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A Comprehensive Review on the Latest Insights into Cold Therapies and Their Impact on the Human Body, with a Focus on Neurophysiological Responses

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Abstract:

Introduction

In contemporary medicine, increasing attention is being devoted to alternative forms of therapy. Immersing oneself in cold water, cryotherapy, or cold showers are practices that have long sparked interest due to their potential health benefits.

Aim of the study

The aim of this comprehensive review is to analyze the impact of cold exposure on the human body, with particular emphasis on its effects on the nervous system. Through the synthesis of available research, the paper seeks to identify health benefits and areas requiring further investigation in the context of various cold application practices.

Materials and methods

An analysis of scientific articles available in the Pubmed and Google Scholar databases was conducted. Publications from recent years that most relevantly addressed the discussed topic were utilized for this study. The search process involved the use of the following keywords: “cold,” “cold showering,” “cold water,” “cryotherapy.”

Results

The results of the literature review unequivocally indicate a positive, multifaceted impact of cold on the human body, particularly with an emphasis on the nervous system. Significant therapeutic effects observed in various fields suggest that the application of cold may be a promising alternative in promoting health and treating numerous medical conditions.

Summary

The focused literature review on the impact of cold on the human body, especially the nervous system, presents various therapies such as cryotherapy or cold water immersion, emphasizing their beneficial effects on the nervous, cardiovascular, endocrine, lymphatic, musculoskeletal, and joint systems. However, despite the observed benefits, further research is needed to gain a more detailed understanding of the mechanisms of action and to ensure the safety of these practices.

Key words: cold; cold showering; cold water; cryotherapy

Introduction

The tradition of cold water swimming, deeply rooted in the history of northern countries, has not only endured but has also evolved into modern times, becoming an area of scientific research and health practices.[1] Exposure to low temperatures poses a remarkable challenge to the human body, triggering a series of physiological reactions aimed at maintaining thermal homeostasis. In response to the cold, blood vessels constrict, limiting blood flow and reducing heat loss. The body also activates thermogenic mechanisms, such as muscle shivering, to increase heat production. Fat plays a crucial role as a natural thermal insulator, protecting against heat loss in challenging conditions. Concurrently, there is an increase in respiratory and heart rates, elevating blood pressure and reducing cerebral perfusion. The rise in noradrenaline levels, acting as a natural analgesic, may influence pain alleviation in cold conditions.[2] Contemporary cold applications encompass diverse methods, including cryotherapy, cold showers, or immersion in cold water. These techniques are employed in conjunction with practices such as meditation [3–5] and exercise [3,6], creating a comprehensive approach to influencing human well-being. Cold exposure is becoming increasingly popular, impacting various aspects of human life.[1] Research suggests that cold therapies have a significant influence on the nervous system, including psychological aspects such as sleep[7–9] and memory.[10] Cold-based methods also affect the physiological systems of the human body, including the cardiovascular and endocrine systems. In this review, we will

focus on analyzing various aspects related to the use of cold on the human body, with particular emphasis on its impact on the nervous system. We will explore the applications of cold therapy in the context of mental and physical health, examining its relationship with fundamental aspects of life, all while considering potential health benefits.

Description of the state of knowledge

A) Nervous system

Beginning with the general conclusion that swimming in icy water has a positive impact on human psyche.[1]

I. Sleep

Over time, it has been observed that cooling the body has a beneficial impact on sleep and circadian rhythm. Research on cold showers or baths in cold water confirms their positive effects on mental health. A contemporary perspective on this tradition points to the stimulation of skin thermoreceptors during cold therapy, influencing the thermoregulatory center in the hypothalamus. This phenomenon, especially in the context of whole-body cryotherapy (WBC), results not only in improved sleep quality but also in the regulation of circadian rhythm and behavioral activation. These findings suggest that cold therapy may represent a promising intervention, enhancing both sleep and the regulatory functions of the body.[11]

Subsequent results have confirmed that cryotherapy improves both subjective and objective sleep quality in 22 physically active men. The reduction in the number of movements during sleep, especially in the Slow Wave Sleep (SWS) phase, suggests that cryotherapy may promote deeper and higher-quality sleep. Additionally, the improvement in sleep quality following whole-body cryotherapy (WBC) facilitates a quick return to good form after evening training sessions.[8]

