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DISCOVERY
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What is the impact of cold-water bathing and swimming on human health? Literature review

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ABSTRACT

Winter swimming has a long tradition that dates back to ancient times. In recent years, there has been an increase in interest in this activity in Poland and European countries. This review aims to present the positive and negative aspects of bathing and swimming in cold water. Regular winter swimming by adapted people has benefits. However, the risk of adverse consequences occurs when inexperienced and unadapted people try winter swimming. Researchers analyzed blood serum of swimmers who regularly took cold baths to search for changes in the concentrations of hematological indicators, which allowed them to demonstrate the beneficial effect of winter swimming on the process of hematopoiesis. The impact on increasing human immunity is probable, though it should be studied on a larger group. The studies did not show any significant effect on human plasma hormone levels. However, the impact of winter swimming on the circulatory system might have positive or negative depending on the degree of adaptation of the practitioner.

Keywords: Winter swimming, cold water bathing, hypothermia.

1. INTRODUCTION

Winter swimming and bathing are increasingly popular ways of spending free time. It involves swimming in a lake, river, sea, or swimming pool, mainly during winter, in colder and polar regions. As a result, the entire body gets exposed to the stressful effects of cold water, usually below five °C (Lubkowska et al., 2013; Knechtle et al., 2020). Initially popular mainly in Scandinavian countries, it now arouses interest among people worldwide (Knechtle et al., 2020). Since 2020, we have noticed increased interest in this form of spending time (Kaniewska and Ossowska, 2021). Many people consider this type of activity as a health-promoting behavior. Many scientific studies also suggest that

swimming in cold water brings health benefits Gibas-Dorna et al., (2016a), positively influencing, among others, glucose and insulin metabolism, the immune system Janský et al., (1996), the hematopoietic system Checinska-Maciejewska et al., (2019) and the cardiovascular system (Manolis et al., 2019).

2. MATERIAL AND METHODS

In order to conduct a thorough review of the selected topic, we have searched for numerous papers and ranked them based on their adequacy and the level of evidence they presented. Our research involved the freely accessible database PubMed which offers up-to-date knowledge resources from around the world. We have used the phrase: “"cold water swimming" OR "winter swimming" OR "cold-water bathing"”. The inclusion criteria consisted of abstracts and full-text formats, comprising all types of articles - books and documents, clinical trials, meta-analyses, randomized controlled trials, reviews, and systematic reviews written in English. We obtained 92 articles, of which 57 presented irrelevant titles, which left us with 35 objects (Figure 1). Finally, we divided the articles according to their topics (some articles were assigned to more than one topic): Introduction and historical outline (5 articles), impact on hematological and biochemical parameters of blood serum (9 articles), impact on the immunity and oxidative stress (7 articles), impact on hormonal balance (7 articles), effects on the circulatory system (9 articles).

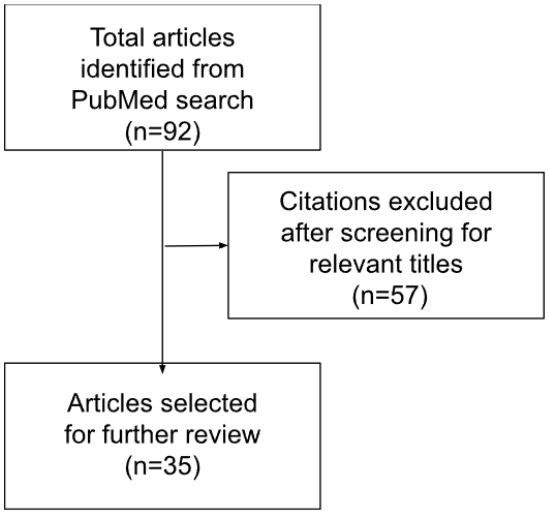

Figure 1 Article selection process for the review.

3. RESULTS AND DISCUSSION

Regular bathing in cold water may increase the erythropoietin concentration and stimulate the hematopoiesis process, which reflects in blood morphology parameters, mainly in women. Moreover, tests of other biochemical parameters in blood serum showed a slight anti-inflammatory effect and a beneficial effect on cardiovascular risk, as shown by authors such as (Checinska-Maciejewska et al., 2019; Teległów et al., 2015). Cold water swimming may affect the number of white and red blood cells, but its direct impact on the increase of immunity and oxidative stress is an unclear issue that should be subjected to further research. Tests of the levels of hormones: prolactin, cortisol, adrenaline, triiodothyronine, thyroxine, after 12 weeks of observations, showed no significant fluctuations.

