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## **Health effects of cold water immersion and swimming and its influence on the human body**

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**Abstract:****Introduction**

Immersing and swimming in cold water is an increasingly popular sport that has recently become a fashionable form of recreation in the winter months. People who regularly swim in cold water mention the many benefits associated with it.

**Aim of the study**

This review aims to present the current state of knowledge about immersion and swimming in cold water and to answer questions about the impact of this phenomenon on the human body and its health benefits.

## **Materials and methods**

The PubMed database was used in this study. A literature review was conducted using the keywords “ice swimming,” “winter swimming,” “cold water swimming,” and “cold water immersion.”

## **Results**

Much research has been done on the effects of cold water swimming, both positive and negative. Ice swimming affects many systems of our body, including the circulatory system, the immune system, and the endocrine system, and also affects metabolic and mental changes in our body, as shown in the work below.

## **Summary**

A single immersion in cold water causes a stress reaction in the human body, while regular swimming in cold water causes the body to develop many positive physiological changes. Despite the benefits, it is still important to remember the risks involved, and more research should be done to minimize these dangers.

**Key words:** ice swimming; winter swimming; cold water swimming; cold water immersion

## **Introduction**

The term "ice swimming" means immersion and swimming in cold water outdoors (in bodies of water such as lakes, rivers, seas, and pools), mainly during winter and in polar regions. This endurance sport originates from traditions in countries such as Finland, Norway, Denmark, Sweden and Russia. Over recent years, this activity has become very popular among all age groups [1]. Research suggests that ice swimming has many health effects, including lowering blood pressure, lowering cholesterol levels, and reducing the incidence of

upper respiratory tract infections [1, 2, 3]. There is no strict definition of "cold water" and "icy water", but it is assumed it is water with a temperature below 15 °C and below 5 °C respectively [4]. Icy water swimming has also become a year-round discipline in recent years due to numerous international competitions [1]. However, it is important to be aware of the dangers of swimming in cold water and the associated possibility of hypothermia. Prolonged exposure to cold water can cause the body temperature to drop below 32 °C, increasing the risk of spontaneous ventricular fibrillation and death [5]. Therefore, the question remains whether this action brings more benefits or may bring more harmful effects.

### **Influence on the cardiovascular system**

Individuals with known cardiovascular disease or current but undiagnosed cardiovascular disease may be more susceptible to the adverse effects of cold water exposure, with provocation or exacerbation of arrhythmias and cardiovascular events that may pose significant risks to health and life [6]. During the winter months, more hospitalizations and deaths from cardiovascular causes and strokes were reported, possibly related to the physiological effects of cold on the body [7]. The main changes resulting from the activation of the sympathetic nervous system occurring during exposure to low temperatures are vasoconstriction and activation of thermogenesis [8]. Other effects in the human body include an increase in blood pressure, heart rate and cardiac output, as well as a decrease in cerebral blood perfusion, an increase in plasma fibrinogen levels and changes in parameters of carbohydrate and lipid metabolism [3, 9]. The mere exposure to cold air in anticipation before entering the water causes an increase in blood pressure, but Zenner et al. noted that subsequent immersion and swimming in cold water does not further increase blood pressure [2]. Muza et al. subjected a group of healthy men to a low-temperature acclimatization program for five weeks. They observed adaptation of the subjects to the low temperature - blood pressure values after immersion in cold water were within normal limits, compared to the increased values measured at the first immersion [10]. Hirvonen et al. observed in a group of regular "ice-swimming" subjects studied from autumn to spring that mean arterial pressure decreased from  $134 \pm 12$  mm Hg to  $128 \pm 12$  mm Hg ( $P < 0.05$ ) compared to the control group, where no significant reduction was observed [11]. If repeated immersion in cold water causes an increase in blood pressure, it may be related to several heart diseases, such as ventricular hypertrophy [12].

## **Metabolic changes**

Siems et al. observed that brief but intense whole-body exposure to cold during ice swimming induces oxidative stress, and higher concentrations of antioxidants such as superoxide dismutase and catalase are observed in those who participate in this sport [13]. The same researcher, in his other work, analyzed changes in the main cytotoxic aldehyde product of lipid peroxidation, 4-hydroxynonenal (HNE), in the levels of glutathione (GSH), ascorbic acid and uric acid as water-soluble antioxidants in people who swim in cold water regularly. Parameters measurements were performed before and one hour after immersion in cold water and for HNE and ascorbic acid immediately after leaving cold water. GSH, ascorbic acid and uric acid decreased after whole-body exposure to cold. HNE (one of the main products of lipid peroxidation and an indicator of oxidative tissue damage and oxygen radical production) increased immediately after leaving the cold water. However, within 1 hour, its level returned to its initial value. This indicates very high dynamics of change in this parameter [14]. Also, the study by Kralova Lesna et al. showed that people adapted to swimming in cold water have a higher ability to cope with oxidative stress. Furthermore, a significant reduction in cardiovascular risk factors, namely apolipoprotein B/apolipoprotein A1 (ApoB/ApoA1) ratio, plasma homocysteine levels and glutathione peroxidase 1 (GPX1) activity, was observed in the cold-adapted group. An increase in triiodothyronine (T3), paraoxonase (PON)-1 activity and zinc levels was also observed compared to the control group. [9].