In the context of analyzing the impact of whole-body cryotherapy on the sleep of patients with fibromyalgia, a study involved 24 participants. Among them, 11 participated in cryotherapy sessions, while 13 constituted the control group. The study suggests that this therapy may be an effective strategy to counteract sleep disorders by regulating pro-inflammatory and anti-inflammatory mediators.[9]

The impact of cold baths on improving sleep is also confirmed by a study published in the "Bangladesh Journal of Medicine."[7]

II. Stress

Swimming in cold water as a form of endurance exercise enhances tolerance to stressors.[1]

III. Depression

Immersion in cold water may have beneficial effects on mental health, especially in the context of depression, which represents a significant concern. Although swimming in cold water entails physiological stress, research suggests that it may yield positive outcomes for mental health. The increase in levels of substances such as noradrenaline and beta-endorphin, induced by the stressful experience of cold, could potentially impact mood improvement and mental well-being. There are reports of alleviation of depressive symptoms and overall well-being improvement in individuals who regularly practice winter swimming.[1,2]

Rymaszewska et al. assessed the efficacy and safety of whole-body cryotherapy (WBC) as an adjunctive intervention in the treatment of depressive episodes. Thirty adult patients diagnosed with a depressive episode participated in a prospective observational analysis. Patients undergoing WBC sessions showed significant improvement, as evidenced by a reduction in overall scores on scales assessing depressive symptoms such as HDRS and BDI-II. The level of anhedonia significantly decreased on the SHAPS scale, and the quality of life increased in the areas of physical health, mental health, and environmental well-being according to the WHOQoL-BREF questionnaire. A comparison of well-being before and after sessions, measured on the VAS scale, revealed a significant improvement. WBC proved to be an effective, safe, and well-tolerated intervention for patients experiencing a depressive episode.[12]

Some time later, Rymaszewska et al. revisited the topic of whole-body cryotherapy (WBC), investigating its impact on depressive symptoms. The study included 92 adults with a depressive episode. Ten WBC sessions were conducted, and the results confirmed a significant improvement in depressive symptoms, especially somatic symptoms, after the first week of intervention. The effect persisted in the following weeks. Additionally, patients reported an improvement in quality of life, mood, and illness acceptance. This time, the study

was conducted in a randomized manner, further enhancing the credibility of the obtained results.[13]

Let's focus on a meta-analysis of studies on whole-body cryotherapy (WBC) in the context of mental health, providing compelling evidence for the effectiveness of this therapeutic intervention. The analyzed studies encompass 294 participants, and particular confirmation of the impact of WBC emerges in the area of depression, where a very large effect was obtained (Hedges's g = 2.45, CI: 2.44-3.45). These results suggest that whole-body cryotherapy may be an effective adjunct therapy for mental health issues.[11]

IV. Pain

In the context of pain relief, a study involving 20 participants compared the impact of cold water immersion (CWI) and partial body cryotherapy (PBC). The results indicate significant differences. CWI induced a strong vasoconstrictive response, contributing to the cold-induced analgesic effect, particularly noticeable in the skin temperature reduction on the thigh up to 30 minutes after the procedure. On the other hand, PBC did not show significant vasoconstriction, resulting in a minimal decrease in skin temperature compared to baseline values. The conclusion drawn from the analysis is that the application of CWI may be more effective in pain relief compared to partial body cryotherapy (PBC), especially concerning the skin vascular response and skin temperature reduction.[14]

The subsequent study demonstrated that whole-body cryotherapy significantly reduced perceived muscle soreness by 58% after exercise. This confirms the analgesic effect of cryotherapy, which stimulates the production of beta-endorphin, a neurotransmitter with pain-relieving properties.[8]

In a study on whole-body cryotherapy (WBC) in the treatment of fibromyalgia (FM) involving 23 FM patients and 30 healthy individuals in the control group (HC), significant benefits in pain relief were achieved. Pain measurement results using the visual analog scale (VAS) showed a substantial reduction in the average pain level in FM patients from 5.91±2.3 mm to 3.43±2.8 mm after 6 WBC sessions. Despite this improvement, after a 3-month hiatus from therapy, the pain increased but still remained at a lower level than at the beginning of the study.[15]

Similar conclusions were reached in the previously mentioned study. The hypothesis that whole-body cryotherapy alleviates pain in patients with fibromyalgia was confirmed. Observations suggest that this therapy affects the balance of pro-inflammatory and anti-inflammatory mediators, resulting in a statistically significant improvement in both self-assessed physical and mental health of the patients.[9]

