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PHYSIOLOGICAL AND HEALTH EFFECTS OF WINTER SWIMMING: A COMPREHENSIVE MEDICAL REVIEW

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ABSTRACT

Winter swimming, defined as immersion in cold water, is gaining popularity as a form of physical activity and a natural health-enhancing intervention. This article provides a comprehensive medical review of the physiological and health effects associated with cold water exposure. Acute bodily responses to cold immersion are discussed, including activation of thermoregulatory mechanisms, cardiovascular, respiratory, and neuromuscular changes, as well as the risks of hypothermia and cold shock. Chronic adaptations observed in regular winter swimmers are also presented, encompassing hormonal, metabolic, and immunological modifications that enhance cold tolerance and support homeostasis. The health benefits of winter swimming are analyzed, highlighting improvements in cardiovascular performance, immune system modulation, mood enhancement, and metabolic regulation. Concurrently, potential risks are emphasized, particularly for individuals with chronic illnesses, children, and the elderly. The article concludes with a comparative analysis of winter swimming and other cold therapies, noting differences in exposure intensity and therapeutic efficacy. This review underscores the need for further research to standardize protocols and better elucidate the long-term effects of winter swimming.

KEYWORDS

Cold Water Immersion, Winter Swimming, Thermoregulation, Anti-Inflammatory Effects, Cardiovascular Health, Cold Therapy, Cryotherapy, Ice Baths, Cold Showers

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1. Introduction

Cold water immersion represents a complex physiological challenge to the human body, activating intricate thermoregulatory mechanisms aimed at maintaining thermal homeostasis. This article provides a comprehensive review of the acute physiological responses to cold water exposure, including cardiovascular, respiratory, and neuromuscular changes. Chronic adaptations developed by regular winter swimmers are also highlighted, including hormonal, metabolic, and immunological modulations that enhance the organism's tolerance to thermal stress. While potential health benefits such as improved cardiovascular and respiratory performance and strengthened immune function are acknowledged, the associated risks, especially for vulnerable populations including the elderly and children, who exhibit increased vulnerability to adverse effects of cold exposure, are emphasized. Furthermore, the article situates winter swimming within the broader context of cold therapies, comparing its intensity and health outcomes with other forms of cold therapy.

2. Acute Physiological Responses to Cold Water Immersion

The thermoregulatory system is a highly complex mechanism comprising several key components, including peripheral thermosensory neurons, which detect changes in surface temperature [1]. These receptors are located in the skin, more precisely in or just beneath the epidermis and are also involved in sensing temperature from oral and urogenital mucosa. Another integral element of the thermoregulatory system is peripheral deep-body sensors positioned in the esophagus, major veins within the abdominal cavity, stomach and other visceral organs, which are responsible for monitoring internal body temperature. Afferent thermal signals are transmitted via the spinal cord and reticular formation to hypothalamic structures. The preoptic area (POA) functions as the principal control center plays an important role in initiation of autonomic thermoeffector responses and thereby maintaining thermal homeostasis and ensuring that body temperature remains within a physiologically safe range [2].

Cold water immersion rapidly activates thermoregulatory mechanisms designed to reduce heat loss and defend core temperature. These responses include cutaneous vasoconstriction and piloerection, followed by increased thermogenesis. [1] When skin temperature falls below around 35 °C, vasoconstriction is initiated. It reaches its peak when the cutaneous surface cools to 31 °C or lower. [10] Narrowing of the blood vessels redirects blood flow from the skin surface to deeper venous pathways to preserve heat. Around 60% of vasoconstriction is mediated by norepinephrine and neuropeptide Y accounts for an additional 20-30%. Furthermore, several hormones- including corticotropin (ACTH), thyrotropin (TSH), vasopressin and cortisol- undergo rapid increase triggered by cold immersion, thereby contributing to the overall elevation in metabolic activity. [4] Piloerection also assists in the thermoregulation process by capturing air between the hairs, which helps improve the insulating layer of the body.[1]

Shivering is activated if these initial responses fail to maintain thermal balance.

In this mechanism, heat is produced via ATP hydrolysis that occurs during rhythmic contractions of skeletal muscles and typically starts in torso muscles and subsequently spreads to the limbs. [5] With prolonged cold exposure, adaptive non-shivering thermogenesis evolves over time, especially through activation of brown adipose tissue (BAT).This tissue produces heat by utilizing free fatty acids via the mechanism of mitochondrial uncoupling and it is found both superficially in the supraclavicular area and in deeper layers around areas such as spine, neck and kidneys [3].

