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Cryotherapy

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Abstract

Rest and recovery are vital for athletes to give their bodies time to repair and strengthen between workouts. Whole-body cryotherapy involves exposing the body to vapors that reach ultra-low temperatures, ranging from -200°F to -300°F. There are several possible beneficial mechanisms from whole-body cryotherapy that support a fast recovery such as muscle temperature decrease, reduction in muscle damage, reduction in inflammation, reduction in heart rate and cardiac output, peripheral vasoconstriction, reduction in peripheral edema formation, and pain-relieving effects. This paper dissects the adaptations cryotherapy provides in athletic recovery, and additionally notes some draw backs of this cooling technique.

Keywords

cryotherapy, cooling technique, athletic recovery

Disciplines

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Introduction to Cryotherapy

Rest and recovery are vital for athletes to give their bodies time to repair and strengthen between workouts. Rest allows athletes to recover both physically as well as neurologically. (combine) For athletes, the ability to maintain a high level of performance over long periods of time regardless of high physical stress is essential. Cooling after exercise has been investigated as a method to improve recovery during intensive training (Poppendieck, 2013). These cooling techniques have traditionally been used in the form of an ice pack on a localized part of the body to now a more advanced version known as whole-body cryotherapy.

Whole-body cryotherapy involves exposing the body to vapors that reach ultra-low temperatures, ranging from -200°F to -300°F (Whole Body Cryotherapy (WBC): A Trend That Lacks Evidence, Poses Risks). There are two ways whole-body cryotherapy can be delivered. The first is by an individual standing in a chamber that is open at the top, and the second is where an individual sits in a chamber that is filled with cool air (Patel, 2019). Ultimately, the entire body is exposed to frigid temperatures with the intention to prevent injuries, counteract inflammation, and promote recovery.

There are several possible beneficial mechanisms from whole-body cryotherapy that support a fast recovery such as muscle temperature decrease, reduction in muscle damage, reduction in inflammation, reduction in heart rate and cardiac output, peripheral vasoconstriction, reduction in peripheral edema formation, and pain-relieving effects (Poppendieck, 2013). Several studies promote the use of cryotherapy in recovery which has recently increased the popularity of this therapy. However, the actual physiological mechanisms generating potential benefits of this cooling intervention are still unclear and need further research.

Protocol for Whole-Body Cryotherapy

The standardized protocol of whole-body cryotherapy involves exposure to extremely cold dry air which is typically between -100°C and -140°C. Individuals are exposed to this environment for relatively short periods lasting anywhere from two and five minutes. During this exposure, individuals wear minimal clothing, gloves, a headband covering their ears, a nose and mouth mask, and dry shoes and socks (Bleakley, 2014). These methods are imperative to use as they reduce the risk of cold-related injury. Further, the number of sessions is crucial for the effectiveness of whole-body cryotherapy. It was concluded that to generate the best results 20 consecutive sessions should be the minimum, and individuals should not exceed 30 sessions (Lubkowska, 2012). It is best that these sessions are initiated within 24 hours after exercise and can be on the same day or over several weeks. However, it is currently debated whether cryotherapy is more effective before or after exercise-induced muscle damage. Ultimately, being exposed to whole-body cryotherapy for the correct time and number of sessions is essential in receiving the maximum benefits (Bleakley, 2014).

Inflammation Reduction with Cryotherapy

One of the primary goals of cryotherapy is to limit inflammation after an athletic performance as it can enhance recovery. Whole-body cryotherapy has been found to successfully do this by increasing levels of anti-inflammatory interleukins and decreasing the secretion of proinflammatory molecules. This finding has been consistent throughout various studies attributing to its reliability. A study concluded that pre-exercise whole-body cryotherapy prevented spikes in interleukin-6. Decreasing interleukin-6 is positive as it is a known marker in

the blood indicating proinflammatory effects when elevated. This decrease indicates an increase in anti-inflammatory markers. This study was also able to find that increasing the number of whole-body cryotherapy sessions a day added to the decrease in pro-inflammatory markers (Patel, 2019).

Not only will athletes benefit from the decrease in pro-inflammatory markers regarding recovery time, but this will also decrease pain and soreness following physical activity. Pain and soreness can both physically and neurologically affect the athlete. Physically the athlete could have a limited range of motion due to the pain, but neurologically the athlete could not want to do as much athletically when pain is being felt. Therefore, the less severe pain and soreness can be attributed to the decrease of interleukin-6 being secreted, making whole-body cryotherapy essential for athletes recovering (Patel, 2019).

