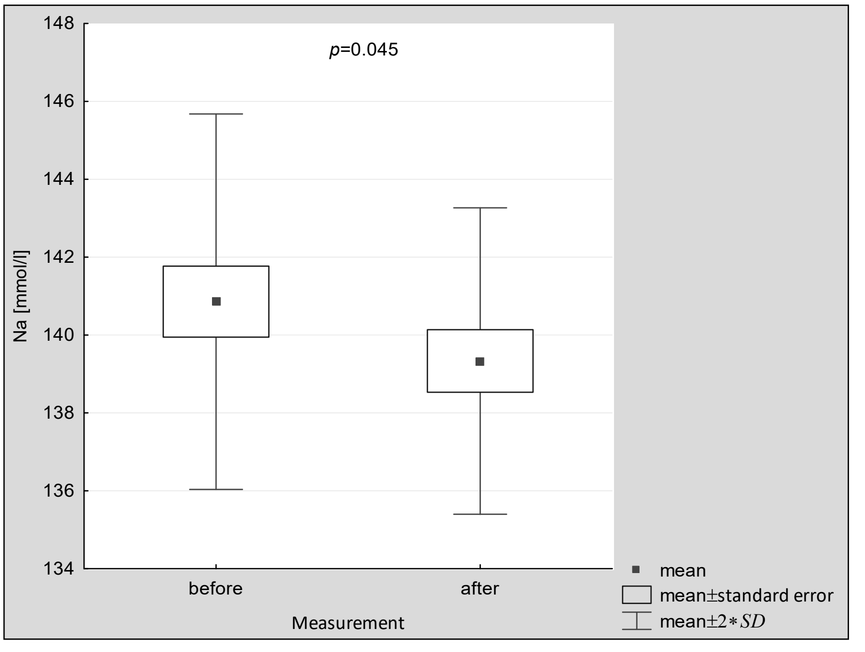

Figure 1

Average values of Na^+ [mmol/l] in the winter swimmer ("Walrus") before and after exiting the water during winter swimming

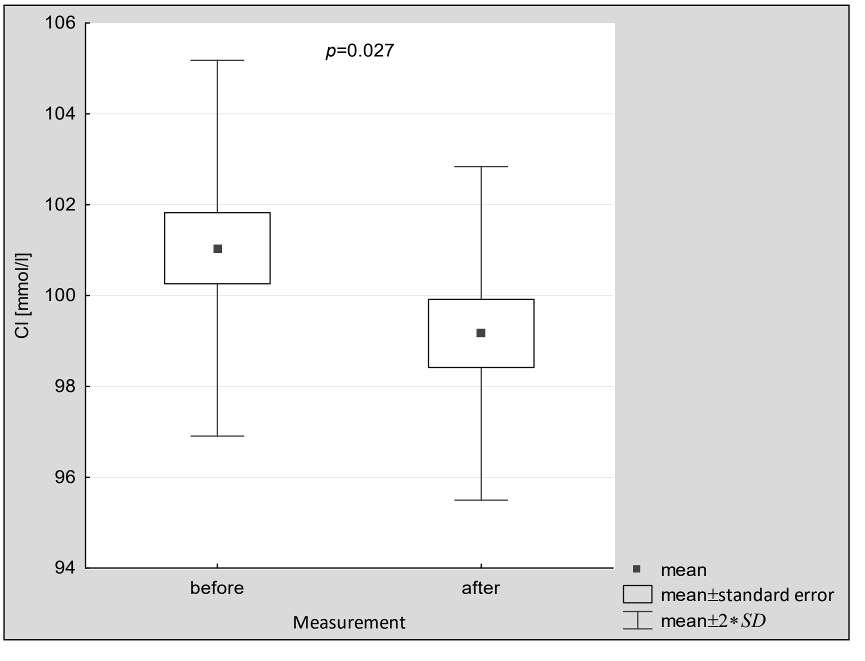

Figure 2

Average values of Cl^- [mmol/l] in the winter swimmer ("Walrus") before and after exiting the water during winter swimming