This process entails β-adrenergic receptors located in the heart, fat tissue, blood vessels and voluntary muscles, which during the initial 20 minutes of cold immersion contribute approximately 80% of the overall elevation in metabolic rate. However, after about 30 minutes of continuous cooling, this contribution decreases to about 20%. Based on Manolis et al.(2019), studies involving adrenaline infusion suggest that adipose tissue accounts for roughly 5% of heat production [1].

2.1 Cardiovascular responses

The heart's autonomic regulation has been known as a reciprocal balance between sympathetic and parasympathetic inputs, with the activation of one branch suppressing the other. Kollai and Koizumi, in 1979 challenged this traditional view, by showing that, depending on the characteristics of the stimulus, both pathways of the autonomic nervous system could be simultaneously activated. Two prominent and opposing physiological responses - the 'cold shock response' and the 'diving response'- are triggered during submersion (<15°C) and breath holding.The cold shock response is defined as rapid acceleration of heart rate, regularly exceeding 20 beats per minute.This is accompanied by peripheral vasoconstriction and an increase in cardiac output, which together cause elevation in diastolic and systolic blood pressure (BP). [1] [6] The response is initiated by stimulation of cutaneous thermoreceptors sensitive to cold and generally escalates to its maximum about 30 seconds after cold immersion. This response in the majority of cases lasts for approximately two minutes during the initial phase, after which the body begins to adapt.[6]

Michael J. Shattock and Michael J. Tipton hypothesized that the simultaneous and pronounced activation of both sympathetic and parasympathetic nervous system - known as "autonomic conflict"- can provoke arrhythmias, primarily supraventricular and junctional. It frequently occur within 10 s after releasing breath-hold. [1] [8]They may appear as a brief episode ventricular tachycardia alternating with periods of decreased heart rate, supraventricular ectopic beats and occasionally atrioventricular block. [8] In susceptible individuals with pre-existing conditions, this process may lead to fatal cardiac events. Nonetheless, for fatal arrhythmias to occur, underlying predisposing factors such as Long QT syndrome, coronary artery disease, hypertension, myocardial hypertrophy, or other cardiac structural anomalies are typically necessary. [1][6][8] Importantly, these cold- water exposure responses generally pose minimal risk to otherwise healthy individuals. [1] The physiological diving reflex, elicited by facial immersion, more precisely trigeminal nerve stimulation, which transmits signals to the brainstem. This response encompasses sinus bradycardia, expiratory apnea and simultaneous activation of sympathetic vasoconstrictor neurons. Sinus bradycardia arises from excitation of vagal motor pathways innervating the heart. Its purpose is to conserve oxygen by slowing down the heart rate, reducing cardiac workload and lowering oxygen consumption. This is accompanied by expiratory apneas, during which central respiratory neurons are automatically suppressed . Apnea (cessation of breathing) leads to arterial hypoxemia and hypercapnia, which trigger peripheral chemoreceptors and increase changes in cardiovascular system and the heart ability to contract is weakened during this response.Vasoconstriction is induced by stimulation of sympathetic nervous system This process mostly targeting the limbs and trunk, which leads to blood being redirected to more critical internal organs, such as the brain and heart. This integrated autonomic response serves a critical function of conserving oxygen and extending underwater survival time. Chemoreceptors in carotid bodies and aorta also contribute to diving reflex. When oxygen level decrease, carotid bodies send signal through the glossopharyngeal nerve to brainstem, which triggers sympathetic nerve to further increase vasoconstriction. [33] Notably, the full expression of this reflex requires inactivity of pulmonary stretch receptors, their stimulation can activate secondary peripheral vasodilatation and increase in heart rate. [7] [8]

