QUALITY IN SPORT

eISSN 2450-3118 · Open Access · Peer-reviewed

apcz.umk.pl/QS Nicolaus Copernicus University in Toruń

BUREK, Rafał, BOCHEN, Jakub, BUDZEŃ, Dominika, ŚMIETANA, Jakub, TOMKIEWICZ-ŚMIETANA, Jagoda and JAWORSKI, Wiktor. Cold-water Immersion as a Form of Body Hardening: a Fad or an Effective Method of Improving Health? A Literature Review. Quality in Sport. 2026;56:72617. https://doi.org/10.12775/QS.2026.56.72617

ARTICLE TIMELINE

Received: 25.05.2026 Revised: 28.05.2026

Accepted: 28.05.2026 Published: 30.05.2026

INDEXING & EVALUATION

MEiN points: 20 Unique ID: 201398

Disciplines: Economics & Finance; Management & Quality Sciences

The journal has been awarded 20 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32553). Unique Journal Identifier: 201398. Scientific disciplines: Economics and Finance (Social Sciences); Management and Quality Sciences (Social Sciences).

Punkty Ministerialne z 2019 – aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

Cold-water Immersion as a Form of Body Hardening: a Fad or an Effective Method of Improving Health? A Literature Review

Rafał Burek[1]

ORCID https://orcid.org/0009-0000-5837-9111

E-mail: rafalburek6@gmail.com

[1]Uniwersytet Medyczny w Lublinie, Lublin, Polska

Jakub Bochen[1]

ORCID https://orcid.org/0009-0007-5853-5410

E-mail: jakubbochen@gmail.com

[1]Uniwersytet Medyczny w Lublinie, Lublin, Polska

Dominika Budzeń[1]
ORCID https://orcid.org/0009-0008-3533-6520
E-mail: budzen.dominika@gmail.com
[1]Uniwersytet Medyczny w Lublinie, Lublin, Polska

Jakub Śmietana[1]
ORCID https://orcid.org/0009-0001-3571-763X
E-mail: Smietana.jakub1@gmail.com
[1]Uniwersytet Medyczny w Lublinie, Lublin, Polska

Jagoda Tomkiewicz-Śmietana[1]
ORCID https://orcid.org/0009-0004-3144-0807
E-mail: Tomkiewiczjagoda@gmail.com
[1]Uniwersytet Medyczny w Lublinie, Lublin, Polska

Wiktor Jaworski[1]
ORCID https://orcid.org/0009-0007-1427-9988
E-mail: wr.jaworski7@gmail.com
[1]Uniwersytet Medyczny w Lublinie, Lublin, Polska

Corresponding Author
Rafał Burek
E-mail: rafalburek6@gmail.com

Abstract

Background

Cold-water immersion, defined as voluntary exposure of the body to cold water, has recently gained popularity as a recreational and lifestyle practice promoted for enhancing immunity, stress tolerance, mental well-being, and recovery. Despite strong public interest and biologically plausible mechanisms involving autonomic, endocrine, thermoregulatory, and immune responses, current clinical evidence remains heterogeneous, protocol-dependent, and limited by methodological weaknesses.

Aim of study

The aim of this narrative review was to synthesize current knowledge on cold-water immersion as a form of "hardening" the organism, with particular focus on physiological mechanisms, potential health benefits, and safety. Specifically, the review sought to evaluate whether cold-water immersion can be regarded as a genuinely health-supporting intervention or mainly as a popular trend shaped by cultural beliefs and social expectations.

Material and methods

A narrative literature review was conducted, including original studies, systematic reviews, meta-analyses, and selected experimental and narrative papers, primarily from the last 10 years, with earlier seminal studies added when essential. The selection focused on adult populations undergoing cold-water immersion, cold baths, or cold showers, with particular attention to healthy individuals and those with minor comorbidities, while studies in athletes were considered separately due to the specific context of post-exercise recovery. Outcomes of interest included physiological variables (e.g. body temperature, blood pressure, heart rate, autonomic responses, inflammatory and immunological markers), as well as subjective stress, sleep quality, well-being, and metabolic indices, with critical assessment of study design, protocol heterogeneity, and clinical relevance.

Results

Cold-water immersion consistently elicited an acute multisystem stress response characterized by sympathetic activation, peripheral vasoconstriction, increases in heart and respiratory rates, and engagement of shivering and non-shivering thermogenesis, including possible activation of brown adipose tissue. Available studies suggested short-term improvements in stress perception, sleep quality, mood, selected cardiovascular and metabolic parameters, and recovery indices, but effect sizes and directions varied across protocols, and robust long-term benefits were not firmly established. The evidence base was limited by small sample sizes, diverse exposure conditions (temperature, duration, frequency), variable participant characteristics, and a paucity of high-quality randomized controlled trials, which constrained generalizability and the formulation of definitive clinical recommendations.

Conclusions

Cold-water immersion represents a biologically plausible stimulus capable of inducing adaptive physiological responses and may confer transient benefits in stress regulation, mental well-being, and selected health-related parameters in some individuals. However, current evidence does not justify viewing cold-water immersion as a universally effective, clinically proven health intervention, and its use should be approached with caution, particularly in people with cardiovascular, respiratory, or other conditions that increase the risk of adverse events. Further high-quality, long-term, controlled studies are required to clarify the magnitude, durability, and safety profile of potential benefits before cold-water immersion can be routinely recommended as a health-supporting strategy.

