Cold therapy: the facts, the myths, and the how-to

PA **peterattiamd.com**/cold-therapy

Peter Attia September 26, 2024

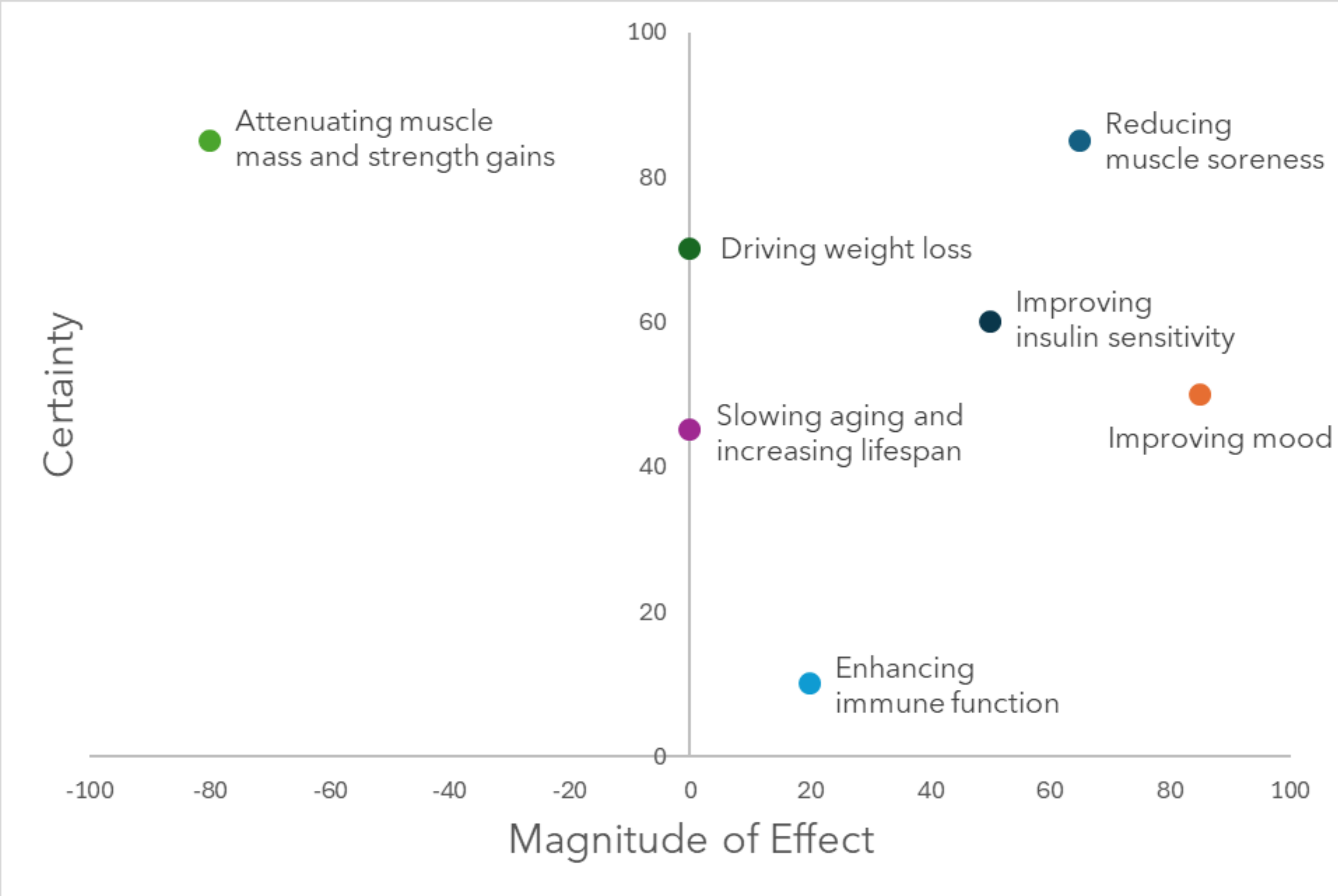

Figure: The benefits and risks of cold therapy, charted by magnitude of effect and certainty of evidence. Magnitude and certainty for each benefit are assessed relative to the magnitude and certainty for other benefits of cold therapy.

Cold therapy has seen a remarkable surge in popularity over recent years. From ice baths and cold plunges to whole-body cryotherapy, these practices are being embraced by a growing number of people seeking to enhance their physical and emotional well-being. Advocates tout a range of benefits–including reduced inflammation, accelerated recovery, improved mood, and even the L-word (“longevity”)–that make cold therapy an appealing addition to one’s health regimen. But as bold claims continue to circulate, it’s worth asking: Are these benefits supported by solid evidence?

Today’s premium newsletter delves into the science behind cold therapy, aiming to assess cold therapy’s benefits and drawbacks. Additionally, we scrutinize the scientific backing for specific cold therapy protocols, providing a clear and comprehensive understanding of what cold therapy can realistically achieve for your health.

What is cold therapy?

Cold therapy encompasses a variety of techniques aimed at exposing the body to cold temperatures to trigger physiological responses that may improve various aspects of health. Purported benefits range from physical to psychological, from short-term to long-term. But what are the mechanistic underpinnings through which cold therapy may exert these effects?

As we discussed in detail in our previous article on [sauna use](), the human body must maintain a temperature of around 37±0.5°C (98.6±0.9°F), which corresponds to the temperature at which most of our enzymes (the proteins that catalyze nearly every biochemical process in the body) function most optimally. Significant deviations below this optimal temperature slow enzymatic activity and thus disrupt countless processes critical for survival, which is why hypothermia (defined as a drop in body temperature below 35°C, or 95°F) will, if left untreated, lead to multi-organ failure and death.[1] Thus, survival necessitates that the body have various means of reacting to inevitable changes in external temperature in order to maintain a safe *internal* temperature. With regard to the physiological stress of cold exposure, these bodily adaptations include changes in cardiovascular dynamics for heat conservation and activation of heat-generating processes such as shivering.

When acutely exposed to cold, skin temperature drops, which triggers a reflex activation of the body's nervous system to cause vasoconstriction (i.e., tightening of the blood vessels) in the skin and peripheral areas like the hands and feet (whereas in the core regions, vessels dilate, enhancing blood flow to essential organs).[2] This thermoregulatory response reduces the amount of heat lost to the body's surroundings, but as vessels constrict, greater pressure is required to pump blood throughout the body. During such conditions, blood pressure can therefore rise by approximately 5 to 30 mmHg in systolic measurements and 5 to 15 mmHg in diastolic measurements.[3] This dynamic shift not only aids in thermoregulation but is also thought to facilitate the elimination of metabolic waste from muscle tissues, potentially alleviating inflammation and expediting recovery from muscular stress.[4,5]

In addition to heat *conservation* through peripheral vasoconstriction, the body also responds to cold exposure by activating processes for heat *generation*. The primary mechanism for heat generation (i.e., "thermogenesis") in adult humans is shivering, which can increase heat production relative to basal metabolic rate by up to 400%.[6] Non-shivering thermogenesis is also possible through activation of "brown fat" – a more mitochondria-rich and metabolically active form of fat than the more familiar "white fat." This process involves the breakdown of triglycerides by brown fat cells in a manner that is uncoupled from cellular energy production – thus, all energy generated by these catabolic reactions is released as heat. While we know that infants and children can produce considerable heat through activation of ample brown fat depots, this mechanism for heat generation is fairly minor after adolescence, as most brown fat is lost by adulthood.

