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*Article*

# Passion and Health: How Winter Swimming Influences Blood Morphology and Rheology

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**Abstract:** An important area of health is health promotion. A healthy lifestyle supports health improvement and early prevention of chronic diseases. Stimulation of the body by cold water swimming and swimming in a swimming pool can lead to adaptive changes beneficial for the human cardiovascular system. Within the winter swimming season of 2023/2024, for a period of 5 months, from November to March, once a week, study participants (n = 30; n = 15 females and n = 15 males) from the Krakow Society of Winter Swimmers 'Kaloryfer' in Krakow (Poland) practiced winter swimming in cold water (4–5 °C) and swam in the sports pool of the University of Physical Culture in Krakow in water at a temperature of 28 °C. After a full season of winter swimming and swimming pool sessions, both males and females exhibited a tendency towards lower erythrocyte ($p = 0.002$), leukocyte ($p < 0.001$), and platelet counts ($p < 0.001$), as well as an increase in blood plasma viscosity (within normal limits) ($p = 0.001$), without any changes in blood aggregation or fibrinogen indicators. The remaining morphological indicators and the elongation index demonstrated only limited variation. Winter swimming induces positive changes in blood morphology and rheology.

**Keywords:** winter swimming; swimming pool; cold water swimming; cold water immersion; blood rheology; blood morphology; blood plasma viscosity; elongation index; aggregation index; adaptive mechanisms; thermoregulation; cardiovascular health

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## 1. Introduction

The beneficial effects of cold on the human body have been known since long ago [1]. Cold water swimming is applied to induce organ- and system-related physiological defense responses that are advantageous and efficient in maintaining or restoring human body homeostasis [2–8]. Winter swimming is a short-term plunge in the cold water of a lake, sea, or other body of water practiced in a group during the autumn and winter seasons, resulting in increased immunity, an improved thermoregulatory system, as well as enhanced cardiovascular function, skin blood flow, and mood. Winter swimming can help reduce body fatigue and soreness [9]. Cold temperature diminishes swelling and tissue breakdown. Ice baths cause a constriction of blood vessels. This has been suggested to be a mechanism that helps with the flushing of waste products, such as lactic acid, out of the affected tissue. Moreover, Roberts et al. [10] demonstrated that cold baths had a positive effect on improving post-workout recovery. Individuals who regularly practice winter swimming exhibit greater tolerance to low temperatures [11]. Regular exposure to cold increases tolerance to cold owing to a number of adaptive mechanisms. Low temperatures exert analgesic and anti-swelling effects, improves circulation, has antioxidant properties, reduces inflammation, and positively influences the function of the neuromuscular system [12,13]. Swimming in icy water has been proved to have a positive effect on the human psyche [14–16] and to bring about antidepressant effects [17]. Regular winter swimming leads to a rise in general well-being in individuals who suffer from rheumatism, fibromyalgia, or asthma [14]. Owing to an increase in catecholamine concentration, swimming in cold water can remedy depression, as it activates the sympathetic nervous system and raises norepinephrine and β-endorphin concentrations [18]. The stress hormones of adrenaline, norepinephrine, and cortisol, released by cold water exposure, stimulate the immune system to mobilize and positively affect the psyche. People who perceive themselves as tolerant of cold experience stable emotions and are characterized by greater activity and vigor [19]. The mechanism of adaptation is considered to be habituation or acclimatization [20]. Cold water immersions (e.g., adapted cold showers, partial or total immersion, cold swimming) are now increasingly used as a complementary procedure to improve the effects of the primary treatment of various clinical conditions, including depressive and anxiety disorders [21]. Sex-specific differences in the response to cold exposure and swimming have also been observed in the literature, and they may play a significant role in how males and females adapt to such conditions. For instance, males and females differ in their thermoregulatory mechanisms, such as skin blood flow and heat conservation, partly due to variations in body composition, including fat distribution and muscle mass. Hematological differences, such as baseline hemoglobin levels and red blood cell counts, are also notable and may influence oxygen delivery and blood viscosity during cold exposure. The rationale for combining cold water and sports pool swimming was based on the hypothesis that alternating exposure to extreme cold and moderate temperatures could enhance thermoregulatory adaptability and cardiovascular benefits. Cold water immersion activates the sympathetic nervous system, induces vasoconstriction, and stimulates non-shivering thermogenesis, while subsequent swimming in a warmer pool allows for muscle relaxation and recovery. This combination is thought to optimize the balance between stress-induced adaptation and recovery, fostering systemic resilience.

The aim of this study was to investigate the effects of winter swimming and swimming in a sports pool on the morphological and rheological characteristics of blood in female and male winter swimmers. We hypothesize that winter swimming has positive effects on blood morphological and rheological parameters.

## 2. Materials and Methods

### *2.1. Participants and Study Design*

The randomized controlled study group consisted of 60 participants aged 35–55 years. The winter swimming group included 30 randomly selected individuals (n = 15 females and n = 15 males) aged 35–55 years from the Krakow Society of Winter Swimmers ‘Kaloryfer’ in Krakow (Poland), and the control group included 30 individuals (n = 15 females and n = 15 males) of the same age range who neither practiced winter swimming nor engaged in regular physical activity.

The inclusion criteria were as follows: age range of 35–55 years; absence of significant cardiovascular, respiratory, or musculoskeletal disorders; provision of written informed consent to participate in this study.

The exclusion criteria were as follows: cardiac arrhythmias; uncontrolled hypertension; neoplasm; oncological treatment; diabetes; rheumatic diseases.

