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Cryotherapy: not as cool as it seems

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In elite sports, a significant concern for many athletes is the ability to completely recover from prolonged exhaustive exercise. Athletes make use of numerous techniques to accelerate the healing process, priming their body for future events. Among the most common is the notion of muscle cooling, widely known as cryotherapy. Cryotherapy is popular among athletes, based on claims that it reduces inflammation of muscles, improves recovery from muscle injury and enhances recovery from injury. Perhaps the most significant finding by researchers is a decrease in subjective indicators of muscle stress such as muscle soreness (Bleakley *et al.* 2014). However, recent studies have begun to call into question the true physiological effects of muscle cooling, providing evidence that neither inflammation nor muscle damage is in fact reduced. A study published in *The Journal of Physiology* has further investigated the value of cryotherapy, looking specifically at the effects of temperature on muscle force generation and fatigue resistance following recovery from endurance-type exercise (Cheng *et al.* 2017).

The researchers recognized that metabolic processes tend to accelerate as a result of temperature increase. They were interested in investigating whether this held true for the process of glycogen synthesis. Glycogen is the primary source of energy exploited by skeletal muscle and is most quickly recovered immediately after prolonged exercise. Previous studies have shown that depletion of glycogen is associated with an impaired release of calcium from the sarcoplasmic reticulum in muscle during long periods of fatiguing exercise (Nielsen *et al.* 2009). Thus, they hypothesized that following prolonged exercise where glycogen is depleted, muscle warming would increase the rate of muscle recovery and glycogen resynthesis, while muscle cooling would hinder these processes. Importantly, Cheng and colleagues have conducted an experimental study involving both humans and mice. Five healthy, recreationally active humans were recruited in a 4-day study during which they participated in a series of arm cycling exercise sessions. During the first visit, subjects were acquainted with the equipment and baseline cardiorespiratory measurements were taken. Through visits 2–4, subjects repeated the same exercise protocol that included two sets of fatigue tests separated by a 2 h recovery period. Recovery conditions varied in each visit as participants were randomly subjected to either muscle cooling, or muscle warming, or physiological temperature maintenance (~33°C). The group examined how recovery temperature affected power output in the second set of fatigue tests following recovery; cardiorespiratory and blood lactate measurements were recorded in tandem. The study's murine model utilized 50 female mice to conduct experiments on both whole hindlimb flexor digitorum brevis (FDB) muscles and single fibres of these muscles. In whole muscles, glycogen depletion was induced by repeatedly stimulating the muscles, and glycogen resynthesis was measured in those that were either heated to 5°C above or cooled to 5°C below mouse FDB physiological temperature of 31°C. Force recovery and fatigue resistance of individual FDB fibres at four different temperatures (16, 26, 31 and 36°C) with and without glucose (0 or 5 mM) were also assessed. Force was measured upon stimulation with repeated tetani of varying frequencies (30, 70 and 120 Hz).

The novel results supported their hypothesis, with the conclusion that the recovery of submaximal force (below the 120 Hz stimulation frequency) was accelerated and fatigue resistance was increased at elevated muscle temperatures and that the opposite was true at lowered temperatures. Interestingly, there was no clear temperature dependence in mouse fibres stimulated with 120 Hz tetani; the authors explained that this was likely because tetanic calcium at this frequency was nearly saturated at all temperatures, so additional calcium did not affect force. They also observed that the results of submaximal force and fatigue resistance tests were not only temperature-dependent but also glucose-dependent – muscle force and endurance of single fibre FDB muscles were markedly low in the absence of glucose. Finally, they demonstrated that as hypothesized, glycogen resynthesis following depletion in whole FDB muscles was slower when the muscle was cooled and faster when the muscle was warmed.

Results of this study indicated that temperature mediated the extent of muscle recovery by influencing the rate of glycogen resynthesis. As such, muscle cooling impaired recovery due to its effect on slowing glycogen resynthesis, while muscle warming promoted recovery due to an accelerated rate. However, this particular experiment did not have a control group, so the results of cooled and warmed muscle, 5°C below and above physiological temperature, were compared only to one another. Perhaps a stronger experimental model would have included a control in which muscle temperature is maintained at physiological temperature, allowing the researchers to draw a more convincing conclusion. Furthermore, the study attributed increased blood lactate concentration in heated muscle to the increased glycogen content of the muscle that was restored following depletion, a correlation found in a previous study (Blomstrand & Saltin, 1999). According to Blomstrand and Saltin, decreased lactate release was observed in muscles with low muscle glycogen content. However, the present study did not find the same trend in cooled muscle; thus, it is unclear as to why this study did not also see a decrease in blood lactate concentration in cooled muscle, where glycogen resynthesis was low. While the study made no claims about the relationship between decreased muscle temperature and blood lactate levels, it would have been interesting for the authors to attempt to seek an explanation for this result. The study concluded by reiterating the relationship

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between temperature and muscle recovery and fatigue resistance, describing both the positive effects of heating and the negative effects of cooling. Thermotherapy in post-exercise muscle recovery is a highly unexplored area and the results of this paper suggest that this is a promising avenue for further research.

In a threefold experimental model utilizing human along with mouse whole muscle and single fibres, the study provided thorough explanations for decreased muscle performance following recovery, at both the physiological and the cellular level. A clear trend was observed in each of their experiments evaluating power, submaximal force and fatigue resistance in mouse fibres over a range of temperatures. While the study discussed the many shortcomings of cryotherapy, it might have been beneficial to also deliberate the potential advantages and risks of muscle warming as a therapy for athletes, given that the data obtained seem to suggest there are benefits. The treatment and management of pain and injury have been the focus of muscle thermotherapy, in which it has been proven, in some ways, superior to cryotherapy (Malanga *et al.* 2015). Although the study opened up several avenues for further research, the results alone are enough to contest the merits of cryotherapy in situations where muscle power output and endurance following a brief recovery period are critical – such as sports like track and field that involve multiple competitions occurring on the same day. While recent studies have challenged claims that muscle cooling decreases inflammation and muscle damage, calling the perceived benefits of muscle cooling into question, the effect of cryotherapy specifically on the short-term recovery of muscle performance is a novel subject, proving results of the study to be extremely significant.

Despite recent studies refuting the numerous claims in support of muscle cooling, cryotherapy remains a leading treatment utilized among high-performance athletes following intense exercise and muscle exhaustion. Many justify the use of muscle cryotherapy following exercise based on the clear benefits of whole-body cryotherapy in decreasing body temperature following exercise in a warm environment along with the evidence that local cooling may assist in muscle soreness. However, in a setting where muscle injury is so prevalent and can have detrimental impacts on an athlete's career and overall quality of life, it is important to consider the many risks outlined in this study and in others. The unique results of this study are noteworthy, bringing us one step forward in uncovering the various shortcomings of muscle cryotherapy.

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Additional information

Conflict of interest

The authors declare that there are no competing interests.

Author contributions

All authors have approved the final version of the manuscript and agree to be accountable for all aspects of the work. All persons designated as authors qualify for authorship, and all those who qualify for authorship are listed.

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