These adaptations are mediated by various neuroendocrine pathways that are activated in response to cold, and it is these neural and hormonal responses that are thought to underlie many of the proposed benefits of cold therapy. For instance, the hormone norepinephrine (also known as noradrenaline) plays a pivotal role in vasomotor responses to cold but additionally contributes to pain reduction, mood elevation, and enhanced cognitive function, underscoring its integral role in the body's adaptive response to cold-induced stress.[4]

What are the main types of cold therapy?

The primary methods of cold exposure therapy are cold water immersion (CWI) and whole body cryotherapy (WBC), each typically utilizing different protocols regarding exposure, temperature, and duration.

CWI involves submerging the body in cold water, typically between ~40-70°F (5-20°C). The duration of immersion can vary: at warmer temperatures within this range, sessions may last up to 30 minutes, while at the colder end, immersion times are generally much shorter. Practices often include brief, repeated immersions of about two minutes or single immersions up to a maximum of 15 minutes. The level of submersion can also differ based on the intended therapeutic outcomes–ranging from waist-high, commonly used after lower-body exercises, to head-out immersion up to the chest or neck.

In contrast, WBC employs specially designed cryogenic chambers to expose the body to much colder air temperatures, typically between -166°F and -256°F (-110°C to -160°C), for a shorter duration of only 2-3 minutes. This extreme cold is necessary because the thermal conductivity of air is so much lower than that of water–approximately 25 times less–meaning that the body cools much more slowly in air. Participants in WBC sessions wear protective clothing, including gloves, socks, underwear, and clogs, to prevent frostbite and other cold-related injuries.

Two (mega) challenges of interpreting this body of literature

Before we get to the clinical data, we need to point out the very, very large elephant standing naked (of course) in the very, very small room. A seismic limitation to studying cold (or heat) interventions is that blinding is impossible. Participants know whether they are receiving a cold exposure intervention versus a control intervention at higher temperatures (or no intervention at all) because they can *feel* it. This opens the door for placebo effects to have a substantial influence on results, especially when the outcome of interest is *subjective*. (This is something sauna studies have going for them – most of the outcomes of interest are at least objective, such as mortality.)

If that isn't a large enough concern, cold therapy literature is also plagued by a dose-duration problem. Unlike the sauna literature in which temperature and time are more convergent, the cold literature is all over the place in terms of therapeutic temperatures and session durations (as you'll see below). There appears to be no "standardization" protocol to normalize interventions and allow for easier comparison across studies, and the list of variables that can vastly alter cooling dynamics is long – indeed, longer than the list of variables that can be modulated with sauna treatments.

Evidence for the benefits of cold therapy

As we mentioned earlier, the alleged benefits of cold therapy are varied, including accelerated recovery post-exercise, mood enhancement, improvements in immune function, facilitation of weight loss through increased energy expenditure, and even the holy grail of all benefits: geroprotection (i.e., longevity). We will discuss all of these in turn to evaluate the level of confidence we can have in each based on existing evidence.

A brief introduction to "standardized mean difference"

Before we start our discussion of each potential health domain impacted by cold therapy, we must first provide a brief introduction to a particular statistical measure that is common in cold therapy literature. "Standardized mean difference," or SMD, is indicative of the *size* of the effect of a given intervention. Often used in meta-analyses to compare results across individual studies, SMD is calculated by dividing a difference in means between groups by a pooled standard deviation to create a summary of the difference between an intervention and control condition. When the absolute value of an SMD is below 0.2, the difference between an intervention group and a control group is generally regarded as non-significant, while an SMD between 0.2 and <0.5 reflects a small effect, an SMD between 0.5 and <0.8 reflects a moderate effect, and ≥0.8 reflects a large effect.

Reducing muscle soreness

In the world of athletics, CWI and WBC have both been touted for their myriad benefits, particularly in aiding muscle recovery post-exercise, both in the sense of recovering muscle power post-exercise and in reducing muscle soreness.

Support for this comes from a 2022 comprehensive meta-analysis of 52 randomized trials examining the impact of CWI (vs. passive recovery) on various output metrics related to muscle recovery in active adults following high-intensity exercise (most typically sprinting or team sports) or eccentric resistance training (most typically drop-jumps or countermovement jumps).[7]

CWI was typically applied within 15 minutes of exercise and involved immersion in water temperatures between 41-68°F (5-20°C) for durations ranging from 10 to 30 minutes, though the specific treatment protocols differed somewhat across included trials. Results revealed statistically significant positive effects of CWI on muscular power recovery 24 hours post-exercise for both high-intensity training and eccentric strength training. In terms of SMD, the effects were small, standing at 0.34 (95% CI: 0.06-0.62) for recovery following eccentric training and slightly lower for high-intensity exercise (SMD: 0.22; 95% CI: 0.00-0.43).

The study also indicated that CWI was effective in alleviating delayed onset muscle soreness (DOMS) 24 hours after high-intensity exercise, with an SMD of -0.89 (95% CI: -1.48 to -0.29, *P*=0.003), indicating a large effect. For eccentric exercise, the reduction in DOMS became significant only at 48 hours or more post-exercise, indicating a delayed but moderate benefit with an SMD of -0.48 (95% CI: -0.79 to -0.16, *P*=0.003). Additionally, CWI moderately enhanced the athletes' *perceived* recovery following high-intensity exercise, but not eccentric exercise (SMD: 0.66; 95% CI: 0.29-1.03, P=0.001). However, the authors also pointed out that CWI does not significantly influence muscle strength recovery, endurance performance, or flexibility, suggesting that while CWI can be beneficial in specific contexts, it is not a panacea for all recovery needs.

The scant comparative evaluations between CWI and WBC present a mixed bag of results. For instance, no significant differences were observed between CWI and WBC in a study employing a downhill running protocol (used to test for recovery from eccentric muscle contraction),[8] but a study investigating recovery post-marathon indicated that CWI was superior to WBC in perceived soreness and muscle function. Still another study using 90-minute sessions of running on an incline reported that WBC was more effective than CWI in promoting faster recovery of muscle function.[9,10] Of note, the inclined running study generally demonstrated greater effect sizes than the marathon study and involved a more comprehensive recovery assessment (including subjective perception of muscle pain, recovery of vertical jump height, and biomarkers of muscle damage such as creatine kinase and C-reactive protein), which might suggest that the results favoring WBC are more reliable than those from the study favoring CWI. However, because the studies involved different exercise modalities, different protocols for CWI and WBC, and different recovery readouts, it may be the case that the relative effectiveness of these two forms of cold therapy might vary depending on the nature of the exercise or the details of the recovery protocol.