The researchers Leppäluoto et al., (2008) only observed increased levels of plasma norepinephrine concentration after exposure to low temperatures. However, Kaniewska and Ossowska, (2021) showed a positive effect on insulin metabolism. Bathing in cold water may also be important for the cardiovascular system. Practicing winter swimming by experienced people may cause positive changes, such as lowering blood pressure or lowering the ratio of lipoprotein B to lipoprotein A. On the other hand, the level of hsTnI may increase, as well as the risk of developing arrhythmia which might be a life-threatening incident (Table 1).

Table 1 Main findings: The effects of cold-water swimming/bathing on health divided into topics.

No.	Subject	Main findings	Authors
1	Hematological and biochemical parameters of blood serum	● Erythropoietin concentration - may increase and stimulate the hematopoiesis process, which reflects in blood morphology parameters (mainly in women); ● Blood serum morphology - slight anti-inflammatory effect ($p<0.05$); ● Cardiovascular risk - a decrease in TG levels, homocysteine concentrations, and a lower Apo-B/ApoA-I	Checinska-Maciejewska et al., 2019 Teległów et al., 2015 Checinska-Maciejewska et al., 2017
2	Immunity and oxidative stress	● Infections - swimmers reported fewer and less severe upper respiratory tract infections ● neutrophils, lymphocytes, and monocytes - substantial increase in total number ● Monocytes, lymphocytes, TNF-α - small but significant increase in the concentrations ($p<0.05$)	Esperland et al., 2022 Lombardi et al., 2011 Janský et al., 1996
3	Hormonal balance	● Norepinephrine - increase in concentration ● TSH, PTH - increase in concentration levels ● T3, T4 - increase in concentration levels	Leppäluoto et al., 2008 Kovaničová et al., 2020
4	Circulatory system	● DBP - increased slightly during bathing but returned to normal four minutes after surfacing ● Risk of arrhythmia increases and it may even result in death in people with additional health burden	Zenner et al., 1980 Shattock and Tipton, 2012 Ishikawa et al., 1992 Wolf, 1964

Historical outline

The beginnings of the use of cold baths in medicine date back to around 2500 BC, when the inhabitants of ancient Egypt immersed their bodies in cold water for health purposes. Over time, for ancient peoples, bathing took on the form of an essential spiritual rite, as well as one of the elements of social life, which contributed to the construction of widely accessible public baths by the citizens of ancient

Rome (Wesołowski et al., 2013). In 377 BC, Hippocrates described the effects of cold and the indications and contraindications for its use, according to which he recommended the use of low temperatures to reduce swelling, bleeding, and pain (Tipton et al., 2017). Józef Strus, physician to King Sigismund Augustus, used methods of treating patients with low temperatures. In 1578, doctor Wojciech Oczko published bathing regulations, indications and contraindications for their use in the treatise "Cieplice" (Wesołowski et al., 2013).

In 1808, the first seaside swimming pool in Poland was organized in Brzeźno and was open in the winter season. Nowadays cold baths have become more and more popular every year, which resulted in the creation of groups bringing together enthusiasts of this form of activity practiced from autumn to spring. The oldest of them - the Gdańsk Walrus Club - was established in 1975, and since then, over 100 clubs have been established throughout the country (Kaniewska and Ossowska, 2021). The Polish name; morsowanie; as a term for short-term, cold baths comes from walruses, animals inhabiting the icy waters of the Arctic. In Russia, as in Poland, winter bathing enthusiasts are called; walruses; in Finland; seals; and; polar bears; in the United States (Malinowski, 2020). The rapid increase in the popularity of winter swimming in Poland in recent years contributed to breaking the Guinness record for most significant number of people taking part in winter swimming at the same time - 1,799 participants during the International Walrus Rally in Mielno in 2015 (Wesołowski et al., 2013).

Impact on hematological and biochemical parameters of blood serum

Cold-water swimming has a significant impact on the levels of selected hematological parameters. The authors of one article noted that seven months of regular cold-water swimming during the winter season results in increased serum EPO concentrations Checinska-Maciejewska et al., (2019) due to adaptive changes in response to transient hypoxia in the body induced by reduced blood flow through the skin and kidneys, which is maintained a few minutes after immersion (Buemi et al., 2010). Women are more susceptible to changes in serum EPO concentration Checinska-Maciejewska et al., (2019) since the female body cools down more quickly (Gleyzer et al., 2005). The previously described increase in EPO concentration due to cold stimulation leads to the stimulation of the hematopoiesis process. In 17 males who regularly practiced cold-water swimming, blood counts showed significantly ($p<0.05$) increased concentrations of several blood parameters: Hematocrit (Ht), erythrocytes (RBC), MCHC, MCH and transferrin (Teległów et al., 2015).

