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New strategies in sport nutrition to increase exercise performance

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ABSTRACT

Despite over 50 years of research, the field of sports nutrition continues to grow at a rapid rate. Whilst the traditional research focus was one that centred on strategies to maximise competition performance, emerging data in the last decade has demonstrated how both macronutrient and micronutrient availability can play a prominent role in regulating those cell signalling pathways that modulate skeletal muscle adaptations to endurance and resistance training. Nonetheless, in the context of exercise performance, it is clear that carbohydrate (but not fat) still remains king and that carefully chosen ergogenic aids (e.g. caffeine, creatine, sodium bicarbonate, beta-alanine, nitrates) can all promote performance in the correct exercise setting. In relation to exercise training, however, it is now thought that strategic periods of reduced carbohydrate and elevated dietary protein intake may enhance training adaptations whereas high carbohydrate availability and antioxidant supplementation may actually attenuate training adaptation. Emerging evidence also suggests that vitamin D may play a regulatory role in muscle regeneration and subsequent hypertrophy following damaging forms of exercise. Finally, novel compounds (albeit largely examined in rodent models) such as epicatechins, nicotinamide riboside, resveratrol, β-hydroxy β-methylbutyrate, phosphatidic acid and ursolic acid may also promote or attenuate skeletal muscle adaptations to endurance and strength training. When taken together, it is clear that sports nutrition is very much at the heart of the Olympic motto, *Citius, Altius, Fortius (faster, higher, stronger)*.

1. Introduction into the growing role of sport nutrition

In keeping with the Olympic motto "*Citius, Altius, Fortius*", the traditional research focus in the field of sports nutrition has been one that has largely centred on those strategies that may improve performance on competition day. In this way, over 50 years of research has investigated strategies to prepare for competition (e.g. pre-exercise fuelling), promote performance during competition (e.g. fluid intake and carbohydrate feeding) and recover from competition (e.g. carbohydrate and protein feeding to promote muscle recovery). Additionally, many investigators have researched those ergogenic aids that may improve exercise performance and/or fatigue through modulating either central or peripheral