Title:

Warming to the ice bath: Don't go cool on cold water immersion just yet!

Comment on:

1) Arthur J. Cheng. Cooling down the use of cryotherapy for post-exercise skeletal muscle recovery. *Temperature. 2018. 5(2): 103-105. doi: 10.1080/23328940.2017.1413284.*

2) Cheng et al. Post-exercise recovery of contractile function and endurance in humans and mice is accelerated by heating and slowed by cooling skeletal muscle. *Journal of Physiology. 2017. 595(24): 7413-7426. doi: 10.1113/JP274870*

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We read with interest the recent commentary on the effects of cold water immersion (CWI) on skeletal muscle recovery following endurance exercise [1]. The narrative describes recent work which reported impaired recovery in arm cycling performance, when triceps brachii muscle temperatures were reduced to approximately 15˚C following a 120 min localized cooling intervention [2]. To elucidate the underpinning mechanisms, complimentary experiments on single muscle fibers from mouse flexor digitorum longus were performed. It was shown that cooling impaired the recovery in submaximal force production and fatigue resistance, in line with decreased sarcoplasmic reticulum Ca^{2+} release and lower rates of muscle glycogen re-synthesis. Conversely, heat application targeted at maintaining muscle temperatures 5˚C above resting physiological temperatures was shown to accelerate glycogen re-synthesis in single fibers, as well as preserved contractile function and performance within the human and rodent experiments. This work nicely demonstrates the influence of muscle fiber temperature on calcium kinetics. Moreover, differences in cardiorespiratory response were adequately controlled for whilst successfully manipulating muscle temperatures, providing mechanistic insights into the effects of prolonged and extreme decreases in tissue temperature per se on the recovery of muscle contractile function. In the narrative [1], the author has cautioned against the use of CWI for skeletal muscle recovery, particularly when multiple competitions or qualifying rounds are performed within the same day. Additionally, it was suggested that competitions performed over consecutive days or weeks can lead to accumulative fatigue and regular CWI can compound the problem. The motivation for this commentary is twofold; firstly, to commend the rigorous mechanistic insight provided by Cheng and colleagues in their work [1, 2], and secondly, encourage the appropriate context be applied to such data by the scientific and applied communities [1].

It is crucial to consider the experimental context within the original work, when extrapolating the findings to applied recommendations [1]. For instance, the cooling protocol utilised (i.e., 120 min) in the original research [2], and the resultant physiological responses (extremely low muscle temperatures i.e., ~15˚C), are atypical from common practice in research and their application to athletes in the 'real world' [2, 3]. Moreover, performing intense exercise soon after cooling the muscles for 120 min is far removed from its application in professional sport given the long-standing evidence supporting warmer temperatures for improved muscle function. It is important to note that post-exercise CWI is typically undertaken at temperatures ranging between 10-15˚C for 10-15 min, resulting in muscle temperatures of approximately 30˚C [3]. Consequently, while these experiments may improve our understanding of the intramuscular factors influencing muscle function following cooling, extrapolation and application to a sports science setting is difficult [1]. Recommending for or against the use of post-exercise CWI is certainly contextual, as the effects of CWI are complex and multifaceted, and the overall influence on adaptations and performance are likely to be influenced by a range of factors including the magnitude, location, timing of cooling and the specific demands of the exercise tasks both prior to and following cooling.

In Cheng et al. [2], arm cycling performance was shown to be impaired, and conversely enhanced when tricep brachii were either cooled to ~15˚C or heated to 38˚C, respectively. Whilst such findings are now largely anticipated following the established work over the recent decades demonstrating enhanced muscle function at warmer temperatures, this new data reiterates that practitioners should exercise caution, and ensure appropriate warm-up and rewarming if the use of CWI is warranted between closely scheduled performances. In their single fiber experiments, it was shown that cooling to 16˚C or 26˚C resulted in decreased submaximal force and fatigue resistance, in line with impaired sarcoplasmic reticulum Ca^{2+} release, despite standardizing the

media temperature to 31˚C when the contraction was initiated [1]. This phenomenon was attributed to the slower rates of glycogen re-synthesis following cooling, which was otherwise shown to be accelerated following heat treatment. The authors should be commended for this research, demonstrating mechanisms other than fiber temperature per se (i.e., glycogen re-synthesis) on muscle contractile function. However, it is unclear if CWI might exacerbate the development of muscle fatigue when competing over consecutive days or weeks based on muscle glycogen measurements determined just 30 min into recovery, aside from implementing a cooling stimulus that is highly dissimilar with practices in the field [1]. Indeed, we have previously [4] demonstrated no detrimental effect of post-exercise CWI (10 min immersion @ 8˚C) on muscle glycogen re-synthesis in human participants throughout a 4-h recovery period, whilst regular CWI (15 min @ 15˚C) undertaken during 3 weeks of intensified training tended to improve training performances amongst national level cyclists [5]. These studies in contrast, support the use of post-exercise CWI during periods of intensified training or competition. Whilst Cheng et al. [2] make an excellent observation, and caution that aggressive cooling strategies harness the potential for impaired muscle recovery, it is now the responsibility of the scientific community to be communicating this clearly to those undertaking such modalities regularly. In this regard, findings from Cheng et al. [2] should discourage practitioners from using aggressive cooling strategies, whilst noting that common CWI protocols are unlikely to show similar impairments due to shorter immersion durations, smaller reductions in tissue temperature and correct timing of application.

We agree that CWI seems not to be the ideal recovery intervention following resistance exercise. However, recent work by Taveres et al. [6] supports the notion that appropriate programming of CWI sessions may negate any adverse effects on strength adaptations to resistance training. Indeed, amongst elite Rugby players, a tendency for improved countermovement jump

performance was evident when regular CWI (10 min @ 10˚C) was undertaken at the end of each training day, whilst resistance training sessions were undertaken in the morning during a 3-week pre-season training period [6]. Nevertheless, we acknowledge that similar research over a longer training period is warranted to further verify this notion.

In conclusion, it should be emphasised that the effect of cooling on exercise performance and adaptations are distinct, and influenced by many factors including the duration, timing, magnitude, individual responses and nature of activity. While mechanistic studies such as Cheng et al. [2] are crucial to help understand the intramuscular factors influencing muscle function following cooling and heating, the extrapolation and application of such data to a sports science setting needs to be within appropriate context and understanding. CWI involving 10-15 min of immersion at 10-15˚C has been shown to improve acute and subsequent day recovery in exercise performance and wellbeing, and may be a useful recovery tool during periods of intensified training or competition [5-7]. Such CWI protocols do not seem to impair muscle glycogen re-synthesis 4h post-exercise [4]. While research by Cheng et al. [2] has indicated important physiological responses to extreme cooling [2], it should not be suggested that post-exercise CWI (10-15 min @ 10-15˚C) will confer synonymous effects. In addition, the use of CWI should be avoided immediately following resistance training. Apart from some caveats, there is evidence supporting the use of CWI to enhance physiological recovery, and in our humble opinion - time to cool down the unnecessary scaremongering against the use of this recovery modality.

References

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