Key words: cold-water immersion, cold exposure, cold adaptation, cold-water therapy, ice bathing, winter swimming, health benefits, thermoregulation, cardiovascular response, mental health

1. Introduction

Cold-water immersion, defined as the voluntary exposure of the body to cold water, has gained considerable popularity in recent years as a recreational practice and lifestyle element promoted as potentially beneficial for health. In the public domain, it is often attributed with enhancing immunity, increasing stress tolerance, positively influencing mental well-being, and supporting regenerative processes. The interest in this form of cold exposure stems from the belief that a controlled environmental stimulus can trigger adaptive mechanisms that improve overall organism function. At the same time, the growing popularity of the practice has not yet been fully supported by unequivocal, high-quality clinical evidence.

From a physiological perspective, cold is a potent environmental stressor that elicits a multi-systemic response. This includes sympathetic nervous system activation, peripheral vasoconstriction, increased heart rate and respiratory rate, and stimulation of thermoregulatory mechanisms responsible for limiting heat loss and maintaining thermal homeostasis. The response also involves shivering and non-shivering thermogenesis, alongside changes in hormonal regulation, energy metabolism, and immune function. Depending on exposure conditions and individual characteristics, the reaction may produce transient increases in arousal and vigilance, accompanied by subjectively perceived improvements in well-being.

Despite substantial public interest, the health significance of cold-water immersion remains debated. Recent reviews suggest that cold exposure may be associated with certain short-term changes in stress levels, sleep quality, mental well-being, and selected physiological parameters; however, effects appear heterogeneous and protocol-dependent. Some findings derive from studies conducted in individuals habitually acclimated to cold, which complicates direct generalization to the wider population. Consequently, cold-water immersion remains a phenomenon that combines elements of fad, recreation, and potentially biologically plausible intervention, while its true efficacy in improving health requires further verification.

2. Aim of the Study

The aim of this study is to present the current state of knowledge on cold-water immersion (defined as voluntary exposure to cold water) in the context of its potential role as a form of organism hardening. In recent years, interest in this practice has increased substantially among both the general population and individuals seeking non-pharmacological approaches to support health, enhance immunity, reduce stress, and improve overall well-being. However, the rapid rise in popularity has outpaced the accumulation of high-quality scientific evidence, making a critical and systematic overview of the available literature warranted.

The analysis primarily focuses on the physiological mechanisms underlying the cold response, including autonomic nervous system activation, thermoregulation, shivering and non-shivering thermogenesis, and the possible involvement of brown adipose tissue in metabolic adaptation. It also considers evidence regarding effects on the cardiovascular system, inflammatory response, immune function, mental well-being, sleep quality, recovery, and parameters related to physical performance and metabolism. This scope is justified because existing studies indicate that the organism's response to cold is multisystemic and depends on exposure duration, water temperature, and the intervention method.

Particular emphasis is placed on evaluating whether cold-water immersion can be regarded as a genuinely health-supporting strategy or whether it primarily reflects a popular trend, with positive reception partly driven by fad effects, cultural beliefs, and social expectations. On the one hand, recent reviews suggest that cold exposure may induce temporally beneficial effects on stress, sleep quality, health-related quality of life, and select physiological parameters. On the other hand, the evidence base remains limited by the relatively small number of randomized controlled trials, modest sample sizes, protocol heterogeneity, and a lack of representative long-term data. Accordingly, the purpose of this review is not only to describe potential benefits but also to critically assess their clinical relevance.

An additional objective is to identify methodological limitations in existing studies and evaluate the safety of cold-water immersion, particularly in individuals with cardiovascular disease, respiratory disorders, and other conditions that may increase the risk of adverse effects. It is essential to recognize that, despite potential adaptive benefits, cold exposure constitutes a substantial physiological stressor and should not be presented as a risk-free intervention.

3. Methods of the Review

This study is a narrative literature review designed to synthesize current knowledge on cold-water immersion as a form of organism hardening, including an evaluation of potential benefits and risks associated with cold exposure. The adopted methodology aims not only to summarize available data but also to critically examine them in terms of evidence quality, consistency of findings, and methodological limitations in both primary and review studies. Particular attention was directed to publications addressing physiological mechanisms of the cold response, health effects of cold baths and showers, and the safety of the practice across different participant groups.

The review primarily included original studies, systematic reviews, meta-analyses, and selected narrative and experimental studies published within the last 10 years, while also incorporating earlier seminal works when they served as key references for contemporary research. Studies on both single and repeated exposures were considered, including cold-water immersion, cold baths, cold showers, and other forms of cold-water exposure. Selection criteria were primarily: thematic relevance, scientific rigor, availability of full text or reliable abstracts, and significance for assessing biological and clinical consequences of cold exposure.

The selection process focused on adult populations, particularly healthy individuals or individuals with minor comorbidities, as this group most commonly participates in cold-water immersion and forms the basis for many interventional studies. Studies conducted in athletes were analyzed separately, since cold exposure is frequently used in this context for post-exercise recovery, which may influence interpretation of outcomes. Evidence regarding physiological variables, such as body temperature, blood pressure, heart rate, autonomic responses, inflammatory markers, immunological parameters, subjective stress levels, sleep quality, well-being, and metabolic indices was given particular priority.

When interpreting results, the heterogeneity of research protocols was considered, including differences in water temperature, exposure duration, intervention frequency, observation time, and definitions of "cold bath" or "cold-water immersion." Variability in participant characteristics such as age, physical activity level, prior cold exposure history, and comorbidities was also taken into account. Such diversity limits direct comparisons across studies and requires caution when drawing conclusions. Therefore, studies were assessed not only for direction of effect but also for effect magnitude, methodological quality, and potential clinical utility.

The review aimed to extend beyond compiling positive and negative reports by assessing the extent to which available data support interpreting cold-water immersion as a clinically meaningful health-supporting method. Consequently, particular weight was placed on the presence of control groups, randomization, assessor blinding, sample size, observation duration, and reporting practices. This approach enabled a balanced evaluation of the literature, distinguishing biologically interesting effects from those of limited practical relevance.