In another study from 2021, it was observed that cold water immersion has a positive impact on headache pain.[7]

In the context of alleviating chronic pain, cryotherapy, encompassing both local and general effects, is a beneficial therapeutic method. A review indicates that cryotherapy can effectively reduce chronic pain associated with various diseases, such as rheumatic and degenerative conditions. Mechanisms such as reducing inflammation, edema, oxidative stress, and slowing down pain nerve conduction suggest various therapeutic benefits.[16]

V. Cognitive functions

In the study, participants with mild cognitive impairment (MCI) underwent 10 sessions of whole-body cryotherapy (WBC). Following this treatment, an improvement in cognitive functions, especially memory processes, was observed ($p<0.05$). Additionally, WBC led to a significant increase in serum nitric oxide (NO) levels, brain-derived neurotrophic factor (BDNF) concentrations ($p<0.05$), and a reduction in interleukin-6 (IL-6) ($p<0.05$). After WBC, a moderate correlation between NO levels and cognitive functioning was also noted. The conclusions suggest that WBC may be beneficial as an adjunct therapy for individuals with MCI.[10]

In the context of cognitive functions, it is worth noting a study on the effects of a 3-minute partial body cryostimulation (PBC) exposure in healthy young adults. The results indicate that a single session of PBC improved cognitive inhibitory control in the Stroop task, especially in men. In this group, an increase in heart rate variability indices was also observed, suggesting better control of the autonomic nervous system. It is also interesting to note that cerebral blood flow remained higher after PBC only in men, which may indicate gender differences in responses to this type of therapy.[17]

VI. Hyperthermia

The conducted meta-analysis, encompassing 63 studies, unequivocally confirmed that cold-based techniques are recognized as the most effective form of hyperthermia treatment. Hyperthermia is a sudden condition characterized by a body temperature exceeding 40°C and dysregulation of the nervous system. The analyzed evidence suggests that rapid cooling through immersion contributes to increased chances of survival with limited complications. In studies on exertional hyperthermia, considering various cold water temperatures, immersion was observed to result in faster cooling compared to passive cooling methods. It is worth emphasizing that there is no conclusive evidence that a specific range of water temperature is more effective than another in rapidly reducing core temperature. Additionally, it has been demonstrated that cold showers also represent an effective alternative.[18]

In the treatment process of heatstroke, thereby expanding the repertoire of effective therapeutic methods, procedures also include ice baths and evaporative cooling, which assist in lowering the patient's body temperature.[7]

VII. Multiple sclerosis (MS)

The significance of cold exposure in the context of progressive neurological disorders should be noted. The aim of the study, involving 60 patients with multiple sclerosis (MS), was to assess the effectiveness of whole-body cryotherapy (WBC) and physical training in improving mental well-being and overall health. Participants were divided into three groups: cryotherapy (Cryo), physical training (Gym), and a combination of both (CryoGym). The analysis of results showed significant improvements in psychosocial well-being, especially in the CryoGym group. Reduction in depressive symptoms and improvement in functional status were noticeable in the Cryo group. The most significant benefits were observed in the CryoGym group, suggesting that WBC in combination with physical training is an effective therapy for MS patients.[6]

VIII. Damage to brain cells

In a randomized study involving patients with acute type A aortic dissection (AAAD), mild hypothermia was applied during the perioperative period, and its impact was compared with conventional therapy. The group subjected to mild hypothermia showed a significantly

shorter time to regaining consciousness (mean of 12.65 hours compared to 25.80 hours in the control group) and a higher rate of regaining consciousness within 24 hours after surgery (74.07% compared to 46.42%). Patients undergoing mild hypothermia therapy also had a shorter stay in the intensive care unit (ICU) than those with conventional therapy (5.53 days compared to 9.35 days). The results suggest that mild hypothermia may significantly reduce brain cell damage and improve neurological outcomes in postoperative patients.[19]