Participants were recruited from the Krakow Society of Winter Swimmers. Out of 70 eligible individuals, 10 were excluded due to either failure to meet inclusion criteria or lack of consent to participate. The remaining participants were stratified by sex before randomization. As a result, the study group, comprising winter swimmers (n = 30), included 15 females and 15 males. Similarly, the control group (n = 30) was composed of 15 females and 15 males. *The study flowchart is presented in Figure 1.*

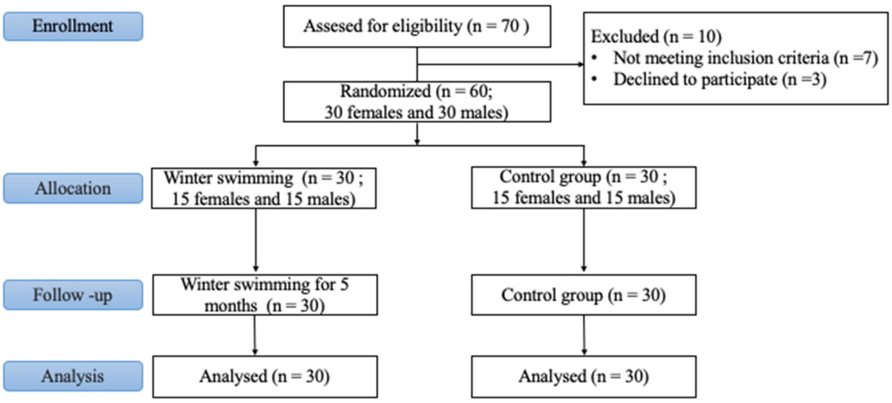

**Figure 1.** CONSORT flow diagram of study participants.

Each participant fulfilled a questionnaire including basic data such as age, sex, comorbidities, height, and weight. Blood samples were collected twice at the beginning and at the end of the winter swimming season by a qualified nurse. All participants gave written informed consent.

### 2.2. Intervention

Within the winter swimming season of 2023/2024, the study participants (n = 30) from the Krakow Society of Winter Swimmers ‘Kaloryfer’ practiced winter swimming in cold water at a temperature of 4–5 °C. The winter swimming was preceded by a warm-up conducted by a slow jogging instructor. The winter swimming was practiced for 5 months, once a week, from November to March, at the Bagry Lagoon in Krakow. At the same time, the winter swimming study group also swam in the sports pool of the University of Physical Culture in Krakow. The swimming was practiced for 5 months, from November to March, once a week, for 1 hour, in water at a temperature of 28 °C, in the winter swimming season of 2023/2024. The winter swimming and the sports pool swimming were performed under medical supervision by a physician.

### 2.3. Research Methods

Blood samples were collected from the subjects from the antecubital vein in the amount of 5 ml into Vacuette EDTA K2 tubes at the beginning and at the end of the winter swimming season by a qualified nurse. Morphological and rheological indicators were determined in the blood tested at the Blood Physiology Laboratory of the Central Research and Development Laboratory, University of Physical Education in Krakow. This study was approved by the Ethics Committee of the Regional Medical Chamber in Krakow (approval No.: 182/KBL/OIL/2023) and followed the tenets of the Declaration of Helsinki.

#### Morphological and Rheological Assessments

The blood morphological analyses included red blood cell count (RBC) [$10^6$/mm$^3$], hemoglobin (HGB) [g/dL], hematocrit (HCT) [%], mean corpuscular hemoglobin (MCH) [pg], mean corpuscular hemoglobin concentration (MCHC) [g/dL], mean corpuscular volume (MCV) [µm$^3$], red blood cell distribution width (RDW) [%], white blood cell count

(WBC) [$10^3$/mm$^3$], platelet count (PLT) [$10^3$/mm$^3$], mean platelet volume (MPV) [µm$^3$], and platelet distribution width (PDW) [%]. The indicator markings were performed with an ABX Micros 60 analyser (Horiba ABX SAS, Montpellier, France).

Blood rheology parameters, such as erythrocyte aggregation index (AI) [%], amplitude and total extent of aggregation (AMP) [arbitrary units], and half-time of total aggregation (T1/2) [s], as well as the deformability parameter of elongation index (EI), were measured with a Laser-Assisted Optical Rotational Red Cell Analyser (Lorrca) (MaxSis Lorrca®, RR Mechatronics, the Netherlands) by using the method described by Hardeman. Mean EI values were determined at shear stress values of 0.30 Pa, 0.58 Pa, 1.13 Pa, 2.19 Pa, 4.24 Pa, 8.23 Pa, 15.95 Pa, 30.94 Pa, and 60.00 Pa with the automatic analysis function of the Lorrca system, which allows for the assessment of erythrocyte deformability as a function of shear stress and erythrocyte aggregation.

Fibrinogen determinations [g/L] were performed by using a CHROM-7 coagulometer (Poland).

Blood plasma viscosity (BPV) [mPas] was measured with a DVNext Brookfield Ametek Cone/Plate Rheometer (Brookfield, Middleborough, MA, USA). The torque measuring system of the device consists of a calibrated beryllium copper spring connecting the drive mechanism to a rotating cone and sensing the resistance to rotation caused by the presence of a plasma sample between the cone and a stationary flat plate. The resistance to the rotation of the cone produces a torque that is proportional to the shear stress in the plasma sample. The measurements were conducted at 37 °C with shear rates of 450/s and employed a CP-40Z spindle.