4. Discussion

Cold-water immersion is defined as voluntary, typically short-term immersion of the whole body or parts of the body, or a brief bath in cold water. In the literature, this concept partially overlaps with cold-water immersion terminology used to describe related practices, including ice baths, cold showers, and immersions in lakes, seas, or specialized low-temperature tanks. In practice, the temperature threshold considered "cold" varies; however, in studies it most commonly ranges up to 15°C, with exposure durations from tens of seconds to several minutes, sometimes longer.

It is important to emphasize that cold-water immersion is not a homogeneous intervention. A single cold shower should be interpreted differently from regular open-water immersion and differently still from exposures applied immediately after exercise. This heterogeneity represents one of the major challenges for comparing study results and formulating unequivocal clinical recommendations.

Direct exposure to cold water induces an abrupt, multisystemic stress response involving sympathetic activation, accelerated heart and respiratory rates, increased peripheral vasoconstriction, and stimulation of complex mechanisms that maintain thermal homeostasis. Physiologically, this is a defensive reaction whose primary goal is to limit heat loss and protect core body temperature from hypothermia. The subjective experience of "arousal" following cold-water immersion may therefore be regarded as a correlate of an acute adaptive response, driven by concurrent autonomic stimulation, heightened vigilance, and increased cardiovascular and respiratory activity.

A fundamental component of this response is cutaneous vasoconstriction, which reduces blood flow in superficial tissues and thereby limits heat loss to the external environment. This mechanism serves as the organism's first line of defense against cold and emerges relatively early in response to peripheral tissue cooling. In practical terms, it involves redistribution of blood flow away from the skin toward deeper structures, favoring thermal stability of internal organs. This phenomenon is particularly relevant during sudden exposures, when the body does not have sufficient time to activate slower adaptive mechanisms.

Concurrently, heat production increases through both shivering and non-shivering thermogenesis. Shivering thermogenesis is associated with involuntary skeletal muscle activity, involving rhythmic muscle contractions whose primary function is heat generation rather than mechanical work. This response may emerge within minutes of cold exposure and is among the most effective means of acutely increasing heat production. As hypothermia progresses, the response strengthens, with magnitude depending on stimulus temperature and exposure modality; contact with cold water typically elicits a stronger reaction than air exposure.

Another important component of the physiological cold response is non-shivering thermogenesis, whose significance has been linked, among other factors, to brown adipose tissue activity. Due to its high capacity for dissipating chemical energy as heat, brown adipose tissue is considered a key element of cold adaptation, particularly under repeated or chronic exposure conditions. The literature suggests that brown adipose tissue may contribute to increased total energy expenditure and improved cold tolerance; however, its role should be interpreted within the context of the entire thermoregulatory system rather than as an isolated mechanism explaining all observed effects. In this sense, cold-water immersion may act as a stimulus that triggers adaptive processes, but it should not be equated with unequivocally proven clinical health benefits.

Cold exposure also influences the cardiovascular system. In response to sudden immersion in cold water, blood pressure may rise, tachycardia may occur, and transient hemodynamic load may increase. These responses are most pronounced during the initial contact phase, before partial adaptation develops. In cases of abrupt immersion, “thermal shock” may occur, characterized by involuntary inspiratory gasping, accelerated breathing, and elevated heart rate. This reaction is reflexive, resulting from intense stimulation of cutaneous receptors by low temperature, which initiates cascades of autonomic and respiratory responses.

As exposure continues, the body transitions from an acute stress response to a more adaptive phase. This process, referred to as habituation or cold acclimatization, involves a progressive attenuation of the physiological response to repeated thermal stimuli. Functionally, it reflects shifts in thermoregulatory reaction thresholds and reduced response amplitude, enabling a more economical cold response with diminished defensive reflexes. In practice, individuals with repeated cold exposure may experience less intense shivering, weaker vascular responses, and reduced subjective discomfort compared with unacclimated individuals.

Cold adaptation does not eliminate defensive responses entirely; instead, it reorganizes and partially “dampens” them to improve tolerance to the stimulus. The literature indicates that habituation is the most commonly observed form of adaptation to chronic low-temperature exposure, affecting both vascular and thermogenic reactions. Depending on stimulus nature and frequency, adaptation may improve cold tolerance; however, implications for overall health remain under investigation. It is essential to differentiate physiological adaptation from clinically meaningful changes in health-related parameters, since the former does not automatically translate into the latter.

It is also noteworthy that the trajectory of the cold response depends on the exposure modality. Cold air exposure produces a different profile from water immersion, largely because water’s higher thermal conductivity causes faster heat loss and greater thermal strain. Therefore, cold-water immersion should be considered a particularly potent environmental stimulus capable of inducing marked changes in circulation, respiration, and thermoregulation. The intensity of this response may make the practice potentially useful as an adaptive stimulus, but it also necessitates caution especially in individuals with cardiovascular disease or reduced compensatory capacity.

One of the most discussed effects of cold exposure concerns the immune system. The latest systematic review and meta-analysis suggested that cold bathing is associated with a transient increase in inflammatory markers immediately after exposure and approximately one hour later, indicating an acute pro-inflammatory response in the immediate phase rather than a suppressive effect. Positive signals regarding well-being and stress emerged later.

Older reviews analyzing more than one hundred studies reported changes in biochemical and physiological parameters related to cold exposure, although clinical significance often remained equivocal. Notably, some data come from "winter swimmers," i.e., individuals long acclimated to cold, while other findings involve novices, which further complicates interpretation. Accordingly, cold-water immersion cannot yet be claimed to reliably and universally "boost immunity."