The mixed outcomes reported in various studies highlight the importance of context in selecting recovery modalities. Factors such as the type of exercise, timing of the therapy relative to exercise, the specific conditions of the cold exposure (temperature and duration), and the fitness level of the participants may all influence the effectiveness of CWI and WBC. However, given the small number of studies and small sample sizes in each, such details are impossible to tease out at present. Nevertheless, while the relative efficacies of CWI and WBC in muscle recovery may not yet be clear, it’s worth noting that most studies indicate that *either* cold therapy modality is more effective than no intervention at all.

Improving mood

In addition to physiological benefits, cold therapy has also gained attention for its potential psychological impacts, particularly with respect to mood and depression.

Indeed, emerging research into cold therapy as a potential treatment for depression has shown promising results. In a 2020 randomized controlled trial (RCT), individuals with depressive symptoms were assigned to either a WBC group or control intervention. The WBC group (n=30, age range 23-73, 70% female) underwent ten two-minute sessions of WBC at extreme cryogenic temperatures, ranging from -166°F to -256°F (-110°C to -160°C), over two weeks.[11] Conversely, the control group (n=26, ages 20-69, 73% female) also participated in ten sessions over the same period but were exposed to less extreme cold conditions, specifically -58°F (-50°C), which is not considered cryogenic.

Results showed a statistically significant improvement in depressive symptoms for those in the WBC group, with participants' conditions shifting from an average moderate depression level to mild or normal on the Beck depression inventory-II (BDI-II) and the Hamilton depression rating scale (HAM-D 17). Additionally, significant enhancements were noted in overall life quality and self-assessed mood among participants in the WBC group compared with the control group. These findings suggest that cold therapy could serve as a novel intervention in the management of depression. That said, the study was relatively small, and it did not include a control group treated with standard pharmacological therapy for depression, so it is unclear how the magnitude of the effect of WBC would compare to existing treatments.

A recent meta-analysis of WBC studies for depression reports significant heterogeneity across investigations, suggesting that more standardized protocols are necessary to better understand and verify the efficacy of WBC as a treatment for depression.[12] Nevertheless, the analysis indicated that effect sizes for the impact of cold therapy on depressive symptoms were very large (effect size=2.95, 95% CI: 2.44-3.45), with more moderate effects on quality of life (effect size=0.70, 95% CI: 0.15-1.24). Thus, the exploration of cold therapy as a viable treatment for mood disorders represents an exciting frontier in mental health research. As the body of evidence grows, cold therapy could potentially emerge as a supplement to conventional pharmacotherapy.

Investigations on the mood-boosting effects of CWI have been more limited than those on WBC, but the few data that exist appear promising. A study in 53 patients with depression or anxiety demonstrated that eight sessions of cold water swimming over four weeks demonstrated reductions from baseline in the severity of depressive symptoms (effect size=1.2) and anxiety (effect size=1.4), as assessed by participant questionnaires.[13] However, we cannot easily differentiate the effects of cold immersion from those of exercise (which is also known to improve symptoms of depression and anxiety), as this study did not specifically recruit participants who were highly trained at baseline (though all were required to be capable of swimming 50 meters), nor did it feature any control intervention involving exercise without cold exposure.

As discussed earlier in this piece, cold therapy's psychological effects lie in the significant uptick in neurotransmitters, such as norepinephrine and dopamine, that is elicited by cold exposure. These neurotransmitters are known for their role in elevating mood, enhancing alertness, and reducing depressive symptoms. For instance, a 2000 study in young men (n=10, mean age: 22) showed a 530% increase in plasma norepinephrine (from 1.17±0.49 to 6.20±4.42 pmol/ml, P=0.003) and a 250% increase in dopamine (0.16±0.03 to 0.73±0.06 pmol/ml) during a 60-minute session of head-out water immersion at 57°F. These levels remained elevated for at least one hour after cessation of cold immersion, though the authors did not monitor further time points to assess at what point the neurotransmitters returned to baseline.[14] These findings demonstrate the pronounced biochemical response triggered by cold exposure, though it's important to note that these changes were detected in the *periphery*, whereas these neurotransmitters generally do not cross the blood-brain barrier. Therefore, while their elevated plasma levels indicate a robust physiological response to cold exposure (which may or may not influence the brain via indirect pathways), the *direct* influence of cold on the brain and central neurotransmission is less clear.

Driving weight loss

At the center of claims regarding cold therapy benefits for weight loss lies the activation of brown fat, or “adipose tissue” (BAT), which, as we described earlier in this piece, is an especially metabolically active type of fat that generates heat by burning triglycerides. The appeal is clear – activate your BAT, and you’ve tapped into a natural tool for burning calories, potentially leading to weight loss and enhanced metabolic health.

In mice, BAT is pivotal in thermoregulation, but the volume and function of BAT in humans are highly variable and less understood.[15] Adult humans do have BAT, but it is less extensive, typically ranging between 60 to 170 *grams*, which suggests a limited role in overall energy metabolism. (Read: BAT is *not* playing any meaningful role in energy expenditure in human adults.) By comparison, skeletal muscle accounts for approximately 40% of body mass in a lean individual weighing 72 kg and can promote heat generation through shivering. But while shivering is regarded as the *primary* mechanism for heat production in adult humans, some have proposed that the contribution of BAT activation may nevertheless be sufficient to tip the balance of whole-body metabolism in favor of weight loss. We disagree.

It is true that mild cold exposure (typically within temperature ranges used in CWI to avoid confounding effects from shivering) has been shown to activate human BAT *slightly* both with short-term and repeated exposures, enhancing BAT uptake of glucose and fatty acids and increasing fuel oxidation in this tissue relative to room-temperature exposures.[16,17] Yet while these effects indicate an increase in energy expenditure within BAT depots, this increase does not translate to significant changes in *whole-body* energy expenditure, even with repeated exposures to cold over time. Given that adults have so little BAT mass, this result is unsurprising and only underscores that BAT activation cannot move the needle on energy balance and weight loss. Further, activation of BAT is impaired in the context of human obesity, so even the local stimulation of fuel oxidation would be less substantial in those for whom weight loss is most relevant.[17]

With *intense* cold exposures, BAT activation may even be *disrupted*, as intense cold can activate pain receptors which also stimulate nerves sensitive to *heat*. These receptors are responsible for the “hot” sensation we sometimes experience from contact with very cold surfaces and can blunt physiological responses to cold, including BAT activation. (I remember, back in my open water swimming days, the first time I did a training swim in sub 50°F water… I could not understand why it felt like I was swimming in boiling water.) Thus, the effectiveness (or lack thereof) of BAT activation for weight loss won’t be enhanced by intensifying the cold stimulus.[18]

Improving insulin sensitivity

While support for cold therapy as a weight loss intervention may be slim, some evidence suggests that cold exposure may nevertheless have benefits for other aspects of whole-body metabolic health. Specifically, a few studies have signaled that cold treatments may improve insulin sensitivity.

