PERSPECTIVES

Post-exercise recovery regimes: blowing hot and cold

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Athletes aiming to improve upon past performances often look to train harder and longer than ever before, but training hard in a single session is of little use if ensuing muscle damage and soreness conspire with other factors to limit performance over the following days. The promise that post-exercise habits may be modified to boost physiological adaptation or recovery is therefore very appealing. The utilisation of post-exercise recovery techniques, via active recovery, cold-water immersion (CWI) or other therapies is a component of the training regimes of many elite athletes. Clearly, the use of a regime post-exercise to aid in recovery is demonstrably better than adopting a sedentary approach. However, the choice of using CWI or potential benefits of using one recovery strategy over another needs to be justified, preferably using evidence of efficacious effects, rather than being based solely on personal preferences. In the current issue of *The Journal of Physiology*, Peake *et al.* (2017) attempt to address this question by comparing the impact of CWI with active recovery on a range of parameters relating to skeletal muscle adaptation, inflammation and repair post-exercise. It is reasoned that reducing the temperature of the muscle and thus blood flow using CWI may dampen the local inflammatory response, helping to reduce the extent of cell and tissue damage, and thereby boost post-exercise recovery. What is striking in the blanket use of CWI as a post-exercise recovery technique is the assumption that inflammation needs to be dampened down or suppressed. The inflammation, which occurs post-exercise, is a crucial component of the adaptive response of skeletal muscle to training. A significant proportion of the scientific evidence justifying the use of CWI as a means of aiding post-exercise recovery (in an anti-inflammatory context) stems from a range of studies conducted in rodents, many using models of gross muscle injury, where the application to human physiology is not clear.

In the present study, Peake *et al.* examined inflammatory cell invasion into muscle, alongside a range of cytokines, heat shock proteins and neurotrophins in muscle, at 2, 24 and 48 h post-heavy resistance exercise, with or without a period of CWI. The authors observed expected increases in inflammatory and cellular stress components in muscle after the exercise. However, there was no anti-inflammatory effect observed in any of the parameters, upon intervention with CWI. These findings are striking and may well pave the way for an alternative approach to post-exercise recovery; however, a closer examination of the impact of CWI is needed before we say anything that may discredit the vocal advocates. The mechanisms that regulate inflammation in muscle post-exercise are complex, encompassing a range of cytokines, chemokines and adhesion molecules. Peake and colleagues examined a discrete range of components involved in these processes, for reasons that were well justified, but the interrogation of a wider range of inflammatory markers may yield a more robust assessment of the impact of CWI. Examination of receptors complimentary to the cytokines or chemokines (e.g. CCR2/4 are receptors for CCL2) described in this study, alongside expression of the cyclo-oxygenases and nitric oxide synthases (NOS) may provide additional mechanistic insight into the adaptive responses. The measurements taken by Peake *et al.* are to a degree temporal, and the examination of a range of parameters between 2 and 24 h may again provide greater insight into the complex mechanisms of inflammation post-exercise.

The study by Peake *et al.* focuses heavily on the inflammatory aspect of exercise; however, there are numerous adaptive processes that occur in muscle post-exercise. CWI has been demonstrated to be beneficial in some contexts and less so in others. Thus, it is important to consider that the differential effects of post-exercise CWI are likely to be dependent upon the nature of the exercise undertaken, as well as the duration and regimen of CWI. For instance, a recent study examined the impact of post-exercise CWI, following intermittent sprint training, on expression of peroxisome proliferator activated-receptor γ co-activator-1 α (PGC-1α) a regulator of mitochondrial biogenesis, and vascular endothelial growth factor (VEGF) (Joo *et al.* 2016). In this study, participants carried out an acute bout of exercise followed by CWI (10 min at 8°C) and it was reported that CWI augmented the exercised-induced gene expression of PGC-1α, and that CWI alone could activate VEGF and PGC-1α. In a similar study, CWI (15 min 10°C) was also shown to enhance PGC-1α gene expression in muscle after 30 min continuous running (70% $\dot{V}_{O_2max}$), which was followed by intermittent running to exhaustion (100% $\dot{V}_{O_2max}$). In contrast, there was no significant effect of post-exercise CWI on VEGF or NOS gene expression (Ihsan *et al.* 2014). Given the well-established role of PGC-1α and VEGF in the adaptive response of muscle to exercise, these studies indicate that CWI may play an important role in mediating these changes.