The influence of cold exposure on inflammatory and immune systems is complex and contingent on stimulus dose, immersion duration, water temperature, prior acclimatization, and the characteristics of the studied population. Mechanistically, cold acts as a potent environmental stressor, activating not only thermoregulatory mechanisms but also neuroendocrine and immune responses. Recent data indicate that immediately after cold-water exposure, acute transient activation of inflammatory markers occurs rather than immediate suppression. A 2025 meta-analysis reported significant elevation of an inflammation index directly after the bath and one hour thereafter, suggesting that the initial phase reflects adaptive stress rather than classic anti-inflammatory action.

Mechanistically, sympathetic activation and subsequent catecholamine release primarily noradrenaline are important. This signaling may modulate immune cell function through adrenergic receptors, influencing leukocyte trafficking, natural killer (NK) cell activity, and cytokine profiles. The literature describes that short-term cold exposure may lead to transient increases in circulating leukocytes and enhanced NK cell activity, interpreted as stress-induced redistribution of immune cells. However, these mobilization effects should not be conflated with enduring "immunity strengthening," since changes are predominantly short-lived and do not consistently translate into clinically relevant endpoints.

Cytokine findings remain inconsistent and protocol-dependent. Some studies report elevations in pro-inflammatory mediators such as IL-6 or TNF-
α
α, especially after longer or more intense exposures, reflecting stress responses and downstream metabolic processes rather than full-blown inflammation. Conversely, other studies suggest that regular moderate exposure may shift the immunological balance toward controlled inflammation, potentially involving anti-inflammatory cytokines such as IL-10. Overall, the evidence supports the conclusion that cold exposure modulates immune responses, but not in a unidirectional or automatically beneficial manner.

It is crucial to distinguish effects following acute single interventions from those observed after multi-week or multi-month hardening programs. Acute exposure more frequently triggers stress-related responses, including transient inflammatory marker elevation and mobilization of effector immune cells. In contrast, studies in regular cold-bath practitioners report certain systemic benefits, such as reduced oxidative stress markers and improved indices of immunological balance. Nonetheless, the evidence remains insufficient to support unequivocal recommendations regarding infection prevention or inflammation treatment.

The most recent systematic review also suggests that participant-reported benefits may be partially delayed and context-dependent. The 2025 analysis found no significant effects on immune function immediately after cold bathing or one hour later; however, narrative synthesis reported reduced sickness absence among cold shower users. This implies that potential clinical relevance may emerge not from immediate immunological shifts, but from longer-term modulation of health behaviors, stress resilience, and subjective well-being.

Because some evidence comes from small samples and often without robust control of confounders, these findings should be interpreted with caution. Prior physical activity, diet, sleep patterns, fitness status, cold acclimatization, and seasonal timing may all influence outcomes. Therefore, immunological changes should be viewed as evidence that cold can modulate biological responses rather than as unequivocal evidence of pro-health action.

Cold exposure elicits a distinct but complex inflammatory and immune response, characterized by acute stress-related changes and adaptive alterations over time. The observed changes include short-term leukocyte mobilization, NK cell activation, and cytokine fluctuations.

Although regular hardening may lead to beneficial adaptations in some individuals, current knowledge does not support the claim that cold-water immersion reliably and universally strengthens the immune system. More precisely, cold modulates immune responses, with effects depending on dose, exposure duration, and individual traits.

In mental health research, cold-water immersion generates substantial interest because many individuals report improved mood, reduced tension, and enhanced psychological resilience after immersion. The latest meta-analysis suggests significant stress reduction approximately 12 hours after exposure, with no consistent changes immediately thereafter. This pattern indicates that effects may be delayed and dependent on assessment timing.

Some reported benefits may also reflect non-physiological factors. Ritual, group belonging, sense of agency, health beliefs, and positive expectations can influence outcomes. In practice, these influences may produce placebo-dependent effects. While this does not negate perceived improvements, it does require caution when attributing effects solely to the biological action of cold.

Cold exposure's impact on stress, mood, and mental well-being is among the most frequently cited arguments by proponents, yet the empirical evidence remains limited and equivocal. Recent studies caution against describing cold bathing as a universal mental health intervention; instead, it may act as a stimulus that modulates subjectively experienced stress and certain well-being indicators, particularly in the short term. Mechanistically, this may relate to acute sympathetic activation, stimulation of the stress axis, and subsequent autonomic modulation, including possible post-reaction parasympathetic up-regulation.

Physiologically, cold acts as a potent environmental stressor that compels rapid adaptive responses. Acute contact with cold water increases arousal, elevates vigilance, and intensifies subjective "alarm" responses, which some interpret as refreshment or mood uplift. However, this does not necessarily translate into enduring mental health improvement. Reviews suggest that post-cold stress reduction may be delayed rather than immediate, reflecting complex psychophysiological dynamics. Practically, the immediate organism response may represent a "cost" rather than a benefit, while relaxation may emerge hours later.

A key interpretive issue is distinguishing genuine biological effects from participant subjective assessments. Studies on cold showers and baths often report improvements in self-reported well-being; however, such data are susceptible to expectation effects, placebo influences, participant selection, and social context. Regular participants may also differ in baseline traits such as physical activity levels, discomfort tolerance, and pro-health motivation, complicating causal attribution to cold exposure alone. Therefore, positive self-reports should be considered supportive evidence, but they do not by themselves constitute proof of efficacy.

Recent literature also explores potential links between cold exposure and autonomic regulation, including vagal function. Although evidence varies in strength, controlled cold stimulation may under certain conditions induce a transient post-exposure shift toward parasympathetic activity, which could correlate with reduced tension and improved recovery. This aligns with the concept of hormesis, whereby a moderate stressor triggers adaptations that enhance tolerance to subsequent loads. Nevertheless, this remains a working hypothesis rather than proof of clinically meaningful mental health benefits across all individuals.