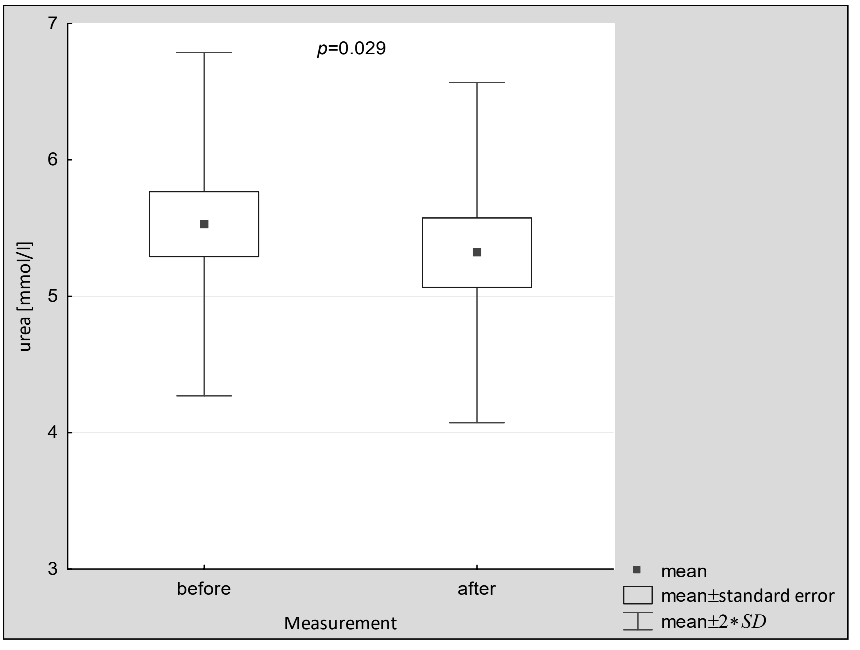

Figure 3

Average values of urea [mmol/l] in the winter swimmer ("Walrus") before and after exiting the water during winter swimming

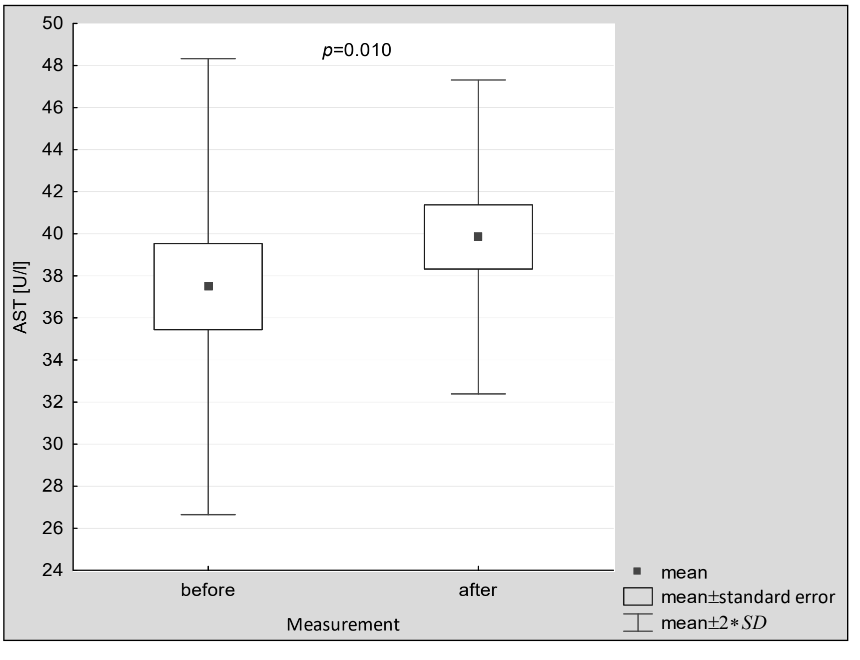

Figure 4

Average AST values [U/l] in the winter swimmer ("Walrus") before and after exiting the water during winter swimming

people suffer less frequently than others and are more resistant to temperature drops in the winter[1,35].