2.2 Respiratory responses

The most critical life-threatening reaction to cold-water immersion is cold-shock respiratory responses.[1] It is particularly dangerous for individuals who are not adapted. A sudden drop in temperature is promptly detected by thermoreceptors, primarily cold-sensitive afferent neurons located within the skin. These signals are immediately transmitted to the central nervous system. In response, the body initiates a neurogenic reflex: a powerful, involuntary gasp-often ranging between 2 to 3 liters- contributes to a significant increase in end-expiratory lung volume. After this gasp, an episode of uncontrollable hyperventilation manifests, causing hypocapnia and pulmonary alkalosis. An intense afferent drive to breathe combined with excessive respiratory rate, is believed to underlie the sensation of dyspnea. [7] A significant increase in alveolar partial pressure and arterial tension of carbon dioxide gives rise to reductions in cerebral circulation and impaired oxygen unloading from hemoglobin to tissues (implied by leftward shift in the hemoglobin dissociation curve),[9] which culminates in cerebral hypoxia. This mechanism contributes to the development of tetany, disorientation, disrupted motor behavior, and reduced cognitive function.[1][10] [11] It is often experienced by individuals in the early stage of cold-water exposure. [1][10] The cold shock-induced decrease in breath-hold time by 25-30%, elevates the possibility of an individual aspirating water and drowning. [1] [7]

2.3 Neuromuscular effects

An additional risk associated with winter swimming is the dysfunction of musculoskeletal structures due to neuromuscular cooling, increased nociceptor sensitivity and inhibition of nerve transmission. Especially susceptible to this process are the head, arms and neck, because of the subcutaneous location of large blood vessels and their high surface area-to-mass ratio. The suppression of enzymatic processes and the consequent slowing of cellular metabolism - comprising diminished secretion of calcium ions and acetylcholine - occur as cold temperatures infiltrate internal layers of muscle tissue. Muscle strength and ability to contract are closely linked to the local tissue temperature. As the heat level decreases by about 1°C, the force generated by muscles falls by approximately 4-6%. When the temperature of nerves within the neuromuscular junction decreases to about 20°C, nerve transmission slows, and the amplitude of the action potential is markedly diminished. Additional cooling to a range of 5-15°C sustained for 1 to 16 minutes may lead to a functional nerve block affecting both efferent and afferent neurons. These impairments in neuromuscular function may lead to a condition resembling peripheral paralysis, which in water environments can substantially elevate the possibility of drowning as a result of impaired motor coordination and inability to maintain airway patency.[6]

2.4 Hypothermia

Hypothermia impairs cellular metabolism and may give a rise to lactic acid accumulation, coagulation, vascular insufficiency and arrhythmia. [6] This condition usually does not occur for healthy subjects until roughly 30 min of cold exposure. Considerable individual differences exist regarding the extent of core temperature decline and the manifestation of hypothermia. As core body temperature gradually falls, a pronounced sequence of physiological and neurological impairments typically manifest. Shivering commonly begins around 36°C, followed by cognitive disturbances such as disorientation near 33°C. A reduced level of consciousness appear between 33-30°C, and ventricular fibrillation occur around 28°C. If core temperature continues to fall below 25°C, death is imminent. [12]

3. Chronic Adaptations in Regular Winter Swimmers

Chronic winter swimming undoubtedly exerts an impact on the human organism by increasing body tolerance to stressors.

According to some researchers there are four types of described cold adaptation, which are: metabolic, isolative, hypothermic and isolative hypothermic. Their mutual aim is to preserve the body heat, prevent heat loss and increase heat production. The hypothermic one is described when the core temperature becomes reduced, and the mean skin temperature changes the same way as in non-adapted subjects resulting in lowering mean body temperature. Metabolic adaptation is mainly characterized by maintaining a higher mean skin temperature along with no changes in core temperature, as well as by a higher metabolic heat production. Another mentioned cold adaptation is the isolative type whose essential features are preserved core temperature along with unchanged metabolic heat production and lower mean skin temperature during cold exposition. The last type of adaptation called isolative hypothermic is a combination of two previous ones with both core temperature and mean skin temperature lowered and unchanged metabolic heat production. [13]

Regularly practiced cold immersions seem to lead to the adaptation of the sympathoadrenal response. Swimming in cold water for 30 min has been found to increase both noradrenaline and cortisol plasma levels. However, throughout some period of exposure, the reactivity of the sympathetic nervous system seems to be diminished, which may indicate an increased cold tolerance among regular winter swimmers. Nevertheless, it needs to be mentioned that higher resting hormone levels at the beginning of the winter swimming season might result from anxiety-induced stress, which diminishes over time due to habituation. [14]