Regarding mood outcomes, findings are moderately promising but heterogeneous. Some analyses suggest modest improvements in quality of life and well-being after regular cold-water exposure, while others report no significant changes in mood, anxiety, or depressive symptoms. Discrepancies may reflect differences in timing of assessment, duration of intervention, participant characteristics, and measurement tools. Short-term studies more often evaluate immediate post-exposure sensations, whereas longer studies frequently show attenuation of effects after weeks or months. This suggests that mood improvements may be transient rather than stable.

Cold-water immersion also has a social and behavioral dimension. For many people, it functions as a ritual combining effortful exposure, high-intensity stimulus engagement, and communal elements. Such context may strengthen agency, belonging, and perceived control over the body, thereby indirectly supporting mental well-being. Clinically, however, it is important not to conflate short-term perceived improvement with proven therapeutic efficacy in depression, anxiety, or chronic stress disorders.

Overall, current data suggest that cold exposure may be associated with transient reductions in subjective stress, improvements in vigilance, and modest mental well-being gains in some individuals. Effects appear nonspecific, timing-dependent, and strongly influenced by context. At the current state of knowledge, cold-water immersion should be viewed as potentially supportive but not a primary or universal psychological intervention. Well-designed long-term randomized studies are clearly needed to disentangle true physiological effects from expectation effects and environmental influences.

Sleep quality is another frequently cited domain. Current systematic reviews suggest possible improvements in sleep quality after cold exposure, although data are limited and few studies provide robustly controlled designs. A plausible explanation is that cold may reduce mental tension, shift autonomic arousal, and influence evening routines, which could indirectly support better sleep onset in some individuals.

However, this does not justify treating cold-water immersion as a standard sleep intervention. Overly late exposure to a potent stressor may increase arousal and delay sleep onset in some people. Therefore, sleep outcomes require individualized consideration, and conclusions should remain cautious given the quality of available evidence.

One of the most commonly claimed but least substantiated effects concerns sleep quality and broader "regeneration." The literature suggests that regular cold-water immersion may improve subjective sleep quality, shorten sleep latency, and increase perceived post-night refreshment. Yet these claims are constrained by a small number of studies, limited sample sizes, and protocol heterogeneity. Practically, cold's influence on sleep appears to depend strongly on exposure timing, intensity, and individual responsiveness. In some cases, particularly with late-evening exposures or high-arousal cold stimuli, it may counteract intended effects by increasing wakefulness rather than promoting relaxation.

Mechanistically, regeneration-related benefits may relate to transient autonomic modulation, reduced post-exposure tension, and a subjective sense of "physiological resetting." Cold may also influence perceived fatigue, especially after exercise, through reduced discomfort, limitation of overheating sensations, or increased "freshness." However, these short-term effects should not be conflated with objectively confirmed cellular or tissue-level repair processes. Post-exercise recovery studies most often attribute benefits to reductions in subjective discomfort rather than unequivocally demonstrated long-term improvements in health parameters.

Sleep effects may follow a biphasic pattern. The initial phase involves sympathetic arousal, increased respiratory rate, and heightened wakefulness, which can hinder sleep onset if exposure is intense or occurs close to bedtime. Only after stimulus offset and the transition to recovery-related physiological states may relaxation and psychophysical tension reduction occur. Therefore, cold-water immersion should not be portrayed as a universal sleep improver, but as an intervention that may indirectly support regeneration in some individuals under appropriate conditions and with consideration of individual tolerance. Given current knowledge, the most cautious interpretation is that cold exposure may support subjectively perceived regeneration, but lacks robust clinical documentation as a method of improving sleep quality or enabling biological renewal.

Another argument discussed by proponents relates to physical performance and metabolism. Physiologically, cold does increase energy demand to maintain thermal homeostasis. Theoretically, this may support energy expenditure and contribute to improved cold tolerance.

However, there is no basis for claiming that cold-water immersion is an effective weight-loss method per se. Available sources emphasize that metabolic effects, if present, are adjunctive rather than comparable to the magnitude of effects achievable through diet and exercise. Similarly, regarding physical performance, cold exposure may aid post-exercise recovery but does not replace training, nor does it universally improve fitness.

Cold exposure affects energy metabolism and exercise capacity in complex ways, largely depending on stimulus intensity, duration, degree of acclimatization, and baseline physiological state. In the short term, cold constitutes a potent thermal stressor that increases heat production and drives shifts in energy substrate utilization. Over time, repeated exposure may enable partial metabolic adaptation; however, existing data do not support framing cold-water immersion as a simple universal solution for improving performance or facilitating weight reduction.

Acutely, cold increases energy expenditure via shivering and non-shivering thermogenesis to sustain thermal homeostasis. Physiological studies show that cold exposure significantly increases heat production and substrate oxidation including glucose, muscle glycogen, and lipids. This shifts the organism into a more resource-demanding utilization mode, which may increase energy burn but also imposes metabolic load. Practically, increased expenditure does not necessarily translate into sustained weight loss without corresponding changes in energy balance, activity patterns, and diet.

Brown adipose tissue is thought to play an important role in these processes through non-shivering thermogenesis. Contemporary reviews indicate that chronic or repeated cold exposure may enhance brown adipose tissue activity and promote beige adipocytes in white adipose tissue, theoretically increasing heat-producing capacity. Nonetheless, the magnitude and significance of these adaptations in humans remain under investigation, and long-term effects on metabolic health indices have not been established. In other words, brown adipose tissue activation is a biologically intriguing mechanism, but it is not yet confirmed as a clinically significant, population-wide contributor to metabolic improvement.

Regarding energy substrates, cold may promote both carbohydrate and fat utilization. Physiological data indicate increased glucose and glycogen oxidation during cold exposure, while shivering-related metabolism may involve lipid utilization as well. Performance-wise, the effects are ambivalent: while cold helps maintain heat, it can also accelerate depletion of reserves and impair tolerance to prolonged effort. During exercise in cold, muscle heat production partly compensates; however, greater hypothermia may reduce muscle flexibility, impair neuromuscular conduction, and increase locomotor fatigue.