Adaptation of the body to repeatedly subjecting it to changes in ambient temperature is defined as a mechanism resulting in increased resistance to stress and disease, but there is little evidence of this[36]. Mila-Kierzenkowska et al.[37] proved the constant readiness of the antioxidant system to protect the body against the adverse effects of reactive oxygen species during exposure to changes in ambient temperature in experienced "walruses"[37].

Based on the authors' research, no statistically significant changes were found in the morphological indices of blood. Vogelaere et al.[38] observed a significant increase in the level of RBC, HGB and HCT in those resting and undertaking efforts (of varying intensity) in cold water[38]. Also, Pendergast et al.[39] concluded that regular immersion in cold water increases the value of haematocrit and haemoglobin. The authors of these reports, as well as their predecessors, showed that the subjects underwent a decrease in plasma volume, which led to the movement of part of the plasma from the intravascular space to extravascular area. This phenomenon is explained by the increased activity of the sympathetic nervous system[39]. Lombardi et al.[40] also noticed an increase in haematocrit, haemoglobin and RBC, investigating those who agreed to swim the distance of 150 meters in 6°C water. They came to the same conclusions as their predecessors, which was confirmation of earlier research[40].

Baković et al.[32] conducted a study among divers submerging in cold water and observed an increase in the number of red blood cells, which they claim is caused by splenic contraction, which implies the ejection of stored erythrocytes, and this may also affect marrow sinus constriction.

In the research carried out by Lubkowska et al.[41], significant decreases were noted in RBC, haematocrit and haemoglobin. The subjects immersed in water 3 times in 5 months. The authors explain that changes in these morphological indices may be caused by cold temperatures, which could have contributed to increased haemolysis.

Wcisło et al.[31] examined 10 people who regularly (once a week) immersed in water during the entire winter swimming season. The authors observed a significant increase in the number of erythrocytes, which they explain by significant peripheral vasodilation. The same tests showed an increase in the value of haemoglobin and haematocrit, which, according to the authors, is a consequence of the shift of plasma from the intravascular space to the interstitial space. The authors also noted a sig-

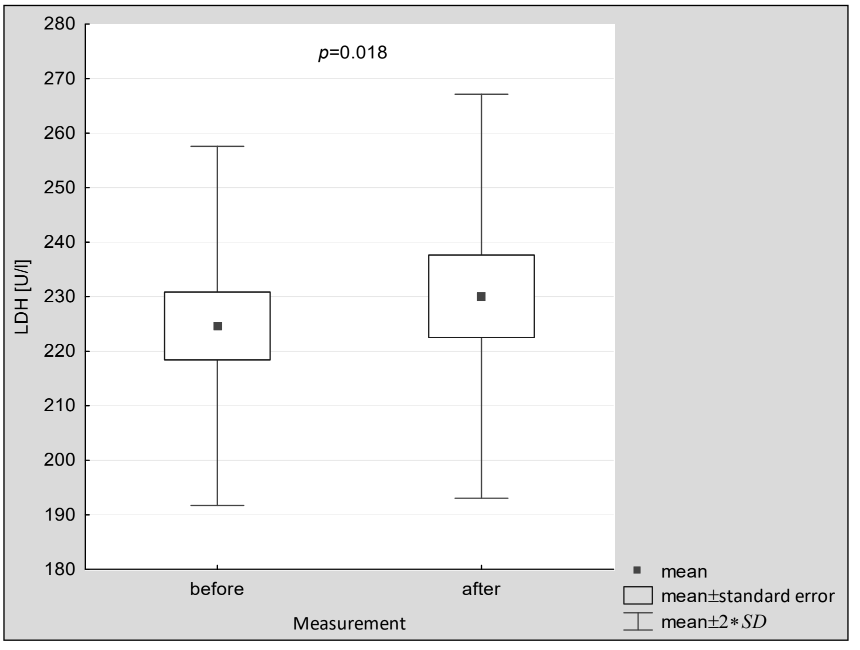

Figure 5

Mean LDH values [U/l] for the winter swimmer ("Walrus") before and after exiting the water during winter swimming

nificant reduction in MCH and a decrease in MCHC.