Experiments in adult rats housed at 5°C (~40°F, n=5) for 5 days revealed that cold exposure enhanced glucose clearance (following an i.v. glucose bolus) by 62% relative to baseline control measurements (in which rats were housed at 20°C/68°F) and increased peripheral glucose utilization in response to insulin infusion. Together, these results indicate that cold exposure induces greater sensitivity to insulin signaling in the liver and peripheral tissues.[19]

Though the results above were obtained with animal experiments involving *constant* cold exposure rather than the brief exposures used in typical CWI or WBC, limited data involving cold therapy in humans also support the notion that these interventions may improve glycemic control and insulin sensitivity. In an evaluation of 14 female recreational swimmers, outdoor winter swimming at least twice per week between October and April (~5-10 minutes per session, typically with water temperatures in the range of 0-10°C, or 32-50°F) reduced circulating insulin levels relative to baseline measurements (8.98±2.29 μIU/mL at baseline vs. 7.43±1.36 μIU/mL at the end of the study, P=0.032), though no improvements were observed in blood glucose levels.[20]

More tellingly, hyperinsulinemic-euglycemic clamp experiments have shown that 10 days of a cold acclimation protocol improved insulin sensitivity by an average of 43% among eight participants with type 2 diabetes – a large effect for an intervention that did not affect total body weight.[21] In agreement with the earlier rat study, this result was mediated largely by increased glucose utilization by peripheral tissues. The investigators also reported modest enhancement of insulin-induced suppression of endogenous glucose production, and, apropos of our evaluation of cold therapy for weight loss, they noted that overall BAT activity remained very low despite modest increases in glucose uptake by brown fat. However, the intervention in this study involved milder cold exposure of much longer durations than are typically used in CWI or WBC – subjects remained in a cold room at 14-15°C (57-59°F) two continuous hours on day 1, four hours on day 2, and six hours on days 3 through 10 – so it is not clear whether we can extrapolate these results to very brief exposures to severe cold, but they offer a promising starting point for future investigations on the impact of cold therapy for metabolic health.

Enhancing immune function

Some mechanistic evidence indicates that the effects of cold exposure may extend to immune system modulation as well. As we alluded to earlier, certain hormones spike during cold exposure. In addition to norepinephrine, these hormones include cortisol and adrenocorticotropic hormone (ACTH), which are known to impact immune function.[4]

Some studies have directly assessed the link between cold exposure and immune function and suggest that the former may have immunostimulatory effects. For instance, acute CWI for three minutes at 8 °C (46°F) post-exercise resulted in greater increases in circulating IL-6 – a pro-inflammatory cytokine – than was observed in a room temperature condition, though other studies have reported mixed results with this metric.[22,23] Further, a study applying repeated exposure to cold via CWI over the course of six weeks (1-hour sessions three times per week at 14°C) indicated that cold-induced increases in immune reactivity may accrue over time and result in sustained adaptation with repeated sessions, as plasma concentrations of activated T and B lymphocytes after six weeks were found to be higher both before and after CWI sessions than they had been at baseline or at the three-week time point, though results were not statistically significant.[24]

However, the net result of these changes is unclear. At present, we have no evidence that the immunostimulatory effects of cold have any implications for the body's ability to respond to pathogens or injury. We also don't know how immune modulation from cold exposure might impact inflammatory diseases or autoimmune conditions. So while we have a few scraps of information regarding cold therapy and immune function, far too many unanswered questions remain, so making conclusions regarding potential benefits in this area would be very premature.

Slowing aging and increasing lifespan

Some have suggested that cold therapy may have implications for overall mortality risk and longevity, perhaps due to effects on immune function and metabolic health.[4,25] However, as we've seen, whether the benefits that might mediate such a link are meaningfully impacted by cold therapy remains uncertain, and our only *direct* evidence of lifespan extension through cold exposure has come from experiments in nematode worms and cultured cells with dubious relevance to human cold therapy practices. Specifically, a 2015 study indicated that *constant* exposure to cold temperatures throughout worms' adulthood extended lifespan relative to normal or elevated ambient temperatures by over 25%,[26] and subsequent research suggested that this effect was related to attenuation of age-related dysfunction in normal protein degradation processes.[27]

Yet as we've discussed in a past newsletter, nematode worms are often very misleading models for lifespan interventions due in part to their ability to enter a "dauer" state of dormancy, effectively hitting pause on their lives when environmental conditions are incompatible with normal growth and development – an ability not shared by mammals. And although the latter study also showed that the cellular mechanisms involved in protein degradation were also affected by cold in human cell cultures,[27] one change in one intracellular process in isolated cells is a far cry from lifespan extension on the scale of an entire human. Indeed, the cell lines used in these experiments represented kidney tissue (hardly a tissue that would be affected by brief cold exposure) and motor neurons affected by amyotrophic lateral sclerosis (ALS, aka Lou Gehrig's disease) – hardly a model of normal human aging.

Meanwhile, *no studies have directly linked cold therapy to increased lifespan in humans.* This, combined with the huge problems in translating worm data to humans, means that we have *zero* evidence that cold exposure – in the form of either brief cold therapy or chronically living in cold environments – might add so much as a minute to one's life.

Are there any drawbacks to cold therapy?

Cold therapy is not without risks and even downsides. First, we must keep in mind that exposure to cold is potentially deadly if sustained too long. For CWI, the amount of time it takes to reach more dangerous levels of exposure (resulting in confusion, exhaustion, unconsciousness, etc.) depends in large part on the temperature of the water – as well as on other variables such as body fat, air temperature, movement, and more – but can be as little as 15 minutes at near-freezing water temperatures.[28] Thus, for those who are new to cold water immersion, it is advisable to start on the warmer end of typical CWI temperature ranges (i.e., ~60-70°F, or 15-20°C) and/or undergo sessions in a supervised setting. For WBC, adverse effects of prolonged exposure can include damage to superficial tissues (e.g., frostbite), but since access to WBC for most individuals is restricted to treatment centers under professional oversight, risks of such damage are extremely low.[29]

In terms of less severe downsides, CWI can negatively impact gains in muscle mass and strength when used immediately after strength training. A 2015 RCT in physically active young men (n=21) revealed that those who participated in 10 minutes of CWI post-training showed significantly less muscle mass accretion following a 12-week strength training program than those who engaged in active recovery (103±71 g in CWI group vs. 309±73 g with active recovery, $P<0.001$), and while mean cross-sectional area of muscle fibers increased significantly between baseline and post-intervention in the active recovery group (14.2±5.4%, indicating muscle hypertrophy, $P=0.021$), no increase was observed in the CWI group.[30] The investigators also assessed maximal muscle strength (one rep-max, tested at room temperature), and although both groups demonstrated gains in both leg press strength and knee extension strength relative to baseline, gains in the active recovery group were significantly greater than those in the CWI group (leg press: 133±43 kg in CWI group vs. 201±65 kg with active recovery, $P=0.033$; knee extension: 17.8±9.2 kg in CWI group vs. 33.8±8.5 kg with active recovery, $P<0.001$). While the reason for the blunting effect of cold exposure on muscle gains is not completely clear, the authors of this study suggested that it may relate to reductions in blood flow to muscle, as well as to reduced activation of satellite cells (skeletal muscle stem cells) that are vital for muscle repair and growth after exercise.