Concerning physical performance outcomes, recent reports suggest that cold exposure may be more limiting than enhancing, particularly in unacclimated individuals. Acutely, cold may reduce muscle strength, coordination, and reaction speed, and shivering can increase the energetic cost of movement. This implies that cold exposure should not be treated as an immediate improvement of physical capacity. Moreover, uncontrolled exposure may transiently impair motor efficiency and increase injury risk. Therefore, potential benefits of cold-water immersion are more plausibly related to adaptation and recovery rather than to immediate fitness gains.

Long-term metabolic adaptation data are somewhat more promising but still equivocal. Recent-year reviews suggest that chronic cold exposure may associate with increased basal metabolic rate, improved mitochondrial activity, and hormonal shifts involving catecholamine and thyroid systems. These changes could support cold tolerance and improved thermal economy;

however, clinical significance depends on the broader lifestyle context, including physical activity, body mass, and nutrition. Practically, cold-water immersion may function as a metabolic adaptation stimulus but should not be viewed as a standalone obesity treatment or general fitness strategy.

Cold exposure increases the organism's energetic demands and activates multiple thermogenic pathways involving shivering, brown adipose tissue, and shifts in substrate utilization. At the same time, acute performance impacts may be disadvantageous, while potential metabolic benefits appear to arise mainly from longer-term adaptation in selected populations. Thus, cold-water immersion can be described as a biologically interesting intervention, but not as a reliable universal strategy for improving performance or metabolism.

Randomized controlled trial data suggest that the health impact of cold exposure is complex and depends on intervention type and chosen endpoints. A frequently cited example is the randomized trial by Buijze et al., evaluating health outcomes and sick leave in adult workers following cold showers. The authors reported that the cold-shower group experienced fewer sick leave episodes, a statistically significant effect for episode count, though not for total days. This suggests a possible influence on subjective work readiness and daily functioning, but it does not constitute direct evidence of immunity strengthening.

Conversely, a 2025 systematic review including 11 studies and 3177 participants suggested that cold bathing may be associated with transient improvements in well-being, reduced stress, and better sleep quality; however, effects were heterogeneous and dependent on timing after exposure. This analysis did not detect consistent immediate anti-inflammatory effects or uniform improvements in measured health parameters. Thus, randomized trials support certain short-term effects, but they do not allow strong conclusions regarding enduring pro-health efficacy for cold-water immersion.

Metabolism-related randomized evidence remains even more limited. While cold exposure studies indicate activation of brown adipose tissue and increased energy expenditure, most protocols are short and vary in intensity, with seldom producing enduring weight-loss effects. Practically, randomized interventions show modest transient metabolic changes rather than substantial improvements in body weight or performance. Some evidence also suggests that regular cold bathing after strength training may attenuate hypertrophic adaptations, which may be relevant for elite athletes and individuals performing resistance training.

Randomized studies confirm that cold exposure is a potent biological stimulus producing measurable physiological effects, but the clinical relevance remains limited. The most credible data suggest possible benefits regarding subjective well-being, sick leave, recovery, and certain aspects of metabolism; evidence for sustained improvements in immunity, performance, or weight remains inadequate.

Despite increasing popularity, cold-water immersion is not risk-free and may pose substantial health burden in selected groups. Primary hazards stem from abrupt sympathetic activation, peripheral vasoconstriction, increased blood pressure, tachycardia, and respiratory reactions sometimes described as thermal shock. Acute responses following sudden cold-water immersion may include involuntary gasping, hyperventilation, perceived dyspnea, transient hemodynamic load increase, and other adverse reactions, raising the risk in individuals with cardiovascular disease.

Particular caution is advised for individuals with coronary artery disease, heart failure, hypertension, arrhythmias, and other cardiovascular conditions. Sudden cold exposure may exacerbate blood pressure fluctuations, provoke rhythm disturbances, or trigger ischemic symptoms. Reviews of voluntary cold exposure emphasize that risk is not determined solely by thermal stimulus, but also by exposure context, such as time in water, ambient temperature, supervision, and the degree of acclimatization.

Significant contraindications include peripheral circulation disorders, such as Raynaud's phenomenon and other conditions characterized by excessive vasoconstriction. In these cases, cold may intensify vasospasm, leading to limb pain, numbness, pallor, and rarely tissue ischemia in extremities. Cold exposure may also be problematic in peripheral artery disease, lower-limb atherosclerosis, and individuals prone to cold injury. In practical terms, a stimulus that is adaptive for healthy individuals may trigger undesirable hemodynamic reactions in patients with vascular disease.

Another risk group includes individuals with asthma or bronchial hyperreactivity, particularly if cold induces bronchospasm or worsens symptoms. Sudden exposure can lead to hyperventilation and a “breathlessness” sensation, amplifying discomfort and potentially triggering panic. Therefore, cold baths are generally inadvisable for patients with unstable respiratory disease, especially those with prior cold-induced symptoms.

Evidence-based materials also recommend caution following recent infections, general debility, insufficient recovery, and chronic disease states associated with reduced exercise tolerance or impaired physiological resilience. Cold exposure requires adequate thermal and circulatory compensation; limited adaptive reserves increase the risk of undesirable reactions. Hence, caution should extend to elderly individuals, those who are frail or cachectic, those who are dehydrated, and generally weakened individuals.

The risk of hypothermia, especially with prolonged water exposure, excessively low temperatures, lack of supervision, or overestimation of one’s tolerance, cannot be ignored. Even if the initial arousal feeling occurs, longer exposure can reduce core temperature substantially, impair coordination, slow reaction times, and cause severe alterations in consciousness. In practice, safety depends not only on health status but also on gradual titration of the stimulus, short initial exposures, and ensuring appropriate supervision.