IX. WHM

In the context of the nervous system and cold exposure, it's worth noting Wim Hof. He serves as an interesting example of an individual who utilizes extreme cold conditions to influence his nervous system. His practice, known as the Wim Hof Method (WHM), involves cold exposure, breath control, and meditation. Studying this Dutchman using various brain imaging techniques (fMRI, PET/CT) during cold exposure has allowed for inferences about the mechanisms involved in these capabilities. fMRI analyses have shown that the WHM activates central control centers for modulating cold/pain stimuli in the periaqueductal gray matter (PAG), likely initiating a stress-induced analgesic response. Furthermore, the WHM engages higher-order cortical areas (left anterior and right middle cingulate cortex) associated with introspection, facilitating focused attention in the face of unpleasant stimuli such as cold. PET/CT studies demonstrated that intense breathing increases sympathetic innervation and glucose consumption in intercostal muscles, generating heat that dissipates into lung tissue. This phenomenon results in an increase in blood temperature in the pulmonary capillaries, counteracting the decrease in body temperature due to cold exposure. These findings provide compelling evidence for the primacy of the brain (CNS) over the body (peripheral mechanisms) in mediating Hof's response to cold. They also suggest the possibility that the WHM allows practitioners to achieve a higher level of control over key elements of the autonomic nervous system, potentially applicable to lifestyle interventions and alleviating various clinical syndromes. Additionally, stress-induced analgesic mechanisms triggered by external cold stimuli may be associated with the release of endogenous opioids/cannabinoids, contributing to feelings of euphoria and well-being.[4]

In another study regarding the Wim Hof Method (WHM), the aim was to examine the impact of the training program on stress responses and hormone release in participants of an Antarctic expedition. Volunteers were divided into an intervention group (participating in an

8-week training program including cold exposure) and a control group. The results showed that the training program significantly reduced stress responses and the number of depressive symptoms. Additionally, it indicated a tendency to decrease cortisol levels compared to the control group. The findings suggest that Wim Hof's training positively influences stress responses and hormonal functions in participants.[20]

Continuing the review of studies on the Wim Hof Method (WHM), the next study confirms that the training intervention, involving a combination of cold exposure, meditation, and breathing exercises, enables voluntary activation of the sympathetic nervous system. The results demonstrate a significant increase in serum epinephrine levels and a attenuation of the inflammatory response induced by lipopolysaccharide (LPS), which was administered to the group of men. These findings open the perspective of utilizing the Wim Hof Method as an effective intervention that not only allows control over the nervous system but may also influence the body's immune responses. In the context of clinical conditions where inflammatory reactions play a significant role, WHM may represent a valuable alternative or complement to conventional therapy.[5]

B) Cardiovascular system

Cold exposure seems to have a beneficial impact on the cardiovascular system, demonstrating positive effects on cardiovascular risk factors.

This phenomenon has been observed among winter swimmers. A reduction in triglyceride levels and lower concentrations of homocysteine have been noted. Elevated levels of homocysteine are associated with an increased risk of accelerated heart disease development. These findings suggest that winter swimming may influence lipid metabolism, especially in physically active individuals.[1]

Regular cold-water swimming may positively impact the cardiovascular system, contributing to the improvement of cardiological markers. Cold adaptation appears to be associated with a reduced apolipoprotein B/apolipoprotein A1 (ApoB/ApoA1) ratio, increased insulin sensitivity, and enhanced activity of glutathione peroxidase 1 (GPX1) and oxidative stress markers. These findings suggest a beneficial cardioprotective effect of regular whole-body cryotherapy.[2]

A study involving 22 physically active men showed that whole-body cryotherapy (WBC) after evening training had a positive impact on the circulatory system. Heart rate variability (HRV) analysis indicated that WBC led to increased parasympathetic activity during the slow-wave sleep (SWS) phase.[8]

Body cooling through a 15-minute cold water shower (CWS) demonstrated effectiveness in faster heart rate (HR) reduction compared to passive regeneration (SIT25). The study involved nine healthy men aged 21 ± 1 years, engaging in cycling for 45 minutes in a hot environment (35°C). Following the CWS intervention, a significant 18% decrease in HR was observed, surpassing the effects of the SIT25 intervention (7%).[21]

In another study, 26 women, including Haenyeo (female divers working in cold seawater), were subjected to cold exposure. The study protocol involved exposure to cold air at a temperature of 12°C for 60 minutes. The results showed that the hearts of older Haenyeo worked significantly slower than those of young non-diving women ($p < 0.05$). It is also noteworthy that older Haenyeo had lower resting blood pressure compared to older non-diving women ($p < 0.01$).[22]