However, a study was able to conclude that cold water immersion after resistance training causes acute changes in both satellite cell numbers and kinase activity. Both satellite cells and kinase regulate muscle hypertrophy. This can create smaller, long-term gains in muscle strength and hypertrophy. All in all, this study concluded that reduced inflammation in response to whole-body cryotherapy may have a negative effect on muscle hypertrophy. Most athletes want to maximize hypertrophy to gain more muscle fibers, but this study suggests that cryotherapy may not be ideal for this (Roberts, 2015).

Cryotherapy Muscle Damage

Muscle damage is another vital aspect that cryotherapy aims to target to promote a faster recovery and enhance performance. During physical activity, muscles become damaged, leading to an inflammatory response. This inflammatory response is suppressed due to the cold

temperature as mentioned above. Further, whole-body cryotherapy may function to decrease catabolic muscle activity which reduces inflammation and therefore muscle damage following exercise. Several studies have aimed to look at the effect of muscle damage and whole-body cryotherapy and there have been several mixed outcomes. Creatine kinase is an enzyme that can be measured to look at the levels of muscle that have been broken down from physical activity. A study concluded that there was a decrease in total creatine kinase when using whole-body cryotherapy, indicating a reduction in muscle damage. Other studies were unable to find a difference between creatine kinase levels in athletes that were exposed to whole-body cryotherapy versus not exposed. Although this can be controversial, in the studies that were successful this substantial evidence supports the positive outcome of whole-body cryotherapy, reducing muscle damage and thus enhancing recovery (Patel, 2019).

Next, a study looked at whole-body cryotherapy as a treatment modality for middle and long-distance runners with exercise-induced muscle damage. When comparing whole-body cryotherapy and cold-water immersion, it was concluded that whole-body cryotherapy was a more effective treatment. Whole-body cryotherapy enhanced and promoted muscle recovery making muscular performance easier for the runners after exercise-induced muscle damage (Chaohi Qu, 2020).

Cryotherapy Fatigue and Pain

Along with muscle damage, the most important positive effects of whole-body cryotherapy are reduced fatigue and pain. Limiting muscle damage, fatigue, and pain in an athlete will allow the individuals to be able to perform at their peak for longer durations. Exercise-induced muscle damage was studied in rugby players where a 40% decrease in CK

activity was reported after five consecutive whole-body cryotherapy sessions (Banfi, 2009). The decreasing trends of CK show how whole-body cryotherapy can limit the release of intracellular enzymes after prolonged and consecutive sessions (Lombardi, 2017). Further, psychological recovery such as perceived pain and muscular tiredness decreased after cryotherapy (Pournot, 2011).

Whole-body cryotherapy is also responsible for reducing the acute inflammatory response as introduced previously. Once muscle damage is induced by exercise, leukocytes rush to the injured tissue area where pro-inflammatory cytokines are released. Whole-body cryotherapy counteracts this by causing vasoconstriction which will reduce the number of leukocytes reaching the injured muscle (Ferreira-Junior, 2014). This ultimately results in decreased inflammation of the damaged muscle tissue, helping the athlete to improve in various areas. One example is that the athlete will have improved range of motion, allowing them to be more mobile during athletic performance. In summary, whole-body cryotherapy is associated with improvements in muscular tiredness, pain, and well-being after strenuous exercise (Lombardi, 2017).

Bone Health and Cryotherapy

Bone health is essential to athletes' performance as a decrease in bone density can lead to various injuries. In terms of recovery, bone metabolism can sustain performance. A study compared exposure versus non-exposure to whole-body cryotherapy to see the differences in bone health. Bone metabolism was measured through biochemical parameters where it was concluded that whole-body cryotherapy was able to counteract the inflammation-induced bone resorption (Lombardi, 2017). A decrease in bone resorption caused the potential to improve bone

health by increasing bone mineral density. Bone resorption is a natural process that is vital for an individual's health. However, when resorption occurs at a higher rate than it can be replaced it can lead to a decrease in bone mass which puts an individual at a greater risk for osteopenia and stress fractures. To continue, osteoprotegerin is a receptor for RANKL which was found to increase significantly with whole-body cryotherapy treatment. RANKL reduces the production of osteoclasts thereby favoring bone formation over resorption causing positive effects for the athlete (Patel, 2019).