There seems to be indirect data indicating restriction of heat loss from the body of regular ice swimmers. Researchers found that winter swimmers show bradycardia and a greater reduction in plasma volume in comparison to subjects unaccustomed to cold immersions. They also present a delayed shivering response which indicates a greater contribution of non-shivering thermogenesis in their response to cooling. The outcomes indicate that winter swimmers tend to tolerate a greater temperature gradient between body and the environment due to cold adaptation. [15]

A study analyzed changes in thermal homeostasis after repeated exposures to cold water among young sportsmen. Researchers found that after a few weeks of regular cold immersions both central and peripheral temperatures were lowered as well as subjective cold sensation. The study revealed a small increase in the body fat content and delayed metabolic response to cold. Those findings may indicate the existence of human cold acclimation. Nevertheless, the induced changes seem to disappear within 2 weeks after termination of regular immersions. [16]

According to a study on hematological changes and serum erythropoietin levels in response to regular cold water immersions, the serum erythropoietin concentration increased after 7 months of regular winter swimming. The researchers also found some changes in blood morphology: elevated levels of hemoglobin, RBC, MCHC and decreased levels of blood platelets. Such alterations either might indicate intensified hematopoiesis, or they might be an organism adaptation resulting from decreased plasma volume observed among winter swimmers. The research also demonstrated lower concentration of white blood cells and lower levels of both general subpopulations and all studied classes of immunoglobulin as a response to repeated cold water exposition. Such changes seem to support the conclusion that regular winter swimming exerts an anti-inflammatory effect and induces immune system adaptation. [17]

4. Health Benefits

Cold Water Swimming (Winter Swimming) is becoming increasingly popular worldwide as a form of physical activity and a natural method to improve health. In recent years, numerous scientific articles have suggested that regular cold water immersion may bring a range of health benefits, both physiological and psychological.

4.1 Effects on the Cardiovascular System

Scientific research indicates that cold water swimming improves exercise tolerance and cardiovascular performance in physically active individuals, which is important for preventing cardiovascular diseases. Immersion in cold water causes a rapid constriction of blood vessels in the skin and centralization of circulation, leading to an increase in blood pressure and heart rate. Over time, the body adapts to cold exposure, improving vascular flexibility and positively influencing the lipid profile. Regular cold water swimming may help lower total cholesterol levels and increase HDL (the "good" cholesterol). [18]

4.2. Modulation of the Immune System

The impact of cold water swimming on the immune system is multifaceted. Many studies show that cold water significantly influences immune function and modulation. Exposure to cold water increases the secretion of anti-inflammatory cytokines (e.g., IL-6, IL-10) and enhances the activity of leukocytes and monocytes. Systematic reviews indicate that cold water swimming boosts the body’s natural immunity and may reduce the incidence of upper respiratory tract infections. [6]

4.3. Effects on Mood and Mental Health

Cold water immersion causes a rapid drop in skin and body temperature, leading to the release of endorphins and adrenaline, which results in feelings of euphoria, self-satisfaction, and improved mood after exiting the water. Clinical studies have confirmed that regular cold water swimming can have a positive effect on mental functioning - reducing symptoms of depression and lowering anxiety levels [19]. It also reduces activity of the hypothalamic-pituitary-adrenal (HPA) axis, promoting lower stress levels. Moreover, being in cold water has been shown to improve sleep quality and duration.

4.4. Metabolic Effects

Cold water swimming stimulates brown adipose tissue, triggering non-shivering thermogenesis, which leads to increased energy expenditure. Exposure to cold water activates brown fat tissue, improving insulin receptor sensitivity and aiding in the control and maintenance of a healthy body weight. Some studies also suggest a beneficial effect on lipid and carbohydrate metabolism [14].

5. Risks and Contraindications

Despite its many health benefits, cold water swimming is also associated with certain health risks, particularly for people with chronic illnesses or those in high-risk groups.

5.1. Hypothermia

The most serious and dangerous risk for cold water swimmers is hypothermia, defined as a drop in core body temperature below 35°C (95°F). The risk of unconsciousness and impaired awareness increases after just a few minutes in water below 5°C (41°F), causing significant body heat loss [18].

Symptoms can include shivering, speech difficulties, confusion, and reduced muscle strength. Particularly dangerous is the phase after leaving the water, when a phenomenon known as “afterdrop” may occur - a further drop in core body temperature even after exiting the cold environment.

