ORIGINAL ARTICLE

The effect of winter swimming on body's external temperature

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Authors Contribution: A- Study design; B- Data collection; C- Statistical analysis; D- Manuscript Preparation; E-Funds Collection

Abstract

Background and Study Aim: The main aim was to compare the changes in external body temperature of students who gave in an immersion of winter swimming.

Material and Methods: The study group consisted of 15 students, including 7 males and 8 females. The average age of the subjects was 22.4+1.12 years. The group was tested by measuring outer body temperature at 30 spots across their bodies by using a FLUXE 64 MAX pyrometer. Afterwards, subjects entered ice-cold water for 3 minutes. Immediately after leaving the water the second temperature measurements at the same 30 spots were conducted, and the third measurements were done 15 minutes after leaving the water. After 15 days of testing the comparison was made: temperature values from before and after the immersion.

Results: The students showed significantly higher average body temperature values before the testing (34.96°C ± 2.21 to 21.85 ± 3.68) and the lowest after the testing (29.86°C ± 4.91 to 6.26°C ± 1.04). The highest difference in average temperatures was obtained in the measurement of the left lower leg - front, the examination before and after (20.73°C), and the lowest in the measurement of the right hand - palm side, the examination after and 15 minutes after (0.19°C).

Conclusions: Winter swimming is becoming an increasingly popular sport activity. Conducted research shows the positive influence of winter swimming on human body and organism. The presented research should be further continued in order to learn more about the influence of cold on human body.

Keywords: winter swimming, thermoregulation, non-invasive temperature measurement, blood flow, body reaction to cold.

Introduction

The thermal balance of the body is one of the fundamental physiological mechanisms by which the human body can function properly. The process of thermoregulation itself is based on increasing the production of thermal energy in case of its excessive loss, or increasing the rate of its dissipation in case of increased heat accumulation. The main sources of heat energy in the body include: basic metabolic changes; increased muscular activity, including muscle tremor; active influence of thyroid hormones and, to a lesser extent, growth hormone and testosterone; increased metabolic activity due to adrenaline, noradrenaline and sympathetic nervous system; increased intracellular spontaneous activity and increased metabolic activity due to food digestion [1, 2]. However, the disposal of excess heat by the human body occurs through four thermophysical processes, i.e. radiation, conduction, convection and evaporation. Depending on the extent of stimulus impact on the human body and its physical characteristics, cooling of skin tissues causes more or less intense systemic reactions [1, 3, 4].

One form of physical activity that can affect the body's thermal balance is winter swimming [5, 6, 7], which involves taking baths in open areas of water during cold temperatures. In case of winter swimming, scientific studies have shown that non-shivering thermogenesis is the main mechanism of heat energy production, within the first hour of immersion in cold water [8, 9, 10]. As indicated by scientific studies, impulses from the hypothalamic thermoregulatory center activate the sympathetic part of the autonomic nervous system, and as a result, stimulate alpha-adrenergic receptors and cause a strong constriction of skin vessels, preventing heat loss. In addition, the cold stimulus induces excessive secretion of noradrenaline, adrenaline, and cortisol. Several studies have shown that noradrenaline concentrations can be increased by 180% to 530% of baseline values shortly after immersion in cold water. It is noradrenaline that is responsible for the stimulation of skeletal muscle for non-shivering thermogenesis processes [8, 10]. Cortisol for instance, modulates many physiological responses to low temperatures including increasing basal metabolic rate, preventing vasodilation, improving free fatty acid availability, and affecting sympathetic nervous system function. Therefore, the increase in cortisol levels observed during exercise in cold environments appears to be related to some changes in internal body temperature [8].