Another investigation found that CWI may also lower the muscle's ability to use dietary proteins for growth. The study, which included twelve healthy young males, involved all participants undergoing a single session of resistance-type exercise. Following the exercise, one leg of each participant was immersed in cold water at 46.6°F (8°C) for 20 minutes, while the other leg was placed in thermoneutral water at 86°F (30°C). This design allowed each subject to serve as their own control, providing a clear comparison of CWI's effects on muscle recovery and protein synthesis. Afterwards, participants consumed a beverage containing carbon-13-labeled protein, and muscle protein synthesis was evaluated via blood and muscle samples taken over the next five hours of recovery. Results showed that the mean incorporation of labeled protein into muscle was 24-26% lower (depending on the specific C^{13}-labeled amino acid measured) in the subjects' CWI-treated legs compared to the controls. Additionally, when the experiment was repeated each day for two weeks, muscle protein synthesis continued to be lower in the CWI-treated leg, illustrating the muscle protein synthesis with CWI does not adapt back to control levels after repeated sessions.[31]

Interestingly, the blunting effects of CWI on muscle hypertrophy and strength are not conclusively linked to changes in inflammation. Conflicting with studies mentioned earlier, the same group that reported blunted hypertrophy following CWI after intense resistance exercise found no significant differences in the levels of inflammatory cells, cytokines, neurotrophins, and heat shock proteins in skeletal muscle between these groups.[30]

Given these findings, the use of CWI immediately following strength training should be avoided if maximizing muscle growth and strength are prioritized. The differences with vs. without CWI for recovery in the studies described above are not only *statistically* significant; they are also *functionally* significant – a whopping three-fold difference in muscle mass gains and two-fold difference in maximal strength gains over 12 weeks. And several studies have reported similar findings regarding cold-induced blunting of muscle hypertrophy post-exercise, increasing the level of faith we can have that this represents a true, reliable effect (though it is worth noting that not all studies have replicated findings with respect to muscle *strength*).[32]

Yet results from the studies above were generated from protocols using CWI *immediately* after exercise. Though we don't have clear data on how longer latencies between exercise and CWI might impact gains in muscle mass and strength, it's worth noting that cold therapy appears effective in reducing muscle soreness when applied up to ~24 hours after exercise (we'll return to this later). Thus, it's certainly possible that waiting a few hours between strength training and CWI might provide an optimal balance between lessening muscle soreness while still avoiding substantial cold-induced attenuation of strength gains. It is probably safe to say that the question as to how the attenuation of strength and hypertrophy vary with CWI from time of training is, to me at least, the biggest gap in our knowledge in this space (hopefully someone reading this wants to do the study to find out!).

A wider look at the evidence

Based on existing evidence, we have summarized the various potential benefits and risks associated with cold therapy in the **Figure** below, with beneficial effects represented as positive values on the "magnitude" scale, and detrimental effects represented as negative values.

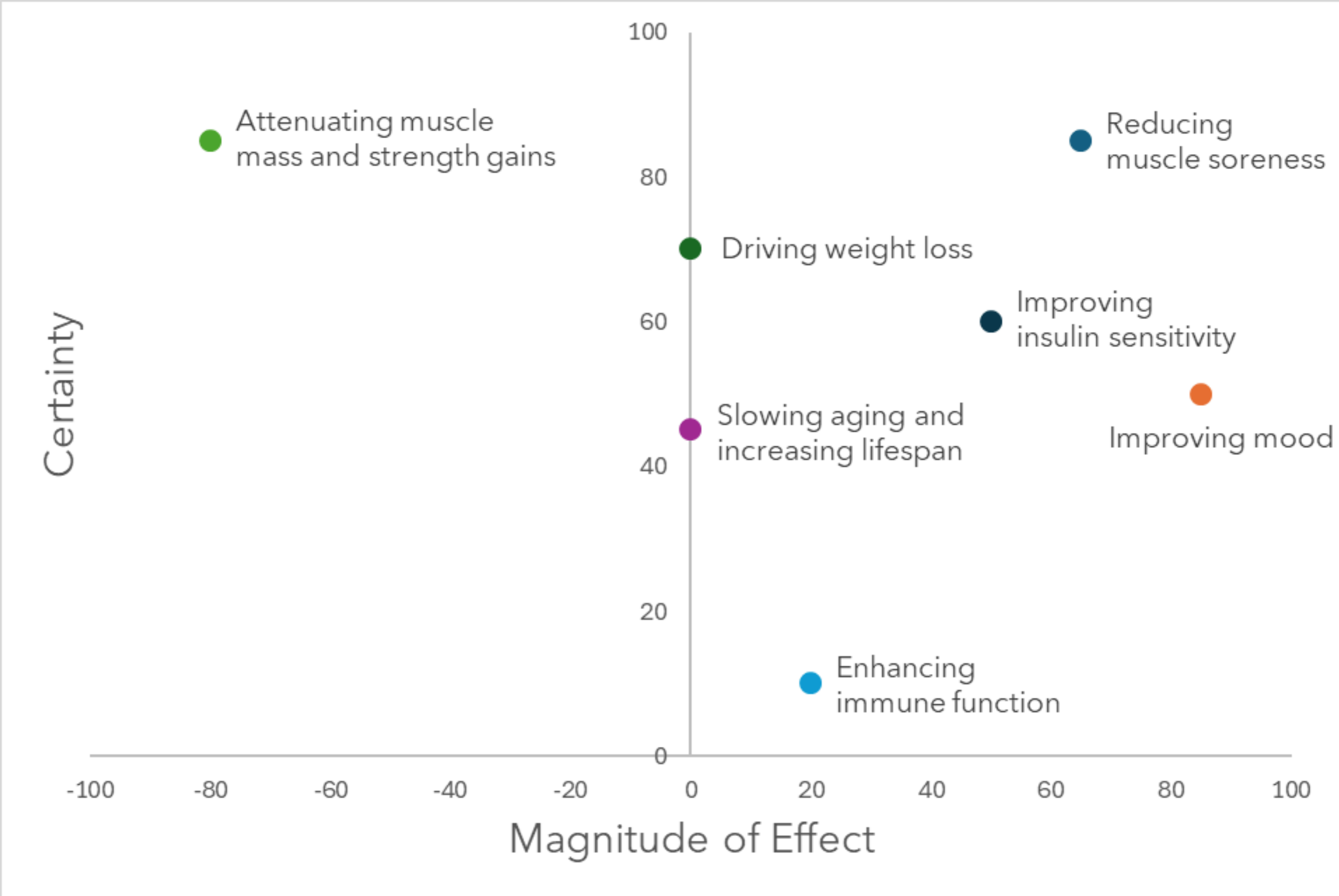

Figure: The benefits and risks of cold therapy, charted by magnitude of effect and certainty of evidence. Magnitude and certainty for each benefit are assessed relative to the magnitude and certainty for other benefits of cold therapy.

Though many of the results we've presented here derive from interventional studies (including many RCTs), a number of limitations apply to this body of literature as a whole, and we must take these into account when drawing conclusions regarding potential causal links between cold therapy and various purported benefits.