The same study showed statistically significant decrease of total protein, albumin and beta-1 globulin levels. These changes were determined at the end of one winter swimming season and in the beginning of another, suggesting that the lack of cold exposure during the break could be the cause. Statistically significant changes in erythropoietin concentrations were more evident in female organisms of another study (Checinska-Maciejewska et al., 2019). The described changes are also intensified by reduced plasma volume resulting from increased diuresis Stocks et al., (2004) and fluid shift due to increased sympathetic activity of the nervous system in the body response to cold (Lubkowska et al., 2013). Subsequent authors noticed that regular exposure of the body to low temperatures in winter swimmers also affects the immune system Missau et al., (2018) with a decrease in WBC values and the levels of IgG, IgA, and IgM immunoglobulins (Lubkowska et al., 2013).

A case study by authors from Krakow showed that winter swimming might have an impact on laboratory results in the kidney and liver profile, where after one 53-year-old swimmer left the water, a slight increase in AST, LDH, and slight fluctuations in the level of electrolytes in the blood serum were observed - a decrease in the concentration of sodium cations and chloride anions and reduced urea concentration, suggesting that winter swimming may indicate the presence of other health problems of the swimmer (Ptaszek et al., 2019). Cold baths may also have a beneficial effect on the cardiovascular risk by causing a decrease in TG levels, homocysteine concentrations, and a lower Apo-B/ApoA-I ratio during the swimming season. The authors note, however, that the beneficial effect of cold bathing on the cardiovascular risk factors might be gender-dependent; further research is therefore needed to draw accurate conclusions. (Checinska-Maciejewska et al., 2017)

Impact on the immunity and oxidative stress

If swimming in cold water has a positive effect on the functioning of the immune system, there should be noticeable changes in the levels of immune markers, and so susceptibility to infections should be lowered during the swimming period. People bathing in cold waters reported fewer and less severe upper respiratory tract infections (URTI) than pool swimmers (Esperland et al., 2022). This effect has not been precisely measured yet (Collier et al., 2021). One study Lombardi et al., (2011) on a group of fifteen who attempted to swim 150 m in water at a temperature of 6 degrees Celsius may indicate a potential cause of such a phenomenon - the number of red

blood cells, white blood cells, and platelets increased significantly compared to the state before swimming. There was also a substantial increase in the total number of neutrophils, lymphocytes, and monocytes.

Another study of ten people tried to measure the effect of winter swimming (three times a week for six weeks) on some components of the immune system. It showed a small but significant increase in the proportion of monocytes and lymphocytes and increased TNF-α concentrations ($p<0.05$). Researchers observed an increase in plasma concentrations of acute-phase proteins, such as haptoglobin and hemopexin. After six weeks of repeated immersions there was an increase in the concentration of IL-6 in plasma and the total number of T lymphocytes (CD3), T helper lymphocytes (CD4), suppressor T lymphocytes (CD8), activated T and B lymphocytes (HLA-DR) and a decrease in the concentration of alpha 1-antitrypsin in blood plasma. However, the researchers pointed out that the clinical significance of these observations remains to be clarified (Janský et al., 1996).

Several studies have also tried to detect the effect of winter swimming on oxidative stress mechanisms (Lubkowska et al., 2013; Siems et al., 1999; Lubkowska et al., 2019). Studies on rats immersed daily in water at a temperature of 5 degrees Celsius for several weeks have shown that females are better able to adapt to cold temperatures than males, as demonstrated by an increase in the activity of erythrocyte superoxide dismutase (SOD) and the concentration of glutathione (GSH) to restore the body pro-oxidant balance (Lubkowska et al., 2019). The study of 36 venous blood samples from people exposed to cold water baths compared to 40 people who had never practiced winter swimming suggests similar effects in humans (Siems et al., 1999).