Mila-Kierzenkowska et al.[42] subjected 30 people to research, 14 of them regularly bathing in cold water for at least a year, while the rest immersed for the first time during the study. The authors observed a significant increase in mean haemoglobin concentration in the red blood cell among the group of walruses and a decrease in the average volume of the blood in the amateurs. The authors concluded that these changes are caused by a change in circulating blood volume due to exposure under conditions of reduced environmental temperature.

In the research by Teległów et al.[43], a decrease in the number of erythrocytes was noted after a 6-month break in winter swimming. Between one winter season and the other, the test group performed other physical activities (i.e. running or cycling). The authors concluded that the decrease in RBC index was caused by irregularity in undertaking physical activity among the subjects or a break in exposure to cold waters, which causes a stress reaction. As expected, an increase in MCH index was observed.

In contrast, in research on animals, i.e. toads, Abdo et al.[44] noticed changes in the majority of indicators associated with the red blood cell system. Frogs (toads) were subjected to a "shock" temperature, acclimatized at 28°C, and were then immersed in ice water. There was an increase in RBC and haemoglobin as well as haematocrit, a decrease in MCV, while the changes in MCHC

Table 1

Mean values ± standard deviation (*SD*) of selected indicators in the examined winter swimmer ("Walrus") before and after exiting the water

Index	Before immersion	After immersion	Level of significance
RBC [1012/l]	4.8 ±0.2	4.8 ±0.2	0.382
HCT [l/l]	45.3 ±2.8	45.5 ±2.8	0.286
HGB [g/l]	15.9 ±0.6	16.0 ±0.6	0.272
MCH [fmol]	33.0 ±0.8	33.1 ±0.8	0.486
MCV [fl]	94.1 ±1.3	94.0 ±1.0	0.850
MCHC [mmol/l]	35.1 ±1.2	35.3 ±1.1	0.491
WBC [109/l]	3.7 ±0.3	3.8 ±0.4	0.556
PLT [109/l]	150.1 ±13.1	150.7 ±15.4	0.573
Na+ [mmol/l]	140.9 ±2.4	139.3 ±2.0	**0.045**
K+ [mmol/l]	4.9 ±0.3	4.5 ±0.3	0.059
Cl- [mmol/l]	101.0 ±2.1	99.2 ±1.8	**0.027**
Urea [mmol/l]	5.5 ±0.6	5.3 ±0.6	**0.029**
Creatinine [mmol/l]	61.1±6.2	61.4 ±5.3	0.098
Uric acid [μmol/l]	420.6 ±55.2	426.4 ±44.4	0.108
Total bilirubin [μmol/l]	12.4 ±4.2	13.4 ±4.9	0.392
AST [U/l]	37.5 ±5.4	39.9 ±3.7	**0.010**
ALT [U/l]	59.8 ±15.5	63.5 ±15.3	0.528
GGT [U/l]	86.1±16.6	88.8 ±16.8	0.600
LDH [U/l]	224.6 ±16.5	230.1 ±18.5	**0.018**

were not significant. The authors report that these changes were caused by the adaptation of toads to fluctuations within their natural living environment.

In the research carried out by Teległów et al.[45], 8-week-old rats showed an increase in HGB and HCT concentrations as well as RBC as a result of immersion in cold water. The authors claim that due to the low temperature, blood density increased, which may have been caused by dehydration of the body. In subsequent studies, Teległów et al.[46], also examining rats, observed an increase in red cell parameters and reached analogous conclusions[45,46].

In the authors' research, there were no statistically significant changes in the red blood cell system of the Walrus before or after exiting the water throughout the entire winter swimming season, which is most likely related to the body adaptation of this particular "Walrus" to the prevailing conditions, all the more so since he was selected from the many winter swimmers of the Krakow "Radiator" Club[39].

In their research, Lombardi et al.[40] and Vogelaere et al.[38] observed a significant increase in the number of white blood cells under the influence of immersion in cold water. The authors agree that this is related to the action of cold water on the body.

When studying divers, Baković et al.[32] noted an increase in the number of leukocytes, which in their opinion, was caused by splenic contraction.