Hematology of Cryotherapy

Whole-body cryotherapy has shown to have effects on hematology such as hemoglobin, total erythrocyte count, and red cell distribution width. First, when looking at the effects whole-body cryotherapy has on iron metabolism erythrocytes and hemoglobin can be measured. Several studies were able to conclude that when measuring erythrocytes, hematocrit, and hemoglobin after 10 sessions of whole-body cryotherapy the levels consistently decreased (Szygula, 2014). This drop could be due to hemolysis which is the breakdown of red blood cells to free hemoglobin. However, when adding additional sessions to around 20-30 the levels ended up increasing. This improvement suggested that bone marrow reacted to the increase in temperature from the addition of more sessions by releasing new red blood cells. Releasing new blood cells is due to the increase in hemoglobin in the blood which promotes the supply of oxygen to the lungs and the rest of the body (Lombardi, 2017). This can greatly favor the athlete as they will be able to sustain peak performance for a greater amount of time.

Further, a study looked specifically at leukocyte levels after whole-body cryotherapy sessions. They were able to conclude that after 4 sessions in one day there was an increase in

neutrophil count (Pournot, 2011). This increased shift of circulating neutrophils can stimulate angiogenesis improving perfusion which is associated with a reduction in delayed onset muscle soreness. Delayed onset muscle soreness can further attribute to improving recovery and performance. Using the same measures this study was unable to find consistent results when reducing the number of whole-body cryotherapy sessions per day. Therefore, increasing the number of sessions is more beneficial to recovery. This is consistent with the above findings regarding hemoglobin. Although these results seem to prove cryotherapy as a successful modality for recovery these results did vary when the type and intensity of physical training changed, indicating further research is essential (Lombardi, 2017).

Hormones Affected by Cryotherapy

Hormonal activity can be altered by whole-body cryotherapy. First, norepinephrine levels were found to increase immediately after a whole-body cryotherapy session (Patel, 2019). This increase is likely due to the cold temperatures spiking a sympathetic nervous system response and most likely does not have a huge role in enhancing recovery. Next, testosterone is the primary hormone that plays a vital role in the generation of muscle mass, strength, and is essential for athletic performance. Salivary testosterone levels in elite female athletes have been known to be associated with an individual's natural desire to compete, giving them increased motivation in training and readiness for competition. Further, serum testosterone levels in elite male athletes also increased over 2 weeks of twice-daily whole-body cryotherapy. This enhancement of testosterone levels in athletes could benefit their motivational levels subsequently increasing performance (Partridge, 2019).

In an additional study, testosterone and cortisol were measured after whole-body cryotherapy sessions in endurance-trained males. Both biomarkers were found to increase significantly. However, increased levels of cortisol after exercise were negatively correlated with running performance. Cortisol levels are typically increased when an individual is exposed to psychophysiological stress which is typically increased due to physical exercise. The additional mechanism of whole-body cryotherapy can potentially increase cortisol levels which may make them high enough during exercise that athletic performance decreases (Krueger, 2019).

Lipids and Cryotherapy

The intense cold stimulus from whole-body cryotherapy can influence lipid concentrations and energy metabolism. Lipids are used as a main source of energy in the body and help produce heat. Lipids are typically known to have a structural role throughout the body, but they also have a functional role in the muscles by providing energy. Triglyceride levels were found to decrease after cryotherapy exposure. This decrease can lead to an increase in blood flow which will, in turn, supply the muscles with more oxygen allowing them to recover more readily. More specifically, the blood had an increase in HDL cholesterol and a decrease in LDL cholesterol. This can benefit the athlete's overall health as the body should have high levels of HDL in the blood and low levels of LDL (Lombardi, 2017). Further, these findings were supported by an additional study where after cryotherapy individuals had lower levels of total cholesterol and LDL. However, this study found that a lower BMI was associated with greater changes in the levels of total cholesterol and LDL (Rymaszewska, 2020). This shows how there could have been a confounding variable causing the decrease in cholesterol levels.

Metabolic benefits can aid athletes in the prevention of cardiovascular disease and can be extremely beneficial to individuals who are seeking health benefits. Further, both types of adipose tissue are activated during this exposure. Adipose tissue has an insulating effect on the body where brown adipose tissue is consumed during the cold exposure to create energy and maintain body temperature. These benefits can help individuals maintain their health if cryotherapy is paired with healthy eating and exercise (Lombardi, 2017).