5.2. Cold Shock Response

Another dangerous phenomenon is the “cold shock response”, which occurs when the body is rapidly immersed in cold water. This results in blood vessel constriction, tachycardia, and rapid breathing. In individuals with undiagnosed heart conditions or an overreactive autonomic nervous system, this can trigger arrhythmias or even cardiac arrest [29]. Therefore, gradual and slow immersion in cold water is recommended.

5.3. High-Risk Groups

Individuals at higher risk during cold water swimming include those with cardiovascular diseases (e.g., coronary artery disease, hypertension, arrhythmias), asthma, epilepsy, and neurological disorders [6].

Absolute contraindications to cold water swimming include:

- History of heart attacks
- Episodes of stroke
- Uncontrolled diabetes
- Certain mental illnesses

5.4. Safety Recommendations

To minimize the risks associated with cold water swimming, it is recommended to consult a physician and undergo cardiovascular testing such as an ECG. Attention should also be paid to the condition of water bodies, weather conditions, and swimming under the supervision of more experienced participants.

General safety guidelines to reduce risk include:

- Gradual acclimatization to low temperatures
- Avoiding substances such as alcohol before and after immersion
- Thermal protection for hands and feet
- Warming up the body after exiting the water

6. Special Populations

Cold water immersion triggers immediate and long-term physiological alterations, including metabolic, cardiovascular and hormonal changes. The body's response involves activation of the autonomic nervous system, modulation of the immune system and release of various biochemical mediators. These responses can have both beneficial and potentially harmful effects, depending on the individual's health status and physiological capacity.

6.1 Elderly Population

The elderly population presents unique challenges when it comes to winter swimming due to age-related physiological changes. Older adults experience decreased thermoregulatory capacity, reduced cardiovascular reserve and altered immune function, all of which can affect their response to cold water exposure.

Research indicates that cold exposure affects cardiovascular responses significantly and these effects may be modified by underlying cardiovascular disease [20]. In elderly individuals, the cardiovascular strain associated with cold water immersion can be particularly pronounced due to reduced cardiac output capacity, decreased vascular elasticity, impaired baroreceptor sensitivity, increased risk of arrhythmias.

Studies have shown that cold-water immersion can be performed safely in older patients under specific circumstances. A case series examining the safety and efficacy of cold-water immersion in treating older patients with heat stroke demonstrated that with special precautions, this intervention could be performed safely. [21].

Despite the risks, some elderly individuals who are healthy and well-conditioned may experience benefits from winter swimming, including improved cardiovascular fitness through adaptive mechanisms, enhanced immune function, improved insulin sensitivity and reduced inflammation markers. However, further investigation is warranted to establish appropriate cooling methods in older adults.

Winter swimming should be avoided by elderly individuals with:

- Heart or respiratory diseases
- High blood pressure
- Cardiac arrhythmias
- Compromised immune systems
- Limited mobility or balance issues [6]

6.2 Pediatric Population

Children are particularly vulnerable to cold water exposure due to several physiological factors:

- Higher surface area to body mass ratio
- Immature thermoregulatory systems
- Limited ability to generate heat through shivering
- Reduced subcutaneous fat for insulation
- Decreased cognitive ability to recognize and respond to hypothermia

Children have a significantly higher surface area-to-body mass (SA/M) ratio compared to adults, which accelerates heat loss during cold exposure. This anatomical characteristic renders children more susceptible to rapid decreases in core temperature during immersion. [22]

Young children possess immature thermoregulatory systems with limited efficiency in shivering thermogenesis and non-shivering thermogenesis. This compromises their ability to maintain normothermia under cold stress. [23]

Children have less subcutaneous fat, which plays a critical role in insulation and thermal protection. Consequently, they exhibit a lower capacity for endogenous heat retention. [24]

Cold-water immersion triggers an acute autonomic response known as the "cold shock response" (CSR), involving involuntary hyperventilation, tachycardia, and peripheral vasoconstriction. These responses can be particularly dangerous in children due to limited cardiovascular reserve. [12]

The current body of scientific evidence highlights clear and substantial risks associated with cold-water immersion in children. Due to their physiological vulnerabilities children are far more susceptible to hypothermia, arrhythmias, and cold shock compared to adults. [25] [8]

At present, no controlled studies exist that confirm any long-term health benefits of cold exposure in the pediatric population.

In light of these findings, cold-water immersion should not be recommended or practiced in children without strict clinical supervision and scientific validation. Further pediatric-focused research is urgently needed before considering this intervention as safe or beneficial.