In the authors' research, there were no statistically significant changes in the number of white blood cells, which indicates very good acclimatisation to these conditions during the entire winter swimming season.

Another change in the blood count indices noted by Lombardi et al.[40] was an increase in the number of platelets. The authors claim that this is associated with an increase in platelet aggregation, which is dependent on the decrease in circulating blood volume, resulting from changes allowing the cardiovascular system to adapt after exposure to low ambient temperatures.

Deveci et al.[47], studying the effect of low ambient temperatures on the blood morphology of hamsters and rats, noticed a significant decrease in the number of thrombocytes in these groups of rodents. The authors point out that this may be associated with a decrease in bone marrow activity, resulting from exposure of the studied groups to unfavourable environmental conditions[47]. In the authors' study, there were no statistically significant changes in the number of platelets.

Based on our own research, statistically significant changes in the concentration of sodium (Na^+) and chlorides (Cl^-) were found. However, no statistically significant changes in potassium concentration (K^+) were observed after the entire winter bathing season. The loss of sodium and chloride ions is most likely caused by increased urine output. At low temperatures, vasospasm occurs, resulting in increased hydrostatic pressure[48]. According to Martineau et al.[49], plasma volume can be reduced by up to 24%.

Other probable reasons for the reduction of the above-mentioned serum electrolytes include, but are not limited to, increased levels of albumin and reduced levels of glucosteroid hormones[50].

Above-normative reduction in sodium levels determined by hyponatremia can lead to many adverse and adverse effects, including nausea, tendency to vomit, headaches, loss of short-term memory, confusion, fatigue, decreased appetite, impulsiveness and nervousness, muscle weakness, spasms, convulsions, impaired consciousness or coma, which can be harmful, especially when in cold water[50].

The observed reduction in chloride (Cl^-) concentration is directly related to the decrease in sodium (Na^+) concentration. A statistically insignificant decrease in potassium concentration (K^+) was also found, although this decrease is, subjectively, quite high. A similar relationship was noted by Rouger et al.[51], who observed slight hypokalemia after a 1,500-m crawl swim in cold water[51]. Dobrev et al.[52] described very low potassium levels were found among athletes who swam 30,000 m in low-temperature water. In the research by Stocks et al.[53,] 7 adult males participated in 14-day cold water swimming, during which no changes due to the cold water were noted in electrolyte concentration.

In the available literature, there are few studies on the effect of winter swimming on kidney and liver function. Our research is the first to describe the effect of swimming in low-temperature water on kidney and liver function based on a single case.

The work by Teległów et al.[50] is the only study describing changes in kidney and liver profile indicators under the influence of cold baths in a comprehensive way. This study was carried out among 11 men at the Bagry reservoir in the winter. There was a downward trend in urea levels but not of statistical significant. In the other parameters, i.e. creatinine and uric acid, no significant changes were observed.

Siems et al.[54] described a reduction in uric acid levels to almost half of its baseline value after immersion in cold water. This effect was only explained by increased uric acid secretion and the hypothesis that this may be due to oxidative stress occurring in hypothermic conditions.

In the authors' study, a significant decrease in urea level by 3.64% was observed after leaving the water during winter swimming. There were no significant changes in the remaining kidney function indicators.

In their research, Teległów et al.[50] as well as Siems[55] did not observe statistically significant changes in the parameters describing liver function.

In this study, significant increases in AST and LDH concentrations were found, while in the case of other parameters, i.e. total bilirubin and ALT, no significant changes were observed.

In summary, winter baths have been gaining more and more popularity, thus, further research is necessary to describe their impact on physiological blood indices, including electrolyte levels as well as renal and hepatic profile.

CONCLUSIONS

The low temperature of water and air did not affect blood morphology indices and did not cause pathological changes in kidney profile during winter baths in the "Walrus" form the Krakow "Radiator" Winter Swimming Club. Under the influence of low water and air temperatures, small fluctuations in serum electrolyte concentrations were observed in the winter swimmer, and changes in his liver profile additionally "revealed" health problems that were present before winter swimming.

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