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To perform your best: work hard not long

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PERSPECTIVES

To perform your best: work hard not long

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The overload principle, that improved performance is the result of systematic and progressive training of sufficient frequency, intensity and duration, is the one overriding truth in exercise physiology. The uncertainty that has cost many a coach their job is: what is the optimal frequency, intensity and duration? With the results in this issue of *The Journal of Physiology*, Gibala *et al.* (2006) have started to determine how short the duration of exercise can be while still increasing cycling performance. As a result of the short duration, the workload of their subjects is extreme: about 4-times as high as regular endurance training. If you can complete the high-intensity exercise, the improvement in performance, mitochondrial mass, muscle buffering capacity, and glycogen supercompensation is the same following as little as 3 min of cycling as it is in subjects who performed 90–120 min of cycling at 65% of their maximum. While these findings probably won't change the training protocols of elite athletes, they may have important implications for those wishing to maintain fitness and they also provide clues as to the complex nature of the response to endurance exercise.

It is becoming increasingly clear that there are at least three molecular signals that can lead to an increase in mitochondrial mass and glucose transport capacity in skeletal muscle following endurance exercise training (Hood *et al.* 2006). The pulsatile decrease of ATP and concomitant increase in AMP during repeated high-intensity exercise can activate the AMP-activated protein kinase; a long-term rise in intracellular calcium can activate calcium–calmodulin kinases; and the cellular stress associated with intense endurance exercise can activate p38 MAP kinase. The reason that many different types of training have a similar net result on muscle phenotype might be explained by the fact that all three signalling molecules have a similar downstream target. In skeletal muscle, all three of these molecules participate in the phosphorylation of the transcriptional repressor HDAC5 (Al-Khalili *et al.* 2004; Bassel-Duby & Olson, 2006). Phosphorylation of HDAC5 results in its dissociation from Mef2 and the subsequent activation of transcription. Two of the targets of this transcriptional activation are the GLUT4 and PGC-1α genes (Bassel-Duby & Olson, 2006). GLUT4 catalyses the rate-limiting step in glucose uptake and glycogen synthesis, the transport of glucose into the muscle cell, while PGC-1α coordinates the expression of the nuclear and mitochondrial genes needed for mitochondrial biogenesis. The result is an increase in the capacity to take up and either oxidize or store glucose, the main fuel used during maximal performance, as well as an increased capacity to generate ATP from fat and spare glycogen during lower intensity exercise.

In support of this hypothesis, the work of Gibala *et al.* (2006) draws on studies performed by Shin Terada (Terada *et al.* 2001, 2005). Dr Terada showed that rats swimming 6 h a day carrying a weight equal to 2% of their body weight had similar increases in GLUT4 and PGC-1α content as rats that swam for 14 intervals lasting 20 s carrying a weight equal to 14% of their body weight. While not all of the cellular signals described above were measured, they did show that the activation of AMP kinase was almost twice as high in the high-intensity group as the low-intensity group (Terada *et al.* 2005). There are two possible explanations for the fact that the change in GLUT4 and PGC-1α were the same after either 8 days or 6 h. The first possibility is that there is a threshold for the adaptation to endurance training over which no greater increase in PGC-1α or GLUT4 is possible. The second is that the sum total of AMPK, p38 and CamK activation is the same under the two protocols: the greater AMPK activity in high-intensity training is made up for by longer periods of elevated calcium.

For those looking to do the least possible work to be fit, the work of Gibala *et al.* (2006) presents hope. In as little as 3 min (40 min total time including warm up and cool down) we can improve our $\dot{V}_{O_2,max}$ and performance. However, there are a couple of caveats. First, high-intensity training does not utilize as many calories as long-duration exercise, meaning that it would not be as good if the goal were weight loss. Second, it is unclear whether performance in other sports (i.e. running) are effected in the same way by high-intensity training, and lastly, as a former strength and conditioning coach I can say that while many people are willing to exercise at a low intensity for a long duration, it is VERY hard to get people to exercise at a high intensity for any period of time.

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