### 2.4. Statistical Analysis

The study sample size was calculated based on previous studies available; the significance criterion was set $\alpha = 0.05$ and power = 0.8. One-way analysis of variance (ANOVA) with repeated measures was used to assess differences between the investigated groups. Differences between means were considered significant at $p < 0.05$. Multiple comparisons were performed using Tukey's HSD test. The Shapiro–Wilk test was used to test normality. The homogeneity of variance was checked using Levene's test. Differences between means were considered significant at $p < 0.05$. The analyses were performed with the Statistica 13 software package (StatSoft Polska).

## 3. Results

### 3.1. Participants' Characteristics

We enrolled 60 individuals. The average age of the entire cohort was 45.6 ± 5.9 years. In the winter swimmer group, females had a mean age of 46.8 ± 5.8 years and a BMI of 25.8 ± 5.3 kg/m$^2$, while males had a mean age of 45.3 ± 5.3 years and a BMI of 26.8 ± 3.1 kg/m$^2$. In the control group, females had a mean age of 44.8 ± 5.1 years and a BMI of 25.2 ± 2.7 kg/m$^2$, while males had a mean age of 44.7 ± 5.6 years and a BMI of 27.6 ± 2.9 kg/m$^2$. No statistically significant differences were observed between these subpopulations.

### 3.2. Blood Morphology and Rheology

Statistically significant increases in MCH, MCHC, RDW, PDW, and BPV were observed in the winter swimmers after the winter swimming season. Statistically significant decreases in WBC, RBC, HGB, HCT, PLT, MCV, MPV, and EI at a shear stress of 0.30 Pa were reported for the winter swimmers after the winter swimming season. Statistically significant increases in MCHC, RDW, EI at a shear stress of 60.00 Pa, and BPV were determined in the control group at the beginning of the season. Statistically significant decreases in HCT, MCHC, PLT, MPV, and EI at a shear stress of 0.30 Pa were noted for the control group at the end of the season (Table 1).

**Table 1.** Blood morphological and rheological parameters in the investigated groups, presented as mean and standard deviation, before and after the winter swimming season.

| Parameter | Controls n = 30 | | *p* | Winter Swimmers n = 30 | | *p* |
|---|---|---|---|---|---|---|
| | **Before Season** | **After Season** | | **Before Season** | **After Season** | |
| WBC [$10^3$/mm$^3$] | **5.51 ± 1.36** | 4.99 ± 0.97 | 0.348 | 6.46 ± 1.42 | 5.25 ± 0.87 | **0.002** |
| RBC [$10^6$/mm$^3$] | 4.45 ± 0.27 | 4.29 ± 0.16 | 0.093 | 4.59 ± 0.35 | 4.12 ± 0.46 | **<0.001** |
| HGB [g/dL] | 13.35 ± 0.90 | 13.00 ± 0.85 | 0.073 | 13.15 ± 1.21 | 12.99 ± 1.24 | 0.658 |
| HCT [%] | 39.87 ± 2.34 | 37.25 ± 2.36 | **<0.001** | 40.91 ± 3.06 | 34.93 ± 4.05 | **<0.001** |
| PLT [$10^3$/mm$^3$] | 260.13 ± 53.19 | 204.87 ± 50.22 | **<0.001** | 270.33 ± 87.48 | 188.47 ± 55.73 | **<0.001** |
| MCV [$\mu$m$^3$] | 89.73 ± 4.87 | 86.80 ± 4.96 | 0.174 | 89.19 ± 5.83 | 85.33 ± 9.82 | **0.045** |
| MCH [pg] | 30.05 ± 1.84 | 30.29 ± 2.03 | 0.964 | 28.77 ± 2.50 | 31.84 ± 3.90 | **<0.001** |
| MCHC [g/dL] | 33.47 ± 0.79 | 34.93 ± 1.55 | **0.049** | 32.16 ± 1.17 | 37.32 ± 2.03 | **<0.001** |
| RDW [%] | 12.88 ± 1.21 | 15.47 ± 2.25 | **0.001** | 13.16 ± 1.30 | 17.85 ± 2.49 | **<0.001** |
| MPV [$\mu$m$^3$] | 11.07 ± 0.70 | 8.28 ± 0.46 | **<0.001** | 10.25 ± 0.88 | 7.99 ± 0.44 | **<0.001** |
| PDW [%] | 13.22 ± 1.58 | 14.02 ± 1.52 | 0.244 | 11.78 ± 1.84 | 13.42 ± 1.22 | **0.001** |
| EI at 0.30 Pa | 0.054 ± 0.014 | 0.048 ± 0.014 | **0.017** | 0.049 ± 0.014 | 0.043 ± 0.02 | **0.031** |
| EI at 0.58 Pa | 0.155 ± 0.017 | 0.151 ± 0.017 | 0.538 | 0.149 ± 0.016 | 0.143 ± 0.02 | 0.092 |
| EI at 1.13 Pa | 0.241 ± 0.014 | 0.242 ± 0.019 | 0.988 | 0.236 ± 0.016 | 0.234 ± 0.02 | 0.917 |
| EI at 2.19 Pa | 0.344 ± 0.015 | 0.345 ± 0.015 | 0.997 | 0.336 ± 0.032 | 0.337 ± 0.02 | 0.999 |
| EI at 4.24 Pa | 0.437 ± 0.011 | 0.439 ± 0.011 | 0.868 | 0.436 ± 0.014 | 0.433 ± 0.01 | 0.627 |
| EI at 8.23 Pa | 0.510 ± 0.012 | 0.512 ± 0.009 | 0.776 | 0.510 ± 0.011 | 0.508 ± 0.01 | 0.826 |
| EI at 15.95 Pa | 0.559 ± 0.013 | 0.563 ± 0.009 | 0.344 | 0.560 ± 0.009 | 0.557 ± 0.01 | 0.632 |
| EI at 30.94 Pa | 0.597 ± 0.012 | 0.602 ± 0.008 | 0.181 | 0.597 ± 0.008 | 0.595 ± 0.01 | 0.909 |
| EI at 60.00 Pa | 0.629 ± 0.009 | 0.637 ± 0.006 | **0.005** | 0.628 ± 0.007 | 0.628 ± 0.01 | 1.000 |
| AMP [au] | 34.96 ± 2.84 | 35.03 ± 2.71 | 1.000 | 33.34 ± 3.75 | 32.01 ± 4.10 | 0.243 |
| AI [%] | 60.25 ± 7.17 | 58.90 ± 7.68 | 0.972 | 61.21 ± 8.52 | 63.26 ± 7.96 | 0.465 |
| T1/2 [s] | 2.74 ± 0.85 | 2.93 ± 0.93 | 0.954 | 2.67 ± 1.06 | 2.43 ± 0.91 | 0.570 |
| BPV [mPas] | 1.37 ± 0.09 | 1.45 ± 0.05 | **0.010** | 1.42 ± 0.09 | 1.52 ± 0.10 | **0.001** |
| FIB [g/L] | 3.46 ± 0.81 | 3.40 ± 0.66 | 0.990 | 3.38 ± 0.45 | 3.41 ± 0.50 | 0.999 |