The review of available literature provides scientific evidence confirming the beneficial effect of winter swimming on the human body [7]. In studies evaluating the influence of winter swimming on blood parameters, the authors have proved that regular water swimming increases the level of immunoglobulin A (IgA), leukocytes, monocytes and interleukin-6, which consequently improves the functioning of the immune system [7, 8, 9]. In addition, beneficial effects of winter swimming on the cardiovascular system have been noted. It has been

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confirmed that winter swimming leads to a decrease in cardiac output (CO) and heart rate as well as an increase in skin vasoconstriction, which results in an improvement of the overall peristalsis of blood vessels [8]. It is also interesting how winter swimming affects oxidative stress indicators. In one of the studies we can find information that antioxidative system of persons who regularly take winter swimming baths is constantly prepared to protect the body against negative activity of reactive oxygen forms [8]. Studies conducted by many authors confirm the beneficial influence of winter swimming on the mood and mental health of people who regularly take winter swimming [1, 10]. Moreover, this form of activity improves memory and reduces fatigue [10]. People who regularly practice winter swimming also show increased vitality and improved self-esteem [7, 11].

Aim of the study: The aim of the study was to test how immersing in the ice-cold water affects the external temperature of the body.

Materials and Methods

Participants

The group participating in the study, consisted of 15 students (n=15), including 7 males and 8 females. The mean age of the subjects was 22.4+1.12 years. All participants had graduated from high school and were in the process of studying at universities. The students were volunteers, mostly first-time trying winter swimming. They were healthy both mentally and physically and had no contraindications to take part in the study, i.e., bathing in icy water, or to physical activity. Everyone who took part led an active lifestyle. Before conducting the experiment, the test subjects signed a consent to participate in the study and to process personal data only for the purpose of the study. Before participation, test subjects were thoroughly briefed about the experiment. Individuals participated voluntarily and free of charge. The test subjects were informed that there were no dangers arising from the study. Throughout the study, the test subjects were free to withdraw from the study at any time, at their request, without being required to give a reason. All successfully completed the test; no one dropped out during the test. None of the participants experienced side effects during the study, immediately after the study, or after an extended period of time. There was no deterioration of health, no ill health, no adverse symptoms. Individuals entering the water were dressed in bathing suits.

Research Design

The study was conducted over two days on January 10 and 19, 2019. The lake used in the study was free of factors that could affect the test results or the health of the test subjects. It was pre-screened by the research team to confirm the safety of the investigators and the test subjects. On the start day, everyone assembled near the lake at 9:00 a.m. On both dates, the air temperature reached below 0°C. There was no snow, rain, or hail. The study was divided into several stages. Participants were tested one at a time.

In order to reduce the total time spent on the study, the stages were performed in parallel for several individuals. After participants arrived at the winter swimming place, the research team checked the external temperature, in the assumed body regions, using specialized equipment, as described below. Subsequently, the test subjects gave in a 10-minute warm-up to warm up the body prior to the winter swimming.

In the next stage, the test subjects wearing swimsuits entered the water. The person stood in water reaching his/her sternum. This lasted for 3 minutes, after that the tested person came out of the water with a quick step, where he/she again had the temperature measured on all body parts. After 15 minutes of winter swimming, the test subjects were subjected to another external body temperature check.

Research method used

The FLUKE 64 MAX pyrometer was used to conduct the study of measuring the external body temperature, which allows precise and non-invasive, non-contact and safe testing [12]. It is a convenient device, small in size, battery-powered. It works well in low ambient temperatures and is accurate to +/- 1°C. An infrared pyrometer can penetrate the human body which helps to check the temperature precisely and at the same time, it is not harmful to the examinee and the tester. It has a short response time of <500ms. The test was performed by one person. The purpose was to check the height of the body temperature in exactly the same place in each person. The results were recorded on a test card, which was attached to the study. A diagram of the human body divided into parts, in the area of which the temperature was tested, was used for this purpose (fig. 1).

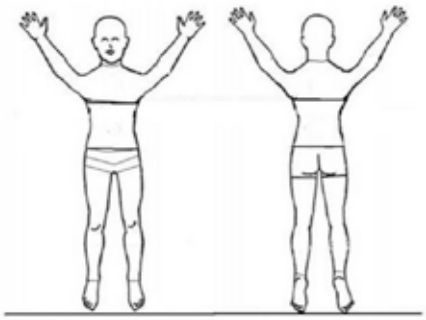

Figure 1. Supporting drawing used for quick temperature recording [13]

Statistical Analysis

The normality of continuous variabilities distribution was evaluated with the Shapiro–Wilk test, and their statistical characteristics were presented as arithmetic means and standard deviations (±SD). To analyze differences in results among several measurements (before, after, 15 min after intervention) the non-parametric ANOVA Kruskal-Wallis test was used. For the detailed comparative analysis of results among separate groups the post-hoc testing for multiple comparisons was used. All calculations were performed with the

package Statistica 10 (StatSoft), with the assumed level of statistical significance of $\alpha<0.05$.