In the context of resistance training, regular use of post-exercise CWI has been reported to attenuate the long-term adaptations (increased strength and muscle mass) to a 3 month period of training (Roberts *et al.* 2017). In contrast, regular post-exercise CWI throughout a 4 week period of endurance training enhanced p38 mitogen activated protein kinases (p38 MAPK), adenosine monophosphate-activated protein kinase (AMPK) and PGC-1α (Ihsan *et al.* 2015). Collectively, these studies highlight the need to understand the impact of CWI in both the short and long term, taking into account the mode of exercise (Ihsan *et al.* 2016). Thus, an integrated approach, encompassing molecular and physiological analyses, is needed to comprehensively address the impact of post-exercise CWI.

Muscle pain and soreness are a typical feature of the adaptive processes occurring after exercise (Leeder *et al.* 2012). There is clear evidence to demonstrate the efficacy of CWI in improving the perception of pain and fatigue post-exercise; however, Peake *et al* suggest this may not be derived from changes at the muscle level. Thus, there may be a psychological element or centrally mediated effects to the (possibly perceived) benefits of CWI post-exercise (Broatch *et al.* 2014) – further investigation

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into this aspect is needed, as psychologically based approaches are already commonplace in the training of elite athletes.

Overall, the study by Peake *et al.* challenges the dogma that CWI is a crucial anti-inflammatory component of post-exercise recovery. However, further work is needed to stratify the impact of CWI on a wide range of adaptive markers in muscle, and in relation to exercise type, duration and intensity.

References

Broatch JR, Petersen A & Bishop DJ (2014). Postexercise cold water immersion benefits are not greater than the placebo effect. *Med Sci Sports Exerc* **46**, 2139–2147.

Ihsan M, Markworth JF, Watson G, Choo HC, Govus A, Pham T, Hickey A, Cameron-Smith D & Abbiss CR (2015). Regular postexercise cooling enhances mitochondrial biogenesis through AMPK and p38 MAPK in human skeletal muscle. *Am J Physiol Regul Integr Comp Physiol* **309**, R286–R294.

Ihsan M, Watson G & Abbiss CR (2016). What are the physiological mechanisms for post-exercise cold water immersion in the recovery from prolonged endurance and intermittent exercise? *Sports Med* **46**, 1095–1109.

Ihsan M, Watson G, Choo HC, Lewandowski P, Papazzo A, Cameron-Smith D & Abbiss CR (2014). Postexercise muscle cooling enhances gene expression of PGC-1α. *Med Sci Sports Exerc* **46**, 1900–1907.

Joo CH, Allan R, Drust B, Close GL, Jeong TS, Bartlett JD, Mawhinney C, Louhelainen J, Morton JP & Gregson W (2016). Passive and post-exercise cold-water immersion augments PGC-1α and VEGF expression in human skeletal muscle. *Eur J Appl Physiol* **116**, 2315–2326.

Leeder J, Gissane C, van Someren K, Gregson W & Howatson G (2012). Cold water immersion and recovery from strenuous exercise: a meta-analysis. *Br J Sports Med* **46**, 233–240.

Peake JM, Roberts LA, Figueiredo VC, Egner I, Krog S, Aas SN, Suzuki K, Markworth JF, Coombes JS, Cameron-Smith D & Raastad T (2017). The effects of cold water immersion and active recovery on inflammation and cell stress responses in human skeletal muscle after resistance exercise. *J Physiol* **595**, 695–711.

Roberts LA, Raastad T, Markworth JF, Figueiredo VC, Egner IM, Shield A, Cameron-Smith D, Coombes JS & Peake JM (2015). Post-exercise cold water immersion attenuates acute anabolic signalling and long-term adaptations in muscle to strength training. *J Physiol* **593**, 4285–4301.

Additional information

Competing interests

None declared.

Author contributions

Both 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.