WBC, white blood cell count; RBC, red blood cell count; HGB, hemoglobin; HCT, hematocrit; PLT, platelet count; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; RDW, red blood cell distribution width; MPV, mean platelet volume; PDW, platelet distribution width; EI, elongation index; AMP, amplitude and total extent of aggregation; AI, aggregation index; T1/2, aggregation half-time; BPV, blood plasma viscosity; FIB, fibrinogen. Bold denotes significant differences ($p < 0.05$).

Statistically significant increases in MCH, MCHC, RDW, PDW, and BPV were observed in female winter swimmers after the winter swimming season. Statistically significant decreases in WBC, RBC, HGB, HCT, PLT, MCV, MPV, and EI at a shear stress of 0.30 Pa were reported in female winter swimmers after the winter swimming season. Statistically significant increases in MCHC, RDW, EI at a shear stress of 60.00 Pa, and BPV were determined in females in the control group at the beginning of the season. Statistically significant decreases in HCT, MCHC, PLT, MPV, and EI at a shear stress of 0.30 Pa were noted in females in the control group at the end of the season.

Statistically significant increases in MCHC and RDW and decreases in EI at a shear stress of 60.00 Pa were observed for female winter swimmers after the winter swimming season (4) compared with the control group after the season (2). When comparing the females in the winter swimming group after the season (4) with the females in the control group before the season (1), statistically significant increases were determined for RDW and BPV, and statistically significant decreases were noted for RBC, HCT, MCHC, PLT, and MPV. When comparing females in the winter swimming group before the season (3) with females in the control group before the season (1), statistically significant decreases were observed for RDW and PDW (Table 2).

Statistically significant increases in MCH, MCHC, RDW, PDW, EI at a shear stress of 2.19 Pa, and BPV were observed in male winter swimmers after the winter swimming season. Statistically significant decreases in WBC, RBC, HCT, PLT, MCV, MPV, EI at a shear stress of 1.13 Pa, and EI at a shear stress of 4.24 Pa were reported in male winter swimmers after the winter swimming season. Statistically significant increases in RDW, EI at a shear stress of 8.28 Pa, EI at a shear stress of 30.94 Pa, and EI at a shear stress of 60.00 Pa were determined in males in the control group. Statistically significant decreases in RBC, HCT, PLT, and MPV were noted in males in the control group.

Statistically significant increases in MCHC, RDW, EI at a shear stress of 60.00 Pa, and BPV, as well as decreases in HCT, MCV, and EI at a shear stress of 15.95 Pa, were observed in male winter swimmers after the winter swimming season (4) compared with males in the control group after the season (2). When comparing males in the winter swimming group after the season (4) with males in the control group before the season (1), statistically significant increases were determined in MCHC, RDW, and BPV, and statistically significant decreases were noted in WBC, RBC, HCT, PLT, MCV, and MPV. When comparing males in the winter swimming group before the season (3) with males in the control group before the season (1), statistically significant decreases in PDW were observed (Table 3).

**Table 2.** Blood morphological and rheological parameters in female winter swimmers compared with controls, presented as mean and standard deviation, before and after the winter swimming season.