For one, as noted at the outset, the practical inability to blind participants as to whether or not they are receiving a cold intervention increases the potential for results to be swayed by placebo effects. We therefore have greater reason than usual to question effects that are small in magnitude or lie near the threshold of statistical significance. For some outcomes (e.g., muscle protein synthesis, hypertrophy) meaningful impacts from placebo effects are less likely, as these outcomes represent objective, physiological changes, but for others (e.g., strength, DOMS), the lack of blinding is a real limitation to this body of literature.

Additionally, most investigations to date on the effects of cold therapy in humans have focused on healthy and physically active participants (e.g., winter swimmers), who may possess unique physiological adaptations or health behaviors that skew results – not to mention that exercise itself improves metabolic health and immune function. Further, several studies have limited their participant pools to homogenous populations made up of a single sex or a narrow range of ages, yet the effects of cold exposure are known to differ across individuals based on age, aspects of baseline health, body composition, sex, sleep patterns, and numerous other variables. For example, many of the body's thermoregulatory responses to cold are compromised following periods of sleep deprivation.[33] They have also been found to decline with advancing age, which means that body temperature will decrease more quickly during cold exposure (whereas the benefits arising from thermoregulatory responses might be attenuated).[34]

Exercising in the cold

The physiological responses to cold alter biomechanical efficiency, and thus, exercising in low-temperature environments impacts a number of performance metrics relative to exercising at room temperature. Lower temperatures result in a decline in maximal aerobic power at VO_2 max and maximal work time. A study using CWI to achieve the desired core body temperature found that for every 1°C decline in esophageal temperature, there was a 5-6% reduction in maximal aerobic power. Over a total esophageal temperature change of 3.5°C (from 38.4 to 34.9°C, or ~101.1 to 94.8°F), maximal heart rate dropped by 28 bpm (15%) and work time to VO_2 max was halved at the coldest temperatures.[35] All of this together suggests that exercising in temperatures cold enough to lower core body temperature will require some degree of gradual training in cold to elicit the same performance as at more temperate climates.

Exercising in cold conditions also triggers a shift towards greater reliance on anaerobic metabolic pathways. As we recently shared in a premium article on Zone 2 training, mildly cool temperatures (~50-65°F or ~10-18°C) can enhance aerobic capacity relative to warmer temperatures,[36] but dropping below this range can have the opposite effect, likely due to the reduced blood flow (and thus, oxygen flow) to muscles caused by peripheral vasoconstriction at lower temperatures. The resultant spike in both blood and muscle lactate levels can lead to quicker onset of fatigue, reducing overall exercise performance and efficiency. Several mechanisms might underlie this effect, including greater muscle fiber recruitment in cold conditions to perform the same work output.

How to approach cold therapy for recovery

Determining the most effective cold therapy protocols can be challenging due to individual variations in cold tolerance, differences in study methodologies, and differences in outcome of interest. Few studies have directly compared different protocols, and those that have done so have focused almost exclusively on outcomes reflecting recovery from exercise. The insights we share below on optimal protocol details therefore derive primarily from these investigations concerned with muscle soreness and related outcomes. Thus, we can't be sure that these details are also optimal for reaping other likely benefits of cold therapy, though it is certainly plausible that this might be the case, given that all potential effects presumably depend on the extent to which the intervention can trigger the body's thermoregulatory responses to cold.

Finally, the protocols we describe here may require some adjustment based on the individual's body composition, sex, and other variables, as these will impact responses to cold therapy as detailed above.

Temperature & Duration

A 2016 meta-analysis on CWI protocols following exercise reported that the most effective water temperatures for reducing DOMS range between 50 and 59°F (10 to 15°C). This temperature range has been shown to provide significant relief from muscle soreness both immediately and with delayed effects compared to passive recovery.[37] In addition, the optimal duration for CWI appears to be between 10 and 15 minutes – a timeframe which appears to confer maximal benefits without the discomfort or risks associated with longer exposure to cold temperatures. Importantly, colder temperatures (41-50°F or 5-10°C) and longer durations did not show improved effects and might in fact be less beneficial, in addition to posing greater risks.

With regard to WBC, a 2018 review noted that efficacy in muscle recovery has been reported over a wide range of WBC temperatures (from as high as -85°C/-121°F to as low as -185°C/-301°F), though typical ranges fall between -110°C (-166°F) and -140°C (-220°F). However, as the authors of this review suggest, the precise temperature at which WBC is performed is likely to have less of an impact on recovery than it does for CWI, given the relatively short duration of WBC treatments.[38] Indeed, according to the same review, optimal WBC durations are likely between 2 and 2.5 minutes. Treatments lasting longer than four minutes should be avoided due to the risk of cold-induced tissue damage with prolonged exposure.[29]

While these findings offer a good basis for developing cold therapy protocols, the studies included in these reviews are generally small and vary in quality. Further, our ability to draw conclusions is limited by the range of parameters tested – for instance, because nearly all WBC studies have utilized treatment durations between 2-3 minutes, we cannot know exactly how treatments in this range compare with shorter or longer exposures.

Timing relative to exercise

According to a 2021 meta-analysis of 32 RCTs, cold therapy is effective for mitigating post-exercise muscle soreness when employed within one hour of the end of training, regardless of whether CWI or WBC is used.[39] However, others have reported efficacy of cold interventions in relieving DOMS up to 24-hours post-exercise,[38] a window which might be sufficiently wide to reap soreness benefits while still permitting a long enough delay to avoid negative impacts on muscle hypertrophy. By contrast, cold therapy beyond 24 hours post-training does not appear to improve muscle soreness or speed recovery. This timing might be explained by the timing of immune cell (i.e., leukocyte) infiltration into muscle tissue, which occurs largely in the first 24 hours after muscle damage and is thought to be a major driver of the secondary damage and soreness that accompany the recovery process.[40] Unfortunately, because very few studies have investigated cold therapy recovery interventions beyond 1-hour post-exercise, the relative effects of different CWI or WBC timings outside of this window aren't well defined.

Table: Optimal cold therapy protocols for muscle recovery

	Cold water immersion (CWI)	Whole-body cryotherapy (WBC)
Temperature	10 to 15°C/50 to 59°F	-110 to -140°C/-166 to -220°F
Duration	10-15 minutes	2-2.5 minutes
Timing	Within 24 hours post-exercise*	Within 24 hours post-exercise*

*While most research supporting benefits for DOMS has utilized interventions within 1-hour post-exercise, this window is likely to negatively impact training-induced gains in muscle mass and strength.

Area of exposure

An additional consideration, primarily with respect to cold water interventions, is the body surface area that is exposed. The efficacy of cold therapy correlates strongly with the amount of body surface exposed. Full-body cold plunges facilitate a more profound reduction in core body temperature than partial exposures and amplify the physiological responses beneficial for recovery and health. In particular, the inclusion of the head in cold immersion nearly doubles the cooling rate, a phenomenon attributable to thermoreceptors in the scalp that regulate blood flow and heat exchange. This suggests a direct link between the exposed surface area during cold therapy and its effectiveness in cooling and recovery, especially with regards to the torso and scalp.[41]

Cold showers, while convenient and easily accessible, typically involve a limited body surface area, thus moderating their physiological impact. However, they may serve well as an introductory method for those new to cold exposure, aiding in the gradual adaptation to the sensations of cold. Even without full head immersion, cold showers can initiate the body's adaptation process, reducing the natural shock response to cold – a process known as habituation.[42]

For individuals exploring cold therapy, the choice between cold showers and full-body plunges should be informed by their specific health objectives and personal comfort with cold exposure. Beginners may find cold showers or partial-body immersion to be less daunting entry points, while full-body immersion provides a more potent response.