Randomized and systematic reviews increasingly emphasize the lack of a universal “safe protocol.” Interventions that may be relatively safe for well-prepared healthy individuals may be inappropriate for patients with chronic disease. Consequently, cold exposure should be individually qualified rather than promoted as universal health prophylaxis.

Cold-water immersion currently lies at the intersection of cultural trend and partly documented biological intervention. The increase in popularity is driven by easily accessible methods that are believed to enhance immunity, mood, recovery, and stress tolerance. In contrast, scientific evidence confirms that cold exposure triggers measurable physiological responses, but its clinical significance appears far less certain than public discourse suggests.

Most credible randomized and systematic reviews indicate potential positive effects mainly in the short term, targeting selected endpoints such as subjective stress, well-being, sick leave, and post-exercise recovery. There is no consistent evidence for sustained immunity enhancement, universal mood improvements, or reduced risk of chronic diseases. Therefore, cold-water immersion is neither a baseless fad nor a fully validated broad pro-health method.

Notably, some attributed benefits may be driven by contextual effects combining physical stimulus with agency, regularity, group belonging, and health-related convictions. For many, systematic engagement in effortful discomfort may also support other pro-health behaviors, such as exercise, improved sleep habits, or mindful recovery practices. Thus, cold-water immersion may play a supportive role, with efficacy not attributable solely to the cold stimulus itself but also to co-occurring behaviors and expectations.

Scientifically, the most defensible position is to treat cold-water immersion as a potentially useful yet insufficiently verified strategy for well-being support. Where discussed, efficacy should be framed with clear limits: potential improvements may concern select and often subjective parameters rather than universal, reliable health outcomes. From a social perspective, the practice exhibits fad-like characteristics, but it is nevertheless grounded in real physiological mechanisms that do not always translate into clinically significant benefits.

5. Limitations of Evidence

The greatest issue in the cold-water immersion literature is methodological heterogeneity. Studies differ in water temperature, exposure duration, repetition frequency, intervention setting, and participant characteristics. Some studies focus on athletes, others on healthy individuals, and still others involve individuals already acclimatized to cold.

Another limitation is the predominance of subjective endpoints, such as well-being, stress, or quality of life. These outcomes are clinically relevant, yet they remain susceptible to expectation bias and placebo effects. Moreover, large-scale long-term studies are lacking, which would be necessary to evaluate whether regular cold-water immersion reduces chronic disease incidence, improves survival, or alleviates overall healthcare burden.

6. Conclusions

Cold-water immersion as a form of organism hardening has physiological plausibility and may induce beneficial short-term changes in subjective well-being, stress levels, and select physiological parameters. Available evidence suggests, however, that these effects are modest, protocol-dependent, and heterogeneous across populations. There are currently insufficient grounds to recognize cold-water immersion as a universal health-improvement method.

In practice, cold-water immersion may be regarded as a potentially beneficial lifestyle element for healthy, well-prepared individuals, but not as a substitute for established primary prophylaxis or treatment. From a scientific perspective, larger, long-term, well-designed randomized controlled trials are needed to clearly establish the scope of benefits and risks.

Author Contributions

Conceptualization: Rafał Burek, Jakub Bochen, Dominika Budzeń,
Methodology:Rafał Burek, Jakub Bochen, Dominika Budzeń
Formal analysis: Rafał Burek, Jakub Śmietana, Wiktor Jaworski
Investigation: Rafał Burek, Jakub Bochen, Jagoda Tomkiewicz-Śmietana
Resources: Rafał Burek, Jagoda Tomkiewicz-Śmietana
Data curation: Rafał Burek, Jakub Bochen, Wiktor Jaworski
Writing – rough preparation: Rafał Burek, Jakub Bochen, Dominika Budzeń, Jakub Śmietana
Writing – review and editing: Rafał Burek, Jakub Bochen, Dominika Budzeń
Visualization: Rafał Burek, Dominika Budzeń, Jakub Śmietana
Supervision: Jakub Bochen
Project administration: Rafał Burek
All authors have read and agreed with the published version of the manuscript.

Funding statement:

No external funding was received to perform this review.

Institutional Review Board Statement:

Not applicable

Informed Consent Statement:

Not applicable

Data Availability Statement:

Not applicable

Conflict of Interest Statement:

The authors declare no conflict of interest.

References

1. Boulares A, Jdidi H, Douzi W. Cold and longevity: Can cold exposure counteract aging? Life Sci. 2025 Mar 1;364:123431. https://doi.org/10.1016/j.lfs.2025.123431 Epub 2025 Jan 28. PMID: 39884345.
2. Broatch JR, Petersen A, Bishop DJ. The Influence of Post-Exercise Cold-Water Immersion on Adaptive Responses to Exercise: A Review of the Literature. Sports Med. 2018 Jun;48(6):1369-1387. https://doi.org/10.1007/s40279-018-0910-8 PMID: 29627884.
3. Buijze GA, Sierevelt IN, van der Heijden BC, Dijkgraaf MG, Frings-Dresen MH. The Effect of Cold Showering on Health and Work: A Randomized Controlled Trial. PLoS One. 2016 Sep 15;11(9):e0161749. doi: 10.1371/journal.pone.0161749. Erratum in: PLoS One. 2018 Aug 2;13(8):e0201978. https://doi.org/10.1371/journal.pone.0161749 PMID: 27631616; PMCID: PMC5025014.
4. Cain T, Brinsley J, Bennett H, Nelson M, Maher C, Singh B. Effects of cold-water immersion on health and wellbeing: A systematic review and meta-analysis. PLoS One. 2025 Jan 29;20(1):e0317615. https://doi.org/10.1371/journal.pone.0317615 PMID: 39879231; PMCID: PMC11778651.
5. Didehdar D, Sobhani S. The effect of cold-water immersion on physical performance. J Bodyw Mov Ther. 2019 Apr;23(2):258-261. https://doi.org/10.1016/j.jbmt.2018.05.001 Epub 2018 May 31. PMID: 31103105.
6. Duffin J, Miller R, Romet TT, Chant RW, Ackles K, Goode RC. Sudden cold water immersion. Respir Physiol. 1975 Apr;23(3):301-10. https://doi.org/10.1016/0034-5687(75)90080-8 PMID: 1144945.
7. Esperland D, de Weerd L, Mercer JB. Health effects of voluntary exposure to cold water - a continuing subject of debate. Int J Circumpolar Health. 2022 Dec;81(1):2111789. https://doi.org/10.1080/22423982.2022.2111789 PMID: 36137565; PMCID: PMC9518606.
8. Galvez-Rodriguez C, Valenzuela-Reyes P, Fuentealba-Sepúlveda S, Farias-Valenzuela C, Salinas AE. Cold Water Immersion, Heart Rate Variability and Post-Exercise