| Parameter | Controls | | Female Winter Swimmers | | p Control | p Swimmers | p c–s After | 4–1 | 3–1 | $\eta^2$ Factor | $\eta^2$ Factor * Group |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before Season (1) | After Season (2) | Before Season (3) | After Season (4) | | | | | | | |
| WBC [$10^3$/mm$^3$] | 5.51 ± 1.36 | 4.99 ± 0.97 | 6.46 ± 1.42 | 5.25 ± 0.87 | 0.348 | **0.002** | 0.935 | 0.928 | 0.135 | 0.36 | 0.09 |
| RBC [$10^6$/mm$^3$] | 4.45 ± 0.27 | 4.29 ± 0.16 | 4.59 ± 0.35 | 4.12 ± 0.46 | 0.093 | **<0.001** | 0.451 | **0.040** | 0.637 | 0.64 | 0.31 |
| HGB [g/dL] | 13.35 ± 0.90 | 13.00 ± 0.85 | 13.15 ± 1.21 | 12.99 ± 1.24 | 0.073 | 0.658 | 1.000 | 0.792 | 0.955 | 0.20 | 0.03 |
| HCT [%] | 39.87 ± 2.34 | 37.25 ± 2.36 | 40.91 ± 3.06 | 34.93 ± 4.05 | **<0.001** | **<0.001** | 0.175 | **0.001** | 0.781 | 0.84 | 0.44 |
| PLT [$10^3$/mm$^3$] | 260.13 ± 53.19 | 204.87 ± 50.22 | 270.33 ± 87.48 | 188.47 ± 55.73 | **<0.001** | **<0.001** | 0.893 | **0.020** | 0.971 | 0.81 | 0.14 |
| MCV [μm$^3$] | 89.73 ± 4.87 | 86.80 ± 4.96 | 89.19 ± 5.83 | 85.33 ± 9.82 | 0.174 | **0.045** | 0.931 | 0.288 | 0.996 | 0.30 | 0.01 |
| MCH [pg] | 30.05 ± 1.84 | 30.29 ± 2.03 | 28.77 ± 2.50 | 31.84 ± 3.90 | 0.964 | **<0.001** | 0.406 | 0.282 | 0.563 | 0.43 | 0.36 |
| MCHC [g/dL] | 33.47 ± 0.79 | 34.93 ± 1.55 | 32.16 ± 1.17 | 37.32 ± 2.03 | **0.049** | **<0.001** | **<0.001** | **<0.001** | 0.077 | 0.73 | 0.47 |
| RDW [%] | 12.88 ± 1.21 | 15.47 ± 2.25 | 13.16 ± 1.30 | 17.85 ± 2.49 | **0.001** | **<0.001** | **0.006** | **<0.001** | 0.978 | 0.72 | 0.18 |
| MPV [μm$^3$] | 11.07 ± 0.70 | 8.28 ± 0.46 | 10.25 ± 0.88 | 7.99 ± 0.44 | **<0.001** | **<0.001** | 0.622 | **<0.001** | **0.006** | 0.96 | 0.22 |
| PDW [%] | 13.22 ± 1.58 | 14.02 ± 1.52 | 11.78 ± 1.84 | 13.42 ± 1.22 | 0.244 | **0.001** | 0.697 | 0.983 | **0.015** | 0.43 | 0.11 |

**Table 2.** *Cont.*

| Parameter | Controls | | Female Winter Swimmers | | p Control | p Swimmers | p c–s After | 4–1 | 3–1 | $\eta^2$ Factor | $\eta^2$ Factor * Group |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before Season (1) | After Season (2) | Before Season (3) | After Season (4) | | | | | | | |
| EI at 0.30 Pa | 0.054 ± 0.014 | 0.048 ± 0.014 | 0.049 ± 0.014 | 0.043 ± 0.02 | **0.017** | **0.031** | 0.832 | 0.174 | 0.779 | 0.40 | 0.00 |
| EI at 0.58 Pa | 0.155 ± 0.017 | 0.151 ± 0.017 | 0.149 ± 0.016 | 0.143 ± 0.02 | 0.538 | 0.092 | 0.554 | 0.240 | 0.831 | 0.20 | 0.02 |
| EI at 1.13 Pa | 0.241 ± 0.014 | 0.242 ± 0.019 | 0.236 ± 0.016 | 0.234 ± 0.02 | 0.988 | 0.917 | 0.674 | 0.766 | 0.912 | 0.00 | 0.02 |
| EI at 2.19 Pa | 0.344 ± 0.015 | 0.345 ± 0.015 | 0.336 ± 0.032 | 0.337 ± 0.02 | 0.997 | 0.999 | 0.734 | 0.815 | 0.768 | 0.00 | 0.00 |
| EI at 4.24 Pa | 0.437 ± 0.011 | 0.439 ± 0.011 | 0.436 ± 0.014 | 0.433 ± 0.01 | 0.868 | 0.627 | 0.589 | 0.819 | 0.994 | 0.00 | 0.07 |
| EI at 8.23 Pa | 0.510 ± 0.012 | 0.512 ± 0.009 | 0.510 ± 0.011 | 0.508 ± 0.01 | 0.776 | 0.826 | 0.760 | 0.964 | 1.000 | 0.00 | 0.06 |
| EI at 15.95 Pa | 0.559 ± 0.013 | 0.563 ± 0.009 | 0.560 ± 0.009 | 0.557 ± 0.01 | 0.344 | 0.632 | 0.553 | 0.985 | 0.987 | 0.00 | 0.13 |
| EI at 30.94 Pa | 0.597 ± 0.012 | 0.602 ± 0.008 | 0.597 ± 0.008 | 0.595 ± 0.01 | 0.181 | 0.909 | 0.295 | 0.940 | 0.998 | 0.03 | 0.12 |
| EI at 60.00 Pa | 0.629 ± 0.009 | 0.637 ± 0.006 | 0.628 ± 0.007 | 0.628 ± 0.01 | **0.005** | 1.000 | **0.024** | 0.992 | 0.992 | 0.20 | 0.20 |
| AMP [au] | 34.96 ± 2.84 | 35.03 ± 2.71 | 33.34 ± 3.75 | 32.01 ± 4.10 | 1.000 | 0.243 | 0.114 | 0.115 | 0.592 | 0.06 | 0.06 |
| AI [%] | 60.25 ± 7.17 | 58.90 ± 7.68 | 61.21 ± 8.52 | 63.26 ± 7.96 | 0.972 | 0.465 | 0.599 | 0.729 | 0.987 | 0.02 | 0.06 |
| T1/2 [s] | 2.74 ± 0.85 | 2.93 ± 0.93 | 2.67 ± 1.06 | 2.43 ± 0.91 | 0.954 | 0.570 | 0.655 | 0.817 | 0.998 | 0.01 | 0.06 |
| BPV [mPas] | 1.37 ± 0.09 | 1.45 ± 0.05 | 1.42 ± 0.09 | 1.52 ± 0.10 | **0.010** | **0.001** | 0.112 | **<0.001** | 0.343 | 0.51 | 0.01 |
| FIB [g/L] | 3.46 ± 0.81 | 3.40 ± 0.66 | 3.38 ± 0.45 | 3.41 ± 0.50 | 0.990 | 0.999 | 1.000 | 0.994 | 0.981 | 0.00 | 0.00 |