## **Influence on the endocrine system**

Cold-induced activation of thermogenesis modulates energy metabolism, but the role of humoral mediators is not fully understood[15]. Cold water swimming appears to have a positive effect on insulin metabolism, although, this effect appears to be gender dependent [16,17]. A study by Gibas-Dorna et al. examined the effect of swimming in cold water at least twice a week for six months on body composition and insulin sensitivity. Compared to the control group, the study group was characterized by a higher percentage of body fat. Men and women with a lower percentage of body fat showed increased insulin sensitivity and decreased insulin secretion and resistance. In summary, ice swimming may have a beneficial effect on insulin sensitivity in people with lower BMIs [16]. Another study showed that insulin sensitivity increased significantly, and insulin and leptin levels decreased ( $p = 0.006$ ,  $p = 0.032$ ,  $p = 0.042$ , respectively). The above findings suggest that insulin and leptin are involved in adaptive metabolic mechanisms triggered by repetitive exposure to cold water

[17]. In their study, Hermanussen et al. examined changes in glucose and insulin levels immediately after a single ice swimming and after 2.5 months of regular cold water swimming. Blood samples were collected before and 30 and 60 minutes after the ice swimming, both on the first and last day of swimming. There was an initial increase in serum glucose after cold water immersion (+ 12 mg/dl, ( $p < 0.01$ )), but this difference disappeared after 2.5 months. However, the long-term effect of this type of training showed a decrease in serum insulin levels by almost 50% [18]. Ice-swimming also affects hormones, such as Adrenocorticotrophic hormone (ACTH) and catecholamines [1]. A single immersion in water causes an increase in plasma catecholamines, but adaptation through regular ice swimming leads to a decrease in catecholamine levels and an attenuation of the physiological response of the hypothalamic-pituitary-adrenal system to cold exposure [19]. Similar results were in another study, except that a decrease in ACTH and cortisol was observed, with a 2-3-fold increase in norepinephrine levels after three months of regular exposure to cold. It has been noted that the increase in norepinephrine may play a role in pain management, improving cold tolerance through shiver-free thermogenesis and insulating peripheral vasoconstriction [20]. Meanwhile, Gundle et al. examined the effects of ice-swimming on pregnant women. They found that regular exposure to low temperatures can lead to a suppression of the stress response, namely by reducing circulating levels of CRH in the mother. Chronic maternal stress is associated with complications such as lower birth weight of the baby and preterm delivery, so reducing stress in pregnant women may affect better outcomes later on [21]. Although the hormonal changes induced by ice swimming in terms of pain relief appear to be largely positive, there is little data on the effects on other endocrine systems in the body. No significant differences were found in testosterone and dehydroepiandrosterone sulfate (DHEA-S) levels in males [22]. Also, measurements of growth hormone, prolactin, follicle-stimulating hormone (FSH) and luteinizing hormone (LH) levels in the serum of healthy women indicate an unchanged hormonal balance after regular cold water immersion [23]. However, in a study by Hermanussen et al., regular ice-swimming for 12 weeks led to a twofold increase in basal prolactin secretion [18], while Smolander et al. observed a decrease in prolactin secretion during the same observation period [23]. A single exposure to cold during ice-swimming causes an increase in serum TSH levels [18, 24]. Kovanicová et al. analyzed the effects of regular exposure to cold water on parathyroid and thyroid hormones. The results suggest that the parathormone (PTH) regulation and thyroid hormones during cold exposure in humans vary depending on the acclimatization to the cold and the intensity of the cold stimulus. After 15 minutes of ice-water swimming, there was an increase in

parathormone (PTH) and thyrotropic hormone (TSH) levels and a decrease in free T3 and T4. The increase in PTH induced by ice water swimming correlated negatively with systemic calcium and positively with phosphorus [15].

### **Influence on the immune system**

There is growing evidence that winter swimmers are more resilient to certain diseases and infections, experiencing them less frequently and more mildly. The incidence of infectious upper respiratory diseases is 40% lower in winter swimmers compared to a control group [14].

One study showed no change in levels of pro-inflammatory cytokines such as IL-1-  $\beta$ , IL-6 or TNF- $\alpha$  during a 12-week follow-up [20].

### **Influence on mental health**

In addition to its impact on somatic aspects of health, ice swimming also affects a person's mental health [1]. Regular exposure to cold has been shown to reduce pain in conditions such as fibromyalgia and rheumatoid arthritis (RA). Cryotherapy, during which patients are exposed to cold, dry air (-110 °C), has found application in the symptomatic treatment of rheumatic diseases. Swimming in low-temperature water causes a stress response in the body, activating the sympathetic nervous system and increasing the secretion of cortisol and catecholamines, especially norepinephrine. Regular exposure to cold may contribute to a change in pain threshold [19]. Huttunen et al. studied the effects of regular cold-water swimming on overall well-being. The group of people who regularly ice-swim four times a week for four months felt less tension and fatigue than the control group ( $p=0.034$  and  $p=0.01$ , respectively). In addition, according to them, they had better moods and memory and felt more energetic [25]. Similar results have been discovered in other studies [26-28].