Impact on hormonal balance

The reaction of the hormonal axes to bathing at low temperatures appears to be interesting (Briganti et al., 2023). One study examined the effect of a long-term exposure to low temperatures on the concentration levels of adrenocorticotropic hormone (ACTH), cortisol, adrenaline, and norepinephrine Leppäluoto et al., (2008) in the blood plasma. The results showed that exposure to low temperatures did not suddenly disturb the functioning of the pituitary-hypothalamic axis, only ACTH levels were slightly decreased, which may have resulted from the body habituation. Plasma adrenaline levels also remained unchanged relative to the control group. However, researchers found an increase in norepinephrine concentration each time after exposure to low temperatures. In another study Smolander et al., (2009), the researchers decided to check how cool baths affect the concentration of prolactin, thyroid hormones, thyroid-stimulating hormones, and growth hormone (GH) in six healthy women.

Researchers observed only slight fluctuations in thyroid-stimulating hormone levels during the 12-week study, but they did not exceed average values for a healthy population. No changes in plasma concentrations of other tested hormones occured. On this basis, the researchers concluded that regular winter swimming does not cause any changes in the levels of the tested hormones in the blood of healthy women. In turn, in another study on a group of 15 middle-aged people staying in cold water for 15 minutes regularly for six months, an increase in the level of parathyroid hormone (PTH), thyrotropin (thyroid-stimulating hormone - TSH) and a reduction of triiodothyronine (T3) and thyroxine (T4). The increase in PTH concentration also correlated with a decrease in systemic calcium concentration and increased phosphorus levels (Kovaničová et al., 2020). Cold water swimming may have a positive effect on insulin metabolism. The effect seems to be sex-specific (Gibas- Dorna et al., 2016b).

For females and swimmers with lower body fat percentage, there was an increased insulin sensitivity as well as a reduction in insulin secretion in a six-month field study (Kaniewska and Ossowska, 2021). There is a study of thermogenic brown adipose tissue (BAT) Søberg et al., (2021) in experienced winter-swimming men performing brief dips in cold water with hot sauna sessions 2-3 times per week. The data suggests a worse thermal comfort state in the winter swimmers compared with controls. In response to cold, there were observed more significant increases in cold-induced thermogenesis and supraclavicular skin temperature in the winter swimmers suggesting both heat and cold acclimation level in winter swimmers. It showcased winter swimming as a potential strategy for increasing energy expenditure.

Effects on the circulatory system

One of the leading indicators of the condition of the cardiovascular system is blood pressure (BP). When it is too high, it is one of the most important factors increasing the risk of developing cardiovascular diseases. For these reasons, BP is a frequent target for research on the impact of winter swimming on the human body. One study conducted on a group of long-distance swimmers showed a significant decrease in diastolic blood pressure (DBP) after a few days of practicing this activity (Huttunen et al., 2000). Another study

on seasonal winter swimmers showed that DBP increased slightly during bathing but returned to normal four minutes after surfacing (Zenner et al., 1980). The ratio of lipoprotein B to lipoprotein A is reflected in the level of LDL and HDL.

However, in a comparative study on ten adapted winter swimmers and sixteen unadapted swimmers, although a reduced ratio of lipoprotein B to lipoprotein A was observed in the first of these groups, no statistically significant changes were noted in the values of other lipoprotein parameters (Kralova et al., 2015). Another critical parameter is the level of troponin, which was significantly increased in swimmers covering distances from 500 to 1000 meters in winter competitions. The peak value of high-sensitivity troponins (hsTnI) occurred within 2 hours after the end of exercise. The researchers also measured concentration of the N-terminal fragment of brain natriuretic peptide type B (NT-proBNP) as a marker of heart failure.

However, no statistically significant changes or connections between hsTnI and NT-proBNP levels were demonstrated (Broz et al., 2017). There have also been studies examining the impact of cold baths on the occurrence of arrhythmia. At the moment of immersion, an autonomous conflict develops. Both the sympathetic and parasympathetic nervous systems are then activated. This results in the simultaneous induction of tachycardia or bradycardia. Therefore, the risk of arrhythmia increases and it may even result in death in people with additional health burden (Shattock and Tipton, 2012; Ishikawa et al., 1992; Wolf, 1964).

4. CONCLUSIONS

After summarizing the collected literature, we conclude that winter swimming may have many health benefits for various aspects of human health, such as: immunity, hormonal balance and cardiovascular system. The greatest benefits are likely to be achieved after proper acclimatization to the temperature under the supervision of experienced trainers. Further research is necessary to assess the impact of this activity on the human body as it is a growing trend and a new discipline that opens possibilities for diversified range of analysis.

Author's Contribution

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Supervision: Jakub Langa
All authors have read and agreed with the published version of the manuscript.

Informed consent

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Conflict of interest

The authors declare that there is no conflict of interests.

Ethical approval

Not applicable.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

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