WBC, white blood cell count; RBC, red blood cell count; HGB, hemoglobin; HCT, hematocrit; PLT, platelet count; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; RDW, red blood cell distribution width; MPV, mean platelet volume; PDW, platelet distribution width; EI, elongation index; AMP, amplitude and total extent of aggregation; AI, aggregation index; T1/2, aggregation half-time; BPV, blood plasma viscosity; FIB, fibrinogen, $\eta^2$ factor—partial eta squared winter swimming; $\eta^2$ factor * group—partial eta squared winter swimming * sex. Bold denotes significant differences ($p < 0.05$).

**Table 3.** Blood morphological and rheological parameters in male winter swimmers compared with controls, presented as mean and standard deviation, before and after the winter swimming season.

| Parameter | Controls | | Male Winter Swimmers | | p Control | p Swimmers | p c–s After | 4–1 | 3–1 | $\eta^2$ Factor | $\eta^2$ Factor * Group |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before Season (1) | After Season (2) | Before Season (3) | After Season (4) | | | | | | | |
| WBC $[10^3/\text{mm}^3]$ | **6.19 ± 1.27** | **5.69 ± 1.28** | **6.26 ± 1.87** | **4.79 ± 1.00** | **0.466** | **0.001** | 0.230 | **0.028** | 0.999 | 0.36 | 0.09 |
| RBC $[10^6/\text{mm}^3]$ | 4.94 ± 0.38 | 4.77 ± 0.38 | 5.04 ± 0.35 | 4.56 ± 0.35 | **0.014** | **<0.001** | 0.360 | **0.033** | 0.899 | 0.64 | 0.31 |
| HGB [g/dL] | 15.29 ± 0.84 | 15.06 ± 0.84 | 14.78 ± 0.79 | 14.80 ± 0.82 | 0.276 | 1.000 | 0.810 | 0.368 | 0.355 | 0.20 | 0.03 |
| HCT [%] | 44.88 ± 2.59 | 43.11 ± 3.10 | 44.90 ± 2.29 | 39.38 ± 3.11 | **0.023** | **<0.001** | **0.002** | **<0.001** | 1.000 | 0.84 | 0.44 |
| PLT $[10^3/\text{mm}^3]$ | 262.47 ± 53.36 | 191.33 ± 30.99 | 240.71 ± 50.36 | 168.07 ± 31.74 | **<0.001** | **<0.001** | 0.437 | **<0.001** | 0.533 | 0.81 | 0.14 |
| MCV $[\mu\text{m}^3]$ | 91.02 ± 3.60 | 90.47 ± 5.11 | 89.49 ± 3.86 | 86.53 ± 3.52 | 0.853 | **<0.001** | **0.028** | **0.011** | 0.737 | 0.30 | 0.01 |
| MCH [pg] | 31.03 ± 1.35 | 31.65 ± 1.52 | 29.49 ± 1.28 | 32.60 ± 2.23 | 0.166 | **<0.001** | 0.362 | 0.056 | 0.077 | 0.43 | 0.36 |
| MCHC [g/dL] | 34.09 ± 0.80 | 34.99 ± 1.29 | 32.86 ± 0.74 | 37.71 ± 2.18 | 0.175 | **<0.001** | **<0.001** | **<0.001** | 0.062 | 0.73 | 0.47 |
| RDW [%] | 12.86 ± 0.74 | 15.04 ± 1.94 | 12.55 ± 0.67 | 17.44 ± 2.34 | **0.002** | **<0.001** | **<0.001** | **<0.001** | 0.952 | 0.72 | 0.18 |