Results

External body temperature

Table 1 shows the results of all parameters acquired during the experiment. The results were taken when body temperature was measured before the test, immediately after the test and 15 minutes after the test. The students showed significantly higher average body temperature values before the test and the lowest after the test. The highest difference in average temperatures was obtained in the measurement of the left lower leg – front (fig. 2)., in the pre- and post-test (20.73°C), and the lowest in the measurement of the right hand - palm side in the post-test and 15 minutes after (0.19°C) (fig. 3).

Post hoc analysis revealed significant differences between the examinations, which are presented in Table 1.

Table 1. Characteristics of all parameters measured during the study.

Parameter	Before [°C]	After [°C]	15 min after [°C]	p
	Mean ± SD	Mean ± SD	Mean ± SD	
Left foot - dorsal side	28.01 ± 2.96	12.53 ± 5.06	21.89 ± 2.57	0.0001
Right foot - dorsal side	28.44 ± 2.32	12.25 ± 5.13	22.24 ± 2.18	0.0003
Left foot - plantar side	24.32 ± 3.96	9.88 ± 3.71	19.11 ± 2.76	0. 0002
Right foot– plantar side	25.54 ± 3.66	11.1 ± 4.41	19.35 ± 2.66	0.0009
Lower leg left - front	27.34 ± 2.97	7.3 ± 1.25	23.91 ± 2.51	0.0001
Lower leg right - front	27.83 ± 2.62	7.1 ± 1.37	24.63 ± 1.84	0.0003
Lower leg right - back	24.5 ± 3.3	7.85 ± 2.22	21.98 ± 1.9	0.0005
Lower leg right - back	24.69 ± 3.41	7.8 ± 2.01	22.46 ± 1.83	0.0001
Thigh left - front	24.93 ± 3.89	6.26 ± 1.04	21.61 ± 2.99	0.0001
Thigh right - front	25.47 ± 4.09	6.27 ± 1.1	21.89 ± 3.39	0.0001
Thigh left - back	25.13 ± 3.51	7.65 ± 1.59	20.91 ± 3.5	0.0002
Thigh right - back	25.88 ± 3.27	7.66 ± 1.57	21.39 ± 3.41	0.0006
Abdomen	33.39 ± 1.87	10.3 ± 4.88	24.18 ± 4.28	0.0004
Chest	34.04 ± 2.36	25.98 ± 2.99	30.69 ± 2.33	0.0001
Back - lower part	34.3 ± 1.54	14.31 ± 4.94	28.89 ± 2.73	0.0001
Back - upper part	34.96 ± 2.21	28.84 ± 3.55	32.52 ± 2.52	0.0001
Left hand – palm site	25.41 ± 3.29	22.43 ± 4.2	23.14 ± 2.66	0.0474
Right hand – palm site	25.75 ± 2.84	23.07 ± 4.68	23.26 ± 2.2	0.0552
Left hand – dorsal site	22.04 ± 3.41	18.09 ± 3.55	19.2 ± 2.98	0.0049
Right hand – dorsal site	21.85 ± 3.68	18.27 ± 3.92	19.98 ± 2.65	0.0198
Forearm left – front	30.03 ± 2.78	22.51 ± 3.64	27.43 ± 2.26	0.0002
Forearm right – front	30.24 ± 2.48	22.33 ± 3.69	27. 09 ± 2.37	0.0001
Forearm left - back	30.77 ± 2.49	23.73 ± 3.21	28.43 ± 2.22	0.0001
Forearm right - back	31.49 ± 1.8	23.85 ± 3.31	28.58 ± 2.1	0.0002
Arm left - front	31.23 ± 2.68	24.06 ± 3.42	28.03 ± 2.63	0.0001
Arm right - front	31.38 ± 2.99	23.29 ± 3.13	28.15 ± 2.61	0.0003
Arm left - back	29.38 ± 2.79	21.11 ± 2.15	24.01 ± 3.03	0.0001
Arm right - back	29.12 ± 2.65	21.71 ± 2.55	24.31 ± 2.88	0.0003
Forehead	32.48 ± 2.86	29.86 ± 4.91	30.89 ± 1.99	0.1115
Head - the occipital.	31.19 ± 3.7	27.56 ± 6.78	30.36 ± 3.01	0.0909
Whole body	28.87 ± 3.89	16.96 ± 8.14	25.12 ± 3.87	0.0001
Whole body - women	28.28 ± 4.03	16.92 ± 7.87	25.0 ± 4.11	0.0003
Whole body - men	28.46 ± 3.46	16.74 ± 7.92	24.37 ± 3.77	0.0004