7. Winter Swimming vs. Other Cold Therapies

Cold therapy encompasses various methods of applying low temperatures for therapeutic and health purposes. Contemporary scientific research shows growing interest in different forms of cold therapy, including winter swimming, whole-body cryotherapy, ice baths and cold showers. Each of these methods is characterized by different exposure intensities, durations and mechanisms of action.

7.1 Characteristics of Different Forms of Cold Therapy

Winter swimming is a form of cold therapy involving brief immersion in natural water bodies at temperatures of 0-4°C. Exposure typically lasts 3-5 minutes once per week and is characterized by gradual adaptation of the organism to extreme thermal conditions.

Whole-body cryotherapy involves exposure to extremely low temperatures (-110°C to -135°C) for 2-4 minutes in specially designed chambers. WBC is characterized by controlled conditions and standardized protocols, requires specialized equipment and is costly.

Ice baths, also called cold water immersion (CWI), involve immersing the body in water at temperatures of 10-15°C for 10-20 minutes.

Cold showers represent the most accessible form of cold therapy, typically involving water temperatures of 10-15°C for durations of 30 seconds to several minutes. Although they are the least intense, they constitute an accessible form of cold therapy for the general population.

7.2 Comparison of Health Outcomes

Meta-analyses show that ice baths (CWI) are more effective than active recovery, contrast water therapy and warm baths in most recovery parameters. Cold therapy appears to exert time-dependent effects on inflammation, stress, resilience, sleep quality and quality of life. Air cryotherapy was significantly more effective than CWI in restoring muscle strength and immediate muscle power recovery. [26] A meta-analysis based on 11 randomized controlled trials demonstrated that whole-body cryotherapy can reduce inflammatory response in humans, focusing mainly on improving the body's regenerative capabilities. [27] After therapy, similar improvements were observed in pain, disease activity, fatigue, walking time and step count over 50m distance, with significant reduction in IL-6 and TNF-α. [28]

Both winter swimming and WBC show positive effects on the body's antioxidant capacity. Research shows that winter swimming results in significant increases in red blood cell deformability and enhanced antioxidant defense systems, particularly glutathione peroxidase activity. Comparative studies show similar patterns of increased antioxidant parameters in both groups. [29, 30, 31, 32]

The evidence suggests that while all cold therapies share common mechanisms of action, winter swimming represents the most extreme form of cold exposure with potentially the greatest physiological adaptations. However, the quality of evidence varies significantly across modalities, with ice baths and cold water immersion having the strongest research support for recovery applications. Evidence for other applications remains limited by methodological constraints and heterogeneous study designs. Cold showers offer the most accessible intervention with moderate evidence for health benefits, while cryotherapy provides controlled exposure with emerging evidence for therapeutic applications.

Future research should focus on standardizing exposure protocols, conducting longer-term studies and directly comparing different cold therapy modalities within the same study populations to establish clearer evidence-based recommendations for specific health and performance outcomes.

8. Conclusions

Winter swimming elicits a wide range of physiological responses resulting in both acute and adaptive changes within the human body. The current body of evidence suggests that regular cold water exposure, when practiced safely, may confer significant health benefits. These include improvements in cardiovascular function such as vascular flexibility, lipid profile, and exercise tolerance as well as positive effects on immune modulation. Enhanced resistance to infections, anti-inflammatory adaptations, and improved metabolic regulation highlighted by increased energy expenditure and potential benefits for glucose and lipid metabolism are among the frequently cited advantages. Additionally, many individuals report notable improvements in mood, reduced symptoms of depression and anxiety, and better overall psychological well-being.

However, despite these promising health outcomes, winter swimming carries inherent risks, particularly for individuals with underlying health conditions, children, and the elderly. Acute dangers such as hypothermia, cold shock response, and cardiac arrhythmias must be carefully considered, and strict safety protocols should be followed. Pre-participation medical screening and gradual adaptation remain essential, and winter swimming should not be recommended for high-risk populations without close clinical supervision.

Overall, while winter swimming presents an intriguing, natural approach to health promotion, further well-designed, long-term studies are necessary to clarify its effect size, mechanisms, and safety across different populations. In conclusion, when undertaken responsibly, winter swimming has the potential to serve as an effective health-enhancing intervention. Yet, its practice should always be individualized and guided by the latest medical knowledge.

Disclosure:

Author's contribution

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