Other considerations

As we discussed in the context of hypothermia risks, numerous other cold exposure parameters have substantial impacts on the body's rate of cooling and thus on the optimal temperatures and durations of cold therapy.

Among the most impactful of these parameters is the extent to which cold water/air is *flowing or circulating* through the space in which an individual is engaging in cold therapy. For example, I'm often asked about my own CWI protocol, which is anywhere from 5 to 10 minutes at 42°F (~5.5°C), but sometimes I do it in still water, and other times I do it with the jets on. Anyone who has experienced cold water knows how big of a difference the jets can make – 5 minutes at 42°F *with* jets feels colder than spending twice that amount of time in 42°F water *without* jets. So how long would I need to spend in 48°F or 55°F to get the same effect? It's not clear.

Likewise, some WBC chambers utilize flowing air, while in others, the air is still, and anyone familiar with the concept of winter wind chill will know just how much more biting a given air temperature can feel when wind is involved. And these differences between flowing versus still water or air are not simply a matter of perception. The body does indeed cool faster when the surrounding medium is moving, as any heat given off by the body to the surrounding air/water is quickly whisked away and replaced by more cold, rather than creating a small barrier of warmth as it might in still media.

Another variable with implications for cooling dynamics is movement of the *individual* engaging in cold therapy. Intense exercise increases the body’s heat production, so cold water swimming or exercising in cold environments can slow the rate of cooling in superficial tissues and core temperature relative to comparable amounts of time spent at rest at the same ambient temperatures.

Other factors relevant to cooling dynamics (particularly for CWI) include air temperature, whether CWI is performed indoors or outside, and the time of year (for instance, the strength of solar radiation will differ between winter and summer months). With such a large number of variables involved and relatively limited data on the magnitude of their respective influences on cold therapy efficacy, those who wish to engage in cold therapy may need to play around with various options to land on a protocol that best suits their needs.

Bottom line

Cold exposure therapies, such as CWI and WBC, have garnered considerable attention for their purported health benefits. These methods are often championed for their ability to enhance recovery, improve metabolic function, and boost mood. However, the scientific landscape surrounding these therapies is complex, and variability in study designs, participant demographics, and therapeutic protocols means that no single study can authoritatively dictate the use of cold therapies across different populations.

One of the more consistent findings is the efficacy of cold exposure in mitigating DOMS following intense physical exertion. However, the timing of such interventions is critical, especially in the context of *resistance* exercise; applying cold therapy immediately after resistance training could impede muscle hypertrophy and strength development. Delaying cold therapy for several hours post-resistance exercise might circumvent these negative impacts, potentially still offering some benefit from reduced soreness without compromising muscle growth.

Beyond physical recovery, cold exposure therapies are linked to improved insulin sensitivity, as well as to enhanced mood states attributed to the increased release of neurotransmitters like norepinephrine and dopamine. In contrast, claims surrounding weight loss through BAT activation, improved immune function, and prolongation of lifespan are largely without merit or evidentiary support.

Despite potential benefits, cold exposure therapies are not without risks. The acute cardiovascular and respiratory responses to cold shock can pose serious health threats, particularly in individuals with underlying medical conditions, as can the risk of hypothermia or cold-induced tissue damage from prolonged exposure. These risks reinforce the necessity for therapies to be adapted to the individual's health status and physical conditioning, ensuring both efficacy and safety.

For a list of all previous weekly emails, click here.

podcast | website | ama

References

1. Duong H, Patel G. *Hypothermia*. StatPearls Publishing; 2024. Accessed September 4, 2024. https://www.ncbi.nlm.nih.gov/books/NBK545239/

2. Johnson JM, Minson CT, Kellogg DL Jr. Cutaneous vasodilator and vasoconstrictor mechanisms in temperature regulation. *Compr Physiol*. 2014;4(1):33-89. doi:10.1002/cphy.c130015

3. Ikäheimo TM. Cardiovascular diseases, cold exposure and exercise. *Temperature (Austin)*. 2018;5(2):123-146. doi:10.1080/23328940.2017.1414014

4. Espeland D, de Weerd L, Mercer JB. Health effects of voluntary exposure to cold water – a continuing subject of debate. *Int J Circumpolar Health*. 2022;81(1). doi:10.1080/22423982.2022.2111789

5. Mohan MS, Sreedevi AS, Sakunthala AN, Boban PT, Sudhakaran PR, Kamalamma S. Intermittent cold exposure upregulates regulators of cardiac mitochondrial biogenesis and function in mice. *Physiol Int*. 2023;110(1):1-18. doi:10.1556/2060.2023.00128

6. Swift RW. The effects of low environmental temperature upon metabolism. *J Nutr*. 1932;5(3):227-249. doi:10.1093/jn/5.3.227

7. Moore E, Fuller JT, Buckley JD, et al. Impact of Cold-Water immersion compared with passive recovery following a single bout of strenuous exercise on athletic performance in physically active participants: A systematic review with meta-analysis and meta-regression. *Sports Med*. 2022;52(7):1667-1688. doi:10.1007/s40279-022-01644-9

8. Haq A, Ribbans WJ, Hohenauer E, Baross AW. The comparative effect of different timings of Whole Body Cryotherapy treatment with Cold Water immersion for post-exercise recovery. *Front Sports Act Living*. 2022;4:940516. doi:10.3389/fspor.2022.940516

9. Wilson LJ, Cockburn E, Paice K, et al. Recovery following a marathon: a comparison of cold water immersion, whole body cryotherapy and a placebo control. *Eur J Appl Physiol*. 2018;118(1):153-163. doi:10.1007/s00421-017-3757-z

10. Qu C, Wu Z, Xu M, et al. Cryotherapy models and timing-sequence recovery of exercise-induced muscle damage in middle- and long-distance runners. *J Athl Train*. 2020;55(4):329-335. doi:10.4085/1062-6050-529-18

11. Rymaszewska J, Lion KM, Pawlik-Sobecka L, et al. Efficacy of the whole-body cryotherapy as add-on therapy to pharmacological treatment of depression—A randomized controlled trial. *Front Psychiatry*. 2020;11. doi:10.3389/fpsyt.2020.00522

12. Doets JJR, Topper M, Nugter AM. A systematic review and meta-analysis of the effect of whole body cryotherapy on mental health problems. *Complement Ther Med*. 2021;63(102783):102783. doi:10.1016/j.ctim.2021.102783

13. Burlingham A, Denton H, Massey H, Vides N, Harper CM. Sea swimming as a novel intervention for depression and anxiety – A feasibility study exploring engagement and acceptability. *Ment Health Phys Act*. 2022;23(100472):100472. doi:10.1016/j.mhpa.2022.100472