The lowest average temperatures were measured after examination in the left anterior part of the thigh (6.26°C ± 1.04), followed by the right anterior part of the thigh with temperatures only 0.01°C higher (6.27°C ± 1.1). The average temperatures between the same areas on the two sides of the body were similar. Differences in body temperatures between measurements showed less disproportion in average temperatures in the test before entering the water and 15 minutes after leaving (fig. 4). The greatest differences in average temperatures are in the comparison between before and after immersion in water.

Discussion

The analysis of external body temperature confirms the observation that individual areas of the body surface definitely differ both in terms of the degree of cooling under the influence of bathing and in the dynamics of temperature changes after the completion of this physical activity. According to the results of the study, the highest difference in average temperatures was obtained in measurements of the lower extremities, particularly the lower legs - both right and left. In the study before and after the intervention, the highest difference was observed in the measurement of the left lower leg and it was 20.73°C. Analysing the results obtained from the upper extremity temperature measurement, it can be observed that in this case the temperature differences were much smaller. The lowest difference, which was 0.19°C, was obtained in the measurement of the right hand - palm side in the examination after and 15 minutes after the intervention.

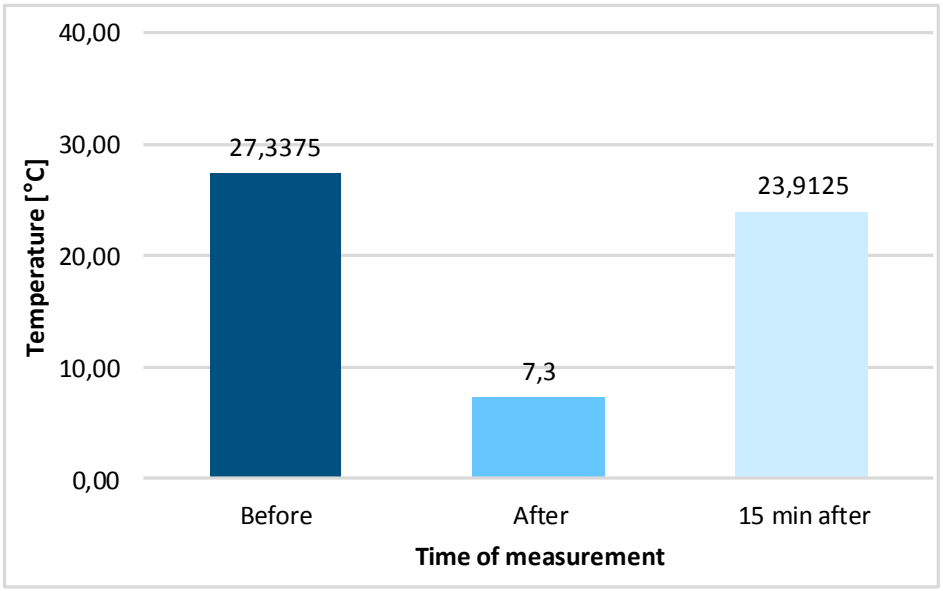

Figure 2. Average external temperature values measured on the anterior side of the left lower leg before, after and 15 minutes after winter swimming.