Cryotherapy and Effects of Redox Balance

Redox balance is commonly interchanged with the term oxidative stress, the main factor affecting an athlete's performance (Lombardi, 2017). Oxidative stress is caused by an imbalance between production and accumulation of oxygen reactive species in cells and tissues (Pizzino, 2017). After extensive muscle activity, the damage causes oxidants to be released into the intercellular space. These oxidants then amplify the production of reactive oxygen species. Reactive oxygen species will damage membranes, cellular structures, and DNA. Inflammation will enhance the activity of reactive oxygen species as well. However, whole-body cryotherapy can reduce these negative effects by enhancing antioxidants and counteracting the exercise and inflammation-induced reactive oxygen species from accumulating (Lombardi, 2017). A study published in 2013 was able to show that professional volleyball players using a single whole-body cryotherapy treatment were able to decrease the activity of RBC enzymes (Lubkowska, 2015). This is most likely due to a decrease in total oxidants and an increase in antioxidants (Lombardi, 2017).

Depression and Anxiety Suppress with Cryotherapy

Along with the cascade of positive effects cryotherapy has on exercise-induced muscle damage, it has also been found to help with mood disorders such as depression and anxiety. Mood disorders are one of the major causes of human suffering in the world and are very challenging to treat (Rymaszewska, 2020). Whole-body cryotherapy can ultimately change hormonal responses which can alter depressive and anxious symptoms. It has been found that with additional exposures there is a decrease in plasma concentrations of catecholamine, cortisol, adrenocorticotropic hormone, and beta-endorphins. Further, cryotherapy aids in decreasing pain. When patients experience a decrease in pain their quality of life immediately increases changing their mood. Depression and anxiety are both neurobiological dysfunctions where there is a dysregulation of the hypothalamic-pituitary-adrenal axis. The positive effects of whole-body cryotherapy on both internal and external pain are due to the activation of the endogenous opioid system and "pain control system" (Bouzigon, 2016). Also, depressive disorders are shown to correlate with inflammation where there can be elevated C-reactive protein, interleukin 6, and tumor necrosis factor-alpha. Cryotherapy can aid in reducing levels related to inflammation which can then possibly help in subsiding depressive disorder symptoms (Rymaszewska, 2020).

Rheumatoid Arthritis Patients benefit from Cryotherapy

Rheumatoid arthritis is a chronic, autoimmune, inflammatory, and destructive joint disease. Patients suffer from a decrease in mobility due to pain and stiffness. Pro-inflammatory cytokines, interleukin-6, and tumor necrosis factor-alpha all play a role in rheumatoid arthritis causing fatigue, pain, and depression. Whole-body cryotherapy has been found to have positive effects on patients with rheumatoid arthritis. This is due to the cold temperatures targeting the inflammatory markers increased with rheumatoid arthritis. A study showed that 40 patients with rheumatoid arthritis reported a decrease in pain sensation and morning stiffness. The protocol of

this study consisted of 20 exposures where the patients had 3 sessions daily for 6 days (Rymaszewska, 2020). Further, another study looked at 60 patients with rheumatoid arthritis where whole-body cryotherapy temperatures varied among the individuals. It was concluded that pain decreased in all treatment groups, however; patients exposed to -110 C° had the largest pain decrease. Ultimately, as the temperature was colder the pain decreased more (Hirvonen, 2006).

Conclusion of Cryotherapy

In conclusion, cryotherapy is a well-known treatment for health and athletic well-being. However, whole-body cryotherapy has just become increasingly more popular for recovery strategies. Whole-body cryotherapy has shown to have vast effects on inflammation, muscle damage, fatigue, and pain. Post-exercise inflammation and muscle damage increase immediately which negatively influences an athlete's future performance. Whole-body cryotherapy can be used as a therapy to suppress these effects. Studies have shown that when the treatment was used more frequently there were more effective results.

Further, there are various studies published about cryotherapy, however; they are controversial. Some studies have shown positive results of cryotherapy and others have shown negative results of cryotherapy. It is also controversial how many sessions are needed, for how long, and if the sessions are more effective before or after training. Some studies have proven whole-body cryotherapy to be essential pre-exercise. Whereas other studies have concluded that whole-body cryotherapy is necessary during the early stages of recovery from muscle-damaging exercise (Mark, 2017).

As stated above, the cold temperatures have shown substantial positive evidence in reducing inflammation, altering lipid concentrations, bone metabolism, endocrine function, and

oxidative stress. These markers are affected directly by cryotherapy where they aid in reducing the amount of muscle damage and speed up the repair process. Ultimately, this can allow athletes to perform at their peak for longer durations. All in all, further research is warranted to investigate the impact of cryotherapy on recovery following exercise-induced muscle damage (Wilson, 2017).

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