**Table 3.** *Cont.*

| Parameter | Controls | | Male Winter Swimmers | | p Control | p Swimmers | p c–s After | 4–1 | 3–1 | $\eta^2$ Factor | $\eta^2$ Factor * Group |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before Season (1) | After Season (2) | Before Season (3) | After Season (4) | | | | | | | |
| MPV [$\mu m^3$] | 10.51 ± 0.93 | 7.83 ± 0.55 | 9.85 ± 0.74 | 7.63 ± 0.41 | **<0.001** | **<0.001** | 0.865 | **<0.001** | 0.068 | 0.96 | 0.22 |
| PDW [%] | 12.72 ± 1.90 | 12.49 ± 1.50 | 11.14 ± 1.37 | 12.02 ± 1.19 | 0.903 | 0.051 | 0.879 | 0.666 | **0.039** | 0.43 | 0.11 |
| EI at 0.30 Pa | 0.058 ± 0.010 | 0.053 ± 0.009 | 0.055 ± 0.017 | 0.051 ± 0.009 | 0.118 | 0.118 | 0.933 | 0.310 | 0.891 | 0.40 | 0.00 |
| EI at 0.58 Pa | 0.156 ± 0.013 | 0.151 ± 0.012 | 0.151 ± 0.020 | 0.144 ± 0.014 | 0.307 | 0.064 | 0.560 | 0.141 | 0.833 | 0.20 | 0.02 |
| EI at 1.13 Pa | 0.242 ± 0.013 | 0.239 ± 0.012 | 0.237 ± 0.020 | 0.229 ± 0.014 | 0.733 | **0.047** | 0.285 | 0.105 | 0.828 | 0.00 | 0.02 |
| EI at 2.19 Pa | 0.346 ± 0.009 | 0.345 ± 0.011 | 0.344 ± 0.016 | 0.337 ± 0.011 | 0.979 | **0.011** | 0.232 | 0.170 | 0.947 | 0.00 | 0.00 |
| EI at 4.24 Pa | 0.438 ± 0.007 | 0.439 ± 0.008 | 0.438 ± 0.013 | 0.433 ± 0.008 | 0.785 | **0.012** | 0.246 | 0.457 | 1.000 | 0.00 | 0.07 |
| EI at 8.23 Pa | 0.512 ± 0.006 | 0.516 ± 0.006 | 0.512 ± 0.008 | 0.510 ± 0.005 | **0.047** | 0.527 | 0.124 | 0.804 | 0.997 | 0.00 | 0.06 |
| EI at 15.95 Pa | 0.563 ± 0.007 | 0.567 ± 0.006 | 0.561 ± 0.009 | 0.561 ± 0.007 | 0.226 | 0.994 | 0.106 | 0.852 | 0.932 | 0.00 | 0.13 |
| EI at 30.94 Pa | 0.600 ± 0.005 | 0.604 ± 0.005 | 0.600 ± 0.006 | 0.599 ± 0.006 | **0.001** | 0.429 | **0.016** | 0.792 | 1.000 | 0.03 | 0.12 |
| EI at 60.00 Pa | 0.630 ± 0.006 | 0.635 ± 0.005 | 0.628 ± 0.006 | 0.630 ± 0.005 | **<0.001** | 0.696 | **0.014** | 0.932 | 0.605 | 0.20 | 0.20 |
| AMP [au] | 37.96 ± 3.10 | 37.26 ± 2.04 | 36.31 ± 2.22 | 36.36 ± 2.74 | 0.714 | 0.996 | 0.664 | 0.257 | 0.331 | 0.06 | 0.06 |
| AI [%] | 62.63 ± 7.44 | 62.04 ± 5.62 | 59.50 ± 7.96 | 63.37 ± 6.17 | 0.982 | 0.056 | 0.867 | 0.947 | 0.627 | 0.02 | 0.06 |
| T1/2 [s] | 2.46 ± 0.91 | 2.49 ± 0.61 | 2.82 ± 1.10 | 2.32 ± 0.61 | 0.999 | 0.082 | 0.874 | 0.907 | 0.651 | 0.01 | 0.06 |
| BPV [mPas] | 1.44 ± 0.10 | 1.46 ± 0.07 | 1.44 ± 0.07 | 1.54 ± 0.08 | 0.982 | **0.007** | **0.029** | **0.012** | 0.995 | 0.51 | 0.01 |
| FIB [g/L] | 3.93 ± 1.23 | 3.54 ± 0.82 | 3.15 ± 0.49 | 3.35 ± 0.67 | 0.482 | 0.835 | 0.970 | 0.373 | 0.099 | 0.02 | 0.06 |

WBC, white blood cell count; RBC, red blood cell count; HGB, hemoglobin; HCT, hematocrit; PLT, platelet count; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; RDW, red blood cell distribution width; MPV, mean platelet volume; PDW, platelet distribution width; EI, elongation index; AMP, amplitude and total extent of aggregation; AI, aggregation index; T1/2, aggregation half-time; BPV, blood plasma viscosity; FIB, fibrinogen, $\eta^2$ factor—partial eta squared winter swimming; $\eta^2$ factor * group—partial eta squared winter swimming * sex. Bold denotes significant differences ($p < 0.05$).

## 4. Discussion

We found that swimming in cold water (4–5 °C) combined with sports pool swimming (28 °C) resulted in beneficial adaptive changes in the human cardiovascular system.

Statistically significant increases in MCH, MCHC, RDW, PDW, and BPV were observed in female and male winter swimmers after the winter swimming season, and increases in EI at a shear stress of 2.19 Pa were reported for males only. Statistically significant decreases in WBC, RBC, HCT, MCV, PLT, and MPV were determined in female and male winter swimmers after the winter swimming season; significant decreases in EI at a shear stress of 0.30 Pa were noted in females only, and significant decreases in EI at a shear stress of 1.13 Pa and EI at a shear stress of 4.24 Pa were established for males only. The present findings align with those of Ptaszek et al. [22] who reported rheological changes in individuals undergoing whole-body cryotherapy, emphasizing the impact of cold exposure on hemorheological properties. However, differences in protocols and study populations warrant further exploration. For instance, cryotherapy involves brief, controlled exposure to extremely low temperatures (−110 to −140 °C), contrasting with the longer-duration immersion in moderately cold water in this study. Both modalities influence blood parameters, but the mechanisms may differ. For example, the significant decrease in leukocyte count observed here suggests acclimatization, whereas cryotherapy often triggers transient leukocytosis. By comparing these modalities, we can better understand the unique and shared benefits of cold exposure practices.

Statistically significant increases in MCHC and RDW were observed in female and male winter swimmers after the winter swimming season compared with the control group after the season. Statistically significant decreases in EI at a shear stress of 60.00 Pa were reported in female winter swimmers after the winter swimming season compared with the control group after the season; statistically significant increases in EI at a shear stress of 60.00 Pa and BPV, as well as and decreases in HCT, MCV, and EI at a shear stress of 15.95 Pa, were determined in male winter swimmers only after the winter swimming season compared with the control group after the season.