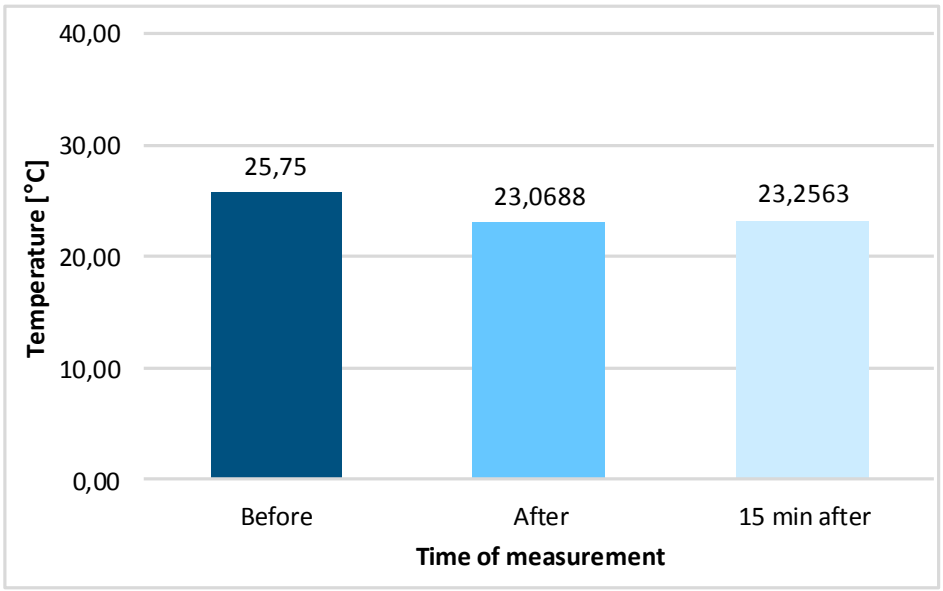

Figure 3. Average external temperature values measured on the palm of the right hand before, after and 15 minutes after winter swimming.

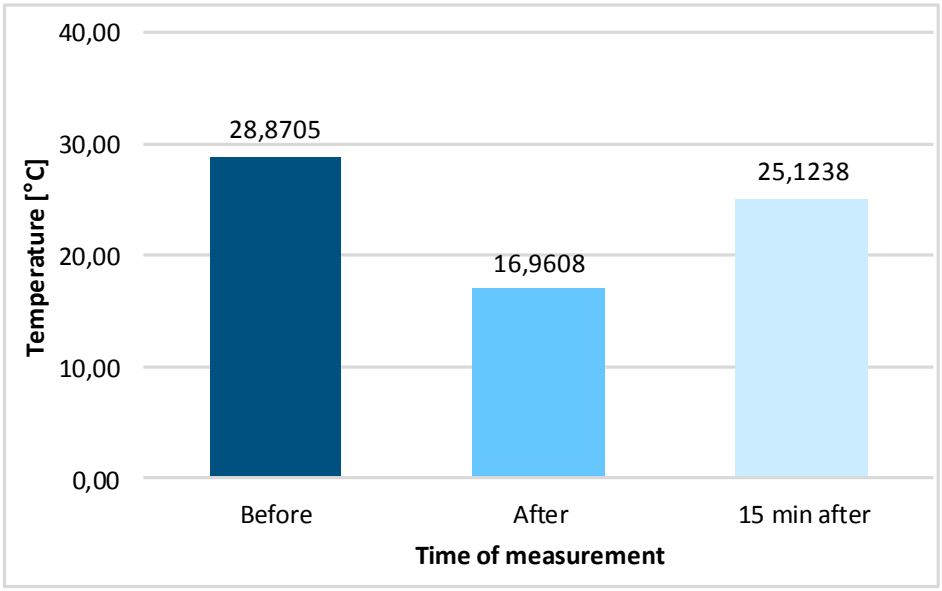

Figure 4. Average values of whole body external temperature measured before, after and 15 minutes after winter swimming.