C) Endocrine system

Swimming in cold water has a positive impact on the endocrine system, especially on various stress-related hormones associated with cold exposure. In a field study involving 30 cold-water swimmers over six months, insulin sensitivity was examined. A reduction in insulin secretion and resistance was observed.[1]

The results of the aforementioned study showed that older haenyeo, experienced diving women, had significantly lower energy expenditure compared to older non-diving women during cold exposure ($p < 0.05$).[22]

In the context of cold water immersion (CWI), diverse influences on the endocrine system and inflammatory state of the body are observed. Regular exposure to cold water leads to a decrease in the concentrations of adrenocorticotropic hormone (ACTH) and cortisol in the serum, suggesting possible acclimatization of the body to this thermal stressor. Studies suggest that older individuals engaging in CWI may maintain a lower level of inflammation, which could be beneficial for healthy aging. CWI induces adaptive changes in the immune system by increasing interleukin-6 levels and T lymphocytes, influencing the immune

response. Another observation is the reduction in uric acid levels and related changes in oxidative stress, suggesting the favorable impact of CWI on the body's ability to cope with stressors. Additionally, regular exposure to cold reduces hypercholesterolemia through the activation of brown adipose tissue.[2]

In a study conducted in Vienna, Bratislava, and Zurich on a group of individuals, it was observed that exposure to cold affects the thyroid and parathyroid glands. An increase in parathyroid hormone (PTH) was noted, suggesting potential thermogenic activation of adipose tissue. Brown adipose tissue (BAT) is crucial in the thermogenic process, and an increase in its volume may indicate an enhanced ability of the body to generate heat in response to cold exposure. After 15 minutes of swimming in icy water, a decrease in levels of free triiodothyronine (T3) and thyroxine (T4) was also recorded.[23]

In the context of fat metabolism, studies suggest that immersions in cold water may impact the mobilization of free fatty acids, which could be significant in the treatment of obesity. Additionally, it has been observed that adiponectin, a key protein produced by adipose tissue, plays a crucial role in defending against insulin resistance, diabetes, and atherosclerosis. Research suggests that exposure to cold, both in the air and in water, increases adiponectin production through thermogenesis, which may have a beneficial impact on health. Regular swimming in cold water has been associated with fat loss in men. These findings suggest potential benefits in terms of insulin resistance, diabetes, and atherosclerosis, supported by research indicating improvements in these parameters after repeated cold water immersions, especially during winter months.[2]

The subsequent results confirm that a favorable impact on lipid metabolism and cholesterol profile may be observed as a result of cryogenic therapy. Regular sessions of whole-body cryotherapy (WBC) performed by physically active men led to a significant decrease in triglycerides and a reduction in LDL cholesterol levels, while simultaneously increasing HDL cholesterol levels.[24]

In the previously discussed study, it was also found that whole-body cryotherapy affects the level of cortisol associated with the activation of the sympathetic nervous system. Elevated cortisol levels may be a key mechanism influencing pain modulation and mood in patients with fibromyalgia.[9]

D) Lymphatic system:

Winter swimming has a positive impact on immunity, reducing the risk of upper respiratory tract infections by 40%, and regular swimming may result in milder illness episodes. [1] On the other hand, the combination of regular cold showers and regular physical activity leads to a 54% reduction in sick leave compared to those who do not engage in these practices. [25] However, studies on the impact of cold exposure on the immune system show discrepancies in results, which may be due to differences in research protocols and participant characteristics. Theoretically, the release of stress hormones due to cold exposure may contribute to improving immune function. Nevertheless, the clinical significance of these benefits remains unclear, and potential health effects may only manifest as reduced susceptibility to respiratory infections. Differences in research outcomes emphasize the need to consider the duration of exposures, the type of cold exposure, and the degree of participant acclimatization.[1]

In a large study involving 3018 participants aged 18 to 65 years, without serious coexisting illnesses and not routinely taking cold showers. Regular cold exposure led to a statistically significant reduction in sick leave among adults. The study found that 29% of participants following a cold shower regimen reported fewer medical absences from work compared to the control group.[25]

It is noteworthy that regular winter swimming led to an improvement in the overall well-being of swimmers suffering from rheumatism, fibromyalgia, and asthma.[1]