Van Tulleken et al. described the case of a 24-year-old woman with symptoms of severe depression and anxiety. The patient had been under treatment since she was 17 years old, and her symptoms did not resolve under conventional therapy, including fluoxetine and citalopram. After the birth of her daughter, the woman wanted to reduce her medication doses. To this end, a novel treatment method was developed, consisting of a weekly program involving cold water swimming. This approach resulted in an immediate improvement in mood after each swim and a sustained and gradual reduction in depressive symptoms. The intervention eventually led to a reduction in the use of medication and then to its discontinuation. After a year of cold-water swimming therapy, the patient was not taking

antidepressants [29]. It is believed that the density of cold receptors on the skin is 3-10 times greater than that of heat receptors, so their simultaneous stimulation can provide a stimulus to the brain comparable to electroconvulsive therapy and result in a positive therapeutic effect. Due to the increase in catecholamines, cold water swimming may be a treatment for depression, as it activates the sympathetic nervous system and increases norepinephrine, serotonin, dopamine and  $\beta$ -endorphin [26, 30, 11].

Whole-body exposure to cold water has been shown to increase blood levels of norepinephrine by up to 4 times [31], as has  $\beta$ -endorphin, which is the neurotransmitter responsible for our well-being and pain suppression by acting on opioid receptors. Since the deficit of these neurotransmitters is a critical point in the development of mental disorders such as depression, anxiety and emotional disorders, ice swimming can become one of the elements of therapy. According to Schevchuk et al., cold baths in the evening can cause interference with sleep physiology and result in insomnia [30].

## **Risks**

While this review focuses on the possible health benefits of ice swimming, we need to mention the possibility of harmful health effects. The health risks associated with ice swimming are complex and include many factors, such as age, general health, body size/composition, experience, water temperature and immersion time. The most common risks are related to cardiorespiratory problems associated primarily with entering cold water [32]. The immediate reaction to immersion in cold water, or cold shock reaction, may be fatal and is responsible for most deaths caused by immersion and subsequent drownings. Cutaneous cold receptors initiate a sympathetic nervous system response, causing rapid inspiration and hyperventilation. During this response, a small amount of water may be aspirated and result in drowning. Another suggested mechanism that may lead to death, even in young and healthy individuals, is arrhythmia initiated by immersion in cold water, resulting from simultaneous stimulation of the sympathetic nervous system by cold receptors in the skin and the parasympathetic nervous system - stimulation of vagus nerve endings in the nasopharyngeal region [4,33].

However, for the risk of arrhythmias to occur, predisposing elements are necessary, such as QT interval syndrome, underlying disease or cardiac hypertrophy [12]. There is a case report of a 12-year-old patient who was diagnosed with congenital long QT syndrome and developed an irregular heart rhythm after a cold water dive. This situation led to further QT



interval prolongation, which resulted in pulseless ventricular tachycardia of more than 300 beats per minute [34]. Another risk associated with irresponsible ice swimming is hypothermia. One study observed changes in the body temperature of two athletes preparing for a swimming competition (2.2 km at a water temperature of 4 °C. During the study, the temperature of one of the swimmers dropped from 37 °C to 32 °C within 20 minutes [5]. However, people with more body fat can stay in cold water longer than those with lower body fat. In a case report by Knechtle et al., an experienced overweight swimmer with a BMI > 35 kg/m<sup>2</sup> and ~45% body fat never succumbed to hypothermia, even after several stays in icy water and the lowest temperature observed in him after 100 minutes in the water was 34.5-35.0 °C [35]. There are no precise studies on how long a person can stay in cold water without succumbing to hypothermia, as this seems to be a very individual matter.

## **Summary**

This review shows that ice swimming has many benefits for the human body. Although a single exposure to cold water is a kind of stress response for the body, the most important physiological changes occur under the influence of regular swimming in cold water. The body's adaptation to low temperatures can have positive health effects and become a form of therapy in some areas, such as pain management and psychiatric disorders. Ice swimming may also help prevent cardiovascular disease in healthy people. However, due to the potential risks associated with ice swimming, further research should be conducted to minimize these risks and maximize the number of potential people who may benefit from this activity.

## **Author contributions**

Conceptualization: LJ; methodology: LJ, L<sup>3</sup>; software: LŁ; check: LŁ, LJ; formal analysis: KI; investigation: KI, KM; resources: KI, MI; data storage: LŁ, LJ, KI, MI; writing - rough preparation: LŁ, LJ, KM, KI, MM; writing - review and editing: KI, LŁ; visualization: LJ, MM; supervision: LJ, MM; project administration: LJ, MM ; All authors have read and agreed with the published version of the manuscript.

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The authors report no conflicts of interest.

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