Based on the reports of other authors, it can be considered that this is due to the construction and structure of the different body areas [14, 15, 16, 17]. Importantly, the students who underwent the study, showed significantly higher average body temperature values before the study (34.96°C ± 2.21 to 21.85°C ± 3.68) and the lowest after the study (29.86°C ± 4.91 to 6.26°C ± 1.04), but no differences due to gender were observed. The results obtained provide information that the average magnitude of body temperature of females before the study was 28.28°C ± 4.03, while after the study was 16.92°C ± 7.87. Similar results were observed for male individuals, they were 28.46°C ± 3.46 to 16.74°C ± 7.92 respectively.

In research evaluating the change in body temperature in individuals who regularly underwent winter swimming, it was observed that at an air temperature of -11°C and a water temperature of 2°C, the decrease in temperature of the lower extremities amounted to 90% and of the upper extremities to 60% [13]. However, the study conducted by Stephens and co-authors provides information that longer duration of immersion in water, affects the amount of decrease in body temperature. They investigated water immersion up to the sternum at 14°C for 5, 10 and 20 minutes. The muscle temperature (Tm) was 38.8°C before each test, and a change of 2.5°C at 5 minutes, 4°C at 10 minutes, and 6°C at 20 minutes was observed after the test. In contrast, core temperature (Tc) achieved smaller decreases under the same assumptions: 5minutes - 0.3°C, 10minutes - 0.6°C, and 20minutes - 1°C. In addition, the authors noted that the area of the immersed body also affects the overall body temperature [17].

Despite the popularity of winter swimming in recent times, there are not enough scientific studies evaluating the effects of this physical activity on external body temperature. However, there are many studies evaluating the effect of cold on the body's external temperature, which confirm our results. One of them is the work by Skrzek et al where a group of patients underwent ten sessions in a systemic cryochamber with a temperature of -130°C. The patients were in the cryochamber for 3 minutes. After analysis, the authors noted that the skin temperature changed significantly when exposed to the extremely low temperature. After whole-body cryotherapy, skin temperature decreased significantly, while other parameters changed only slightly. Additionally, the authors noted that the upper and lower extremities were more sensitive to cold application than other parts of the body. It was these body parts that showed the greatest differences before and after the application of systemic cryotherapy [18]. The above results correlate with the changes observed in our study. The students subjected to winter swimming also showed a significant decrease in body temperature after immersion in cold water. In another study evaluating the effect of a cryogenic factor on the external temperature of the human body, the authors exposed the study group to two sessions in a cryochamber. The first session was held at -140°C and the second at -120°C. The results they obtained indicate that the cryostimulation treatment reduced the body surface temperature from 5-20%, depending on the body segment. The greatest changes were noted in the lower extremities, while the least changes were noted in the trunk [19]. It is worth noting that the group of students subjected to winter swimming also obtained the greatest difference in temperature decline precisely in the measurements assessing the external temperature of the lower extremities. A 2017 study by Hohenauer and co-authors compared the effects of using cold water immersion (CWI) and partial body cryostimulation (PBC) on body temperature changes. The authors demonstrated that the application of CWI has a greater effect on the change in human body temperature than the application of PBC. The greatest decrease in temperature, after the application of cold water immersion, was observed in the

lower parts of the body, particularly the lower extremities. Interestingly, the least decrease in temperature was observed on the surface of the right hand - dorsal side, in both the CWI and PBC treated groups [20]. The above conclusion is consistent with the changes observed in our measurements. In the winter swimming group, the least decrease in temperature was observed on the surface of the right hand - in this case, it was the palmar side.

Conclusion

In recent years, winter swimming has become a very popular form of physical activity that can bring many health benefits to the human body. It is necessary to conduct further research that will thoroughly and profoundly examine the effects of taking water baths at low air temperatures on human functioning and body.

The results obtained, as well as the analysis of available scientific reports, provide the following information:

- the cold factor significantly affects the change of the body's external temperature;
- the highest average temperature difference was obtained in measurements of the lower extremities;
- the lowest average temperature difference was found in the upper limb measurements;
- no significant changes between male and female sex were observed in the measurement of average body temperature.

Conflict of interests

The authors have no conflict of interests to declare.

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