Recovery: A Systematic Review. Physiother Res Int. 2025 Apr;30(2):e70033. https://doi.org/10.1002/pri.70033 PMID: 39918163.

9. Grigg MJ, Thake CD, Allgrove JE, Broom DR. Effects of cold-water immersion on energy expenditure, ad-libitum energy intake and appetite in healthy adults. Physiol Behav. 2025 Jul 1;296:114914. https://doi.org/10.1016/j.physbeh.2025.114914 Epub 2025 Apr 10. PMID: 40221072.
10. Haman F, Péronnet F, Kenny GP, Massicotte D, Lavoie C, Scott C, Weber JM. Effect of cold exposure on fuel utilization in humans: plasma glucose, muscle glycogen, and lipids. J Appl Physiol (1985). 2002 Jul;93(1):77-84. https://doi.org/10.1152/japplphysiol.00773.2001 PMID: 12070189.
11. Higgins TR, Greene DA, Baker MK. Effects of Cold Water Immersion and Contrast Water Therapy for Recovery From Team Sport: A Systematic Review and Meta-analysis. J Strength Cond Res. 2017 May;31(5):1443-1460. https://doi.org/10.1519/jsc.0000000000001559 PMID: 27398915.
12. Lipińska, J., Kowalczuk, M., Lipiński, Łukasz, Kopeć, I., & Margas, M. (2024). Health effects of cold water immersion and swimming and its influence on the human body. *Journal of Education, Health and Sport*, *52*, 155–168. https://doi.org/10.12775/JEHS.2024.52.011
13. Li Y, Wu J, Xu Y, Dong J, Xing B, Wang Y, Zhou Z, Sun B, Li J, Yu L, Wang H. Cold exposure and the cardiovascular system: from physiological adaptation to pathological risk. Front Physiol. 2026 Jan 7;16:1740919. https://doi.org/10.3389/fphys.2025.1740919 PMID: 41574187; PMCID: PMC12819719.
14. Peake JM, Roberts LA, Figueiredo VC, Egner I, Krog S, Aas SN, Suzuki K, Markworth JF, Coombes JS, Cameron-Smith D, Raastad T. The effects of cold water immersion and active recovery on inflammation and cell stress responses in human skeletal muscle after resistance exercise. J Physiol. 2017 Feb 1;595(3):695-711. https://doi.org/10.1113/jp272881 Epub 2016 Nov 13. PMID: 27704555; PMCID: PMC5285720.
15. Reed EL, Chapman CL, Whittman EK, Park TE, Larson EA, Kaiser BW, Comrada LN, Wiedenfeld Needham K, Halliwill JR, Minson CT. Cardiovascular and mood responses to an acute bout of cold water immersion. J Therm Biol. 2023 Dec;118:103727. https://doi.org/10.1016/j.jtherbio.2023.103727 Epub 2023 Oct 14. PMID: 37866096; PMCID: PMC10842018.

16. Srámek P, Simecková M, Janský L, Savlíková J, Vybíral S. Human physiological responses to immersion into water of different temperatures. Eur J Appl Physiol. 2000 Mar;81(5):436-42. https://doi.org/10.1007/s004210050065 PMID: 10751106.
17. Tipton MJ, Collier N, Massey H, Corbett J, Harper M. Cold water immersion: kill or cure? Exp Physiol. 2017 Nov 1;102(11):1335-1355. https://doi.org/10.1113/ep086283. Epub 2017 Sep 21. PMID: 28833689.
18. Tipton MJ. The initial responses to cold-water immersion in man. Clin Sci (Lond). 1989 Dec;77(6):581-8. https://doi.org/10.1042/cs0770581; PMID: 2691172.
19. Wang Y, Liu W, Han D, Qiao Y, Sun W, Wang C, Qin X, Xu J. Integrated effects of cold acclimation: physiological mechanisms, psychological adaptations, and potential applications. Front Physiol. 2025 Jul 2;16:1609348. https://doi.org/10.3389/fphys.2025.1609348; PMID: 40671705; PMCID: PMC12263699.
20. Versteeg N, Clijsen R, Hohenauer E. Effects of 3-week repeated cold water immersion on leukocyte counts and cardiovascular factors: an exploratory study. Front Physiol. 2023 Aug 29;14:1197585. https://doi.org/10.3389/fphys.2023.1197585; PMCID: PMC10497764.
21. Yurkevicius BR, Alba BK, Seeley AD, Castellani JW. Human cold habituation: Physiology, timeline, and modifiers. Temperature (Austin). 2021 May 25;9(2):122-157. https://doi.org/10.1080/23328940.2021.1903145. PMID: 36106151; PMCID: PMC9467574.