When comparing the females and males in the winter swimming group after the season with the control group before the season, statistically significant increases were observed in RDW and BPV, and decreases were reported in RBC, HCT, PLT, and MPV. For males only, statistically significant increases in MCHC were determined after the winter swimming season compared with the control group before the season, and decreases were noted in WBC and MCV. When comparing the winter swimming group before the season with the control group before the season, statistically significant decreases were observed in PDW for females and males and in RDW for females only.

To sum up, in the present study, after a full season of winter swimming, both males and females exhibited a tendency towards lower erythrocyte, leukocyte, and platelet counts, as well as an increase in BPV (within normal limits). Slight individual differences were noted in the change in red blood cell deformability, with no change in erythrocyte aggregation or fibrinogen. The changes in plasma volume could be attributed to the shift in plasma water from the intra- to the extravascular compartments owing to sympathetic system activation and consequent reactive vasoconstriction [23]. According to Brenner et al. [24], the severe stress evoked by cold stimulates hemopoiesis in the bone marrow through leukocytosis; in our study, in turn, regular winter swimming and sports pool swimming resulted in lower leukocyte counts, which could be explained by the participants' acclimatization to the given conditions. On the other hand, the decrease in PLT counts observed in our study contrasts with the findings of Dugué and Leppänen [25], who noted increased PLT in inexperienced winter swimmers. This discrepancy likely reflects the effect of regular exposure and acclimatization, which may modulate platelet dynamics differently over time. Reduced PLT counts, while remaining within normal limits, could indicate a shift towards a less prothrombotic state, potentially lowering cardiovascular risk.

The changes reported in the groups investigated in the present study, although statistically significant, remained within the physiological limits and did not endanger the health or life of the subjects. The data obtained, especially with regard to blood morphology, provide evidence of changes occurring under the influence of winter swimming (4–5 °C) in combination with sports pool swimming (28 °C) and indicate normal body thermoregulation. Low temperatures exert anti-inflammatory, analgesic, and immunological effects and influence thermoregulatory responses. They protect the body from hypothermia via the stimulation of the sympathetic nervous system, contraction of peripheral blood vessels, and shivering and non-shivering thermogenesis, which promotes heat production. In contrast, at high temperatures, proper thermoregulation protects the body from overheating via heat dissipation. This research study demonstrates the subjects' good acclimatization to low and high temperatures. As a result of adaptive and functional changes, tolerance to extreme temperatures increases. Body stimulation through cold water swimming and swimming in a sports pool at 28 °C brings about beneficial adaptive changes in the cardiovascular system, as evidenced in the present study. Dugué and Leppänen [25] indicate that after exposure to sauna, winter swimming, and consecutive thermal stresses, the capacity of isolated mononuclear blood cells to produce IL-1 beta and IL-6 was significantly suppressed in inexperienced subjects but tended to increase in regular winter swimmers, pointing out that habitual winter swimming slightly stimulates the immune system, which leads to the speculation that winter swimmers are better prepared to react to an infection. Teległów et al. [26] also confirmed that regular winter swimming for 4 months positively influenced blood rheological characteristics in males aged 34–53 years, which is indicative of an efficient hemorheological system cooperating with the cardiovascular system. In the present study, the lack of changes in blood aggregation indicators and fibrinogen in females or males reflects the absence of factors that would impair blood flow. The combination of winter swimming and swimming in a sports pool proves to have a positive effect on blood circulation, and this translates into good health in both males and females.

### 4.1. Study Limitations

Although the study design was robust, certain limitations should be acknowledged. The inclusion of relatively young, healthy participants without significant comorbidities limits the generalizability of these findings to broader populations. Investigating older individuals or those with specific health conditions could provide valuable insights into the potential therapeutic applications of winter swimming. Additionally, the relatively small sample sizes of the male and female subgroups may limit statistical power, although careful randomization and prospective design mitigate this concern. Future studies could also integrate functional assessments, such as quality-of-life measures, to complement biochemical and rheological data.

### 4.2. Practical Applications

The results of this study underscore the safety and physiological benefits of winter swimming when combined with sports pool swimming, particularly in promoting cardiovascular health and systemic homeostasis. Regular exposure to cold water, coupled with warmer recovery phases, appears to enhance thermoregulatory efficiency and resilience. These findings suggest a promising role for winter swimming as a preventive health strategy. Expanding this research study to diverse populations and exploring tailored protocols could unlock its full potential in public health and clinical practice.

## 5. Conclusions

The obtained results lead to the following conclusions:

1. In the investigated participants of both sexes, winter swimming combined with swimming pool sessions resulted in changes in selected indicators of peripheral blood morphology. In both males and females, a tendency was observed towards lower erythrocyte, leukocyte, and platelet counts after the whole season of winter swimming and swimming pool sessions.
2. In the investigated participants of both sexes, winter swimming in combination with swimming pool baths resulted in increased blood plasma viscosity (BPV), although within normal limits, after the whole winter swimming season, reflecting the body’s adaptation to cold exposure and physical activity.
3. No changes in blood aggregation indicators or fibrinogen were reported, which implies a positive influence of winter swimming combined with swimming in a sports pool.
4. The remaining morphological indicators and the elongation index demonstrated only limited variation.

5. Winter swimming-induced blood morphological and rheological changes have potential benefits for overall cardiovascular and hematological health, highlighting its role as a health-promoting activity for thermoregulation and systemic resilience.

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**Institutional Review Board Statement:** This study was approved by the Ethics Committee of the Regional Medical Chamber in Krakow, Poland (approval No.: 182/KBL/OIL/2023), and followed the tenets of the Declaration of Helsinki.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in this study.

**Data Availability Statement:** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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