In the study on axial spondyloarthritis, participants underwent an 8-week intervention combining cold exposure with additional breathing exercises and meditation. The intervention group ($n = 13$) showed a significant decrease in ESR ($p = 0.040$) and ASDAS-CRP ($p = 0.044$), with similar trends observed in serum calprotectin levels. It is worth noting that cold exposure can be effectively combined with meditation and breathing exercises, suggesting potential therapeutic benefits. The obtained results justify further large-scale investigations into this therapeutic approach. Significant changes in inflammatory markers and improvement in disease activity indicate potential health benefits resulting from the program.[3]

During the analysis of cytokine levels (IL-1, IL-6, TNF-a, IL-10) in patients with fibromyalgia (FM), it was observed that whole-body cryotherapy (WBC) significantly

influenced the concentrations of these substances. After 3 sessions of WBC and 3 months post-therapy, significant changes in the levels of these substances were observed in FM patients compared to the control group. These changes correlated with the improvement in disease activity, measured by the Fibromyalgia Impact Questionnaire (FIQ). In summary, WBC demonstrated efficacy in alleviating FM symptoms, and the changes in cytokine levels suggest that this therapy affects mechanisms related to inflammation. Study participants expressed satisfaction with WBC, indicating positive perceptions of its effectiveness in the context of fibromyalgia.[15]

E) Common shell

A study on the impact of cold water immersion (CWI) and partial body cryotherapy (PBC) on skin microcirculation perfusion was conducted with 20 healthy men. The results unequivocally indicated that CWI significantly reduced skin microcirculation perfusion, especially between 10 and 30 minutes after the procedure. On the other hand, PBC increased microcirculation perfusion only in the first measurement immediately after the procedure. The final conclusions from the study suggest that the application of the conduction cooling method, such as CWI, may have a more favorable impact on skin microcirculation perfusion compared to partial body cryotherapy (PBC), especially in the context of therapeutic interventions.[14]

In the context of the impact of cold on the skin discussed earlier, the Haenyeo demonstrated a greater decrease in the average skin temperature compared to the other two groups ($p < 0.05$). Particularly significant was the reduction in temperature in the forehead and calf areas compared to the remaining two groups. This suggests that older Haenyeo maintain internal body warmth through focused restriction of blood flow in specific skin areas.[22]

F) Musculoskeletal system

The study conducted by Siqueira et al. aimed to assess the impact of multiple exposures to cold water immersion (CWI) on muscle recovery after exercise-induced damage. Thirty men were divided into a control group and a group practicing CWI. Multiple CWI sessions resulted in a attenuation of muscle damage, showing an earlier reduction in muscle thickness and lower ratings of delayed onset muscle soreness (DOMS). Meanwhile, no

differences were observed in the systemic inflammatory state and extracellular matrix degradation between the control group and the CWI group. The conclusion is that multiple CWI sessions may reduce muscle damage after exercise, but they do not expedite muscle recovery between training sessions or competitions.[26]

Pawłowska et al. investigated the impact of a 3-minute cold water immersion (CWI) after physical exertion on muscle recovery and potential anti-inflammatory effects in 22 healthy recreational athletes. CWI had a positive influence on post-exercise recovery by inducing vasoconstriction and limiting the infiltration of inflammatory cells into the muscles. An increase in the level of IL-6 was also observed as a result of CWI. This interleukin acts as a growth factor in the muscle rebuilding and regeneration process. The rise in IL-6 levels after physical exertion was accompanied by an increase in IL-10, a key anti-inflammatory cytokine that inhibits the production of pro-inflammatory cytokines by activated monocytes and macrophages. This indicates a favorable impact on the balance of the inflammatory state.[27]

The study by Straburzyńska-Lupa et al. aimed to examine the impact of whole-body cryotherapy (WBC) at temperatures of -110°C and -60°C on disease activity, selected pro-inflammatory cytokines, and oxidative stress in patients with ankylosing spondylitis (AS). Sixty-five AS patients were assigned to one of three study procedures. Disease activity indices (BASDAI, ASDAS-CRP), C-reactive protein levels, and the concentrations of interleukin 8 and 17 (IL-8, IL-17) were measured at the beginning and after the intervention. The concentration of thiobarbituric acid reactive substances (TBARS) was also measured as an indicator of the body's antioxidant potential. All investigated groups showed a significant reduction in disease activity after therapy, expressed by BASDAI, ASDAS-CRP, and IL-8 concentration. The TBARS concentration after therapy was significantly increased in the WBC group.[28]