14. 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;81(5):436-442. doi:10.1007/s004210050065

15. Hankenson FC, Marx JO, Gordon CJ, David JM. Effects of rodent thermoregulation on animal models in the research environment. *Comp Med*. 2018;68(6):425-438. doi:10.30802/aalas-cm-18-000049

16. Blondin DP, Labbé SM, Tingelstad HC, et al. Increased brown adipose tissue oxidative capacity in cold-acclimated humans. *J Clin Endocrinol Metab*. 2014;99(3):E438-E446. doi:10.1210/jc.2013-3901

17. Saari TJ, Raiko J, U-Din M, et al. Basal and cold-induced fatty acid uptake of human brown adipose tissue is impaired in obesity. *Sci Rep*. 2020;10(1):1-11. doi:10.1038/s41598-020-71197-2

18. Blondin DP, Tingelstad HC, L. Mantha O, Gosselin C, Haman F. Maintaining thermogenesis in cold exposed humans: Relying on multiple metabolic pathways. *Compr Physiol*. 2014;4(4):1383-1402. doi:10.1002/cphy.c130043

19. Cunningham JJ, Gulino MA, Meara PA, Bode HH. Enhanced hepatic insulin sensitivity and peripheral glucose uptake in cold acclimating rats. *Endocrinology*. 1985;117(4):1585-1589. doi:10.1210/endo-117-4-1585

20. Gibas-Dorna M, Checinska Z, Korek E, et al. Variations in leptin and insulin levels within one swimming season in non-obese female cold water swimmers. *Scand J Clin Lab Invest*. 2016;76(6):486-491. doi:10.1080/00365513.2016.1201851

21. Hanssen MJW, Hoeks J, Brans B, et al. Short-term cold acclimation improves insulin sensitivity in patients with type 2 diabetes mellitus. *Nat Med*. 2015;21(8):863-865. doi:10.1038/nm.3891

22. Pawłowska M, Mila-Kierzenkowska C, Boraczyński T, et al. The effect of submaximal exercise followed by short-term Cold-Water immersion on the inflammatory state in healthy recreational athletes: A cross-over study. *J Clin Med*. 2021;10(18):4239. doi:10.3390/jcm10184239

23. Brenner IK, Castellani JW, Gabaree C, et al. Immune changes in humans during cold exposure: effects of prior heating and exercise. *J Appl Physiol*. 1999;87(2):699-710. doi:10.1152/jappl.1999.87.2.699

24. Janský L, Pospíšilová D, Honzová S, et al. Immune system of cold-exposed and cold-adapted humans. *Eur J Appl Physiol*. 1996;72-72(5-6):445-450. doi:10.1007/bf00242274

25. Kunutsor SK, Lehoczki A, Laukkanen JA. The untapped potential of cold water therapy as part of a lifestyle intervention for promoting healthy aging. *GeroScience*. Published online July 30, 2024. doi:10.1007/s11357-024-01295-w

26. Zhang B, Xiao R, Ronan EA, et al. Environmental temperature differentially modulates C. elegans longevity through a Thermosensitive TRP channel. *Cell Rep*. 2015;11(9):1414-1424. doi:10.1016/j.celrep.2015.04.066

27. Lee HJ, Alirzayeva H, Koyuncu S, Rueber A, Noormohammadi A, Vilchez D. Cold temperature extends longevity and prevents disease-related protein aggregation through PA28γ-induced proteasomes. *Nat Aging*. 2023;3(5):546-566. doi:10.1038/s43587-023-00383-4

28. Westpac Marine. Accessed September 14, 2024. https://westpacmarine.com/samples/hypothermia_chart.php

29. Bleakley CM, Bieuzen F, Davison GW, Costello JT. Whole-body cryotherapy: empirical evidence and theoretical perspectives. *Open Access J Sports Med*. 2014;5:25-36. doi:10.2147/OAJSM.S41655

30. Roberts LA, Raastad T, Markworth JF, et al. Post-exercise cold water immersion attenuates acute anabolic signalling and long-term adaptations in muscle to strength training. *J Physiol*. 2015;593(18):4285-4301. doi:10.1113/jp270570

31. Fuchs CJ, Kouw IWK, Churchward-Venne TA, et al. Postexercise cooling impairs muscle protein synthesis rates in recreational athletes. *J Physiol*. 2020;598(4):755-772. doi:10.1113/jp278996

32. Petersen AC, Fyfe JJ. Post-exercise Cold Water immersion effects on physiological adaptations to resistance training and the underlying mechanisms in skeletal muscle: A narrative review. *Front Sports Act Living*. 2021;3:660291. doi:10.3389/fspor.2021.660291

33. Keramidas ME, Botonis PG. Short-term sleep deprivation and human thermoregulatory function during thermal challenges. *Exp Physiol*. 2021;106(5):1139-1148. doi:10.1113/EP089467

34. Degroot DW, Kenney WL. Impaired defense of core temperature in aged humans during mild cold stress. *Am J Physiol Regul Integr Comp Physiol*. 2007;292(1):R103-R108. doi:10.1152/ajpregu.00074.2006

35. Bergh U, Ekblom B. Physical performance and peak aerobic power at different body temperatures. *J Appl Physiol*. 1979;46(5):885-889. doi:10.1152/jappl.1979.46.5.885

36. Fink WJ, Costill DL, Van Handel PJ. Leg muscle metabolism during exercise in the heat and cold. *Eur J Appl Physiol Occup Physiol*. 1975;34(3):183-190. doi:10.1007/BF00999931

37. Machado AF, Ferreira PH, Micheletti JK, et al. Can water temperature and immersion time influence the effect of Cold Water immersion on muscle soreness? A systematic review and meta-analysis. *Sports Med*. 2016;46(4):503-514. doi:10.1007/s40279-015-0431-7

38. Adnan H, William J R, Anthony W B. Enhancing the physiology and effectiveness of whole-body cryotherapy treatment for sports recovery by establishing an optimum protocol: A review of recent perspectives. *J Phys Med*. 2018;1(1). doi:10.36959/942/338

39. Wang Y, Li S, Zhang Y, et al. Heat and cold therapy reduce pain in patients with delayed onset muscle soreness: A systematic review and meta-analysis of 32 randomized controlled trials. *Phys Ther Sport*. 2021;48:177-187. doi:10.1016/j.ptsp.2021.01.004

40. Paulsen G, Mikkelsen UR, Raastad T, Peake JM. Leucocytes, cytokines and satellite cells: what role do they play in muscle damage and regeneration following eccentric exercise? *Exerc Immunol Rev*. 2012;18:42-97. https://www.ncbi.nlm.nih.gov/pubmed/22876722

41. Pretorius T, Bristow GK, Steinman AM, Giesbrecht GG. Thermal effects of whole head submersion in cold water on nonshivering humans. *J Appl Physiol*. 2006;101(2):669-675. doi:10.1152/japplphysiol.01241.2005

42. Eglin CM, Tipton MJ. Repeated cold showers as a method of habituating humans to the initial responses to cold water immersion. *Eur J Appl Physiol*. 2005;93(5-6):624-629. doi:10.1007/s00421-004-1239-6