In another study involving 21 athletes, the aim was to assess the impact of cold water immersion (CWI) on markers of recovery during competitions. The results indicated that cold water immersion improved the sprint speed recovery of the athletes and also reduced the release of creatine kinase (CK).[29]

Not all studies present positive effects of cold therapy on the musculoskeletal system. The cited study aimed to understand the impact of whole-body cryotherapy (WBC) and cold water immersion (CWI) on recovery processes after a marathon. Thirty-one men post-marathon were randomly assigned to CWI, WBC, and placebo groups. The results revealed

that WBC had a negative effect on muscle function compared to CWI but positively influenced the perception of training stress. Neither form of cryotherapy showed a significant impact on markers of inflammation or structural damage, except for C-reactive protein at 24 and 48 hours. These findings question the effectiveness of cold therapies as regeneration strategies, suggesting that placebo effects may play a significant role in the positive influence of cryotherapy on recovery after intense physical exertion.[30]

G) Risks and contraindications

Swimming in cold water poses significant health risks. There is a risk of hypothermia, which can lead to loss of consciousness and death, especially with prolonged immersion. Additionally, extreme conditions can activate the nervous system, increasing the risk of arrhythmias, especially in individuals with heart conditions. Fatalities during official ice swimming events confirm the seriousness of these dangers. Pulmonary threats, such as cold water-induced pulmonary edema, add an extra health risk associated with this activity. Therefore, approaching cold-water swimming should be done with great caution, under appropriate supervision, and individuals with existing health issues should avoid extreme conditions.[1]

Cold therapy should also be avoided in the following conditions: severe organic deficiencies, severe brain injury, open wounds, hydrophobia, cold intolerance, and balance issues. [7] and in cases of anemia, heart defects, cardiac arrhythmias, angina pectoris, and untreated arterial hypertension.[6]

In the case of starting with cold showers, the most common adverse reaction is a lingering sensation of cold in the body, hands, and/or feet. Other related harmful effects are mild and not very frequent.[25]

In summary, guidelines for winter swimming also include avoiding alcohol consumption before bathing, being cautious of sudden cooling during immersion, and avoiding overly prolonged stays in cold water, especially in extreme conditions. Regular cold showers and gradual acclimatization can contribute to maintaining safety. It is crucial to monitor the body's reactions and maintain training regularity to prevent the risk of hypothermia and other cold-related conditions.[31]

Summary

The above study provides significant insights into various methods of using cold exposure on the human body. The fundamental physiology of the human response to cold involves a series of adaptive processes, such as vasoconstriction, increased blood pressure, and activation of the sympathetic nervous system. These responses aim to preserve heat and regulate body temperature. However, analyzing both therapeutic aspects, such as cryotherapy, and the body's reactions to other forms of cold over an extended period, we observe promising potential for improving the functioning of various systems, particularly in influencing the nervous system.

Lowering the temperature induces a range of responses within this system: reducing pain perception, preventing brain cell damage, improving cognitive function, positively affecting sleep, and enhancing the condition of individuals with multiple sclerosis. Differences in effectiveness between methods arise from the duration of exposure and the type of cold applied. Discoveries indicate a growing importance of cold therapy as an effective supportive tool, not only in neurology and psychiatry but also in other medical fields.

In conclusion, though there is promising evidence of therapeutic benefits associated with cold exposure, further research is necessary. It is essential to delve into the molecular and neurophysiological mechanisms and develop standardized protocols. Safety aspects and potential contraindications also require detailed analysis. Research should expand to cover additional medical conditions to better understand the full range of therapeutic possibilities associated with cold exposure. Therefore, the continuation of studies is indispensable for a comprehensive understanding and effective utilization of these methods in clinical practice.

Author’s contribution

Conceptualization, Karol Stachyrak, Anna Greguła and Bartosz Mazur; methodology, Dawid Mika; software, Mateusz Pawlicki; check, Dawid Mika, Aleksandra Kłos and Maciej Lambach; formal analysis, Aleksandra Mazurek and Wiktoria Wilanowska; investigation, Kamila Turek and Wiktoria Wilanowska; resources, Aleksandra Mazurek; data curation, Anna Greguła; writing - rough preparation, Karol Stachyrak; writing - review and editing, Maciej Lambach, Kamila Turek; visualization, Karol Stachyrak; supervision, Mateusz Pawlicki; project administration, Dawid Mika; receiving funding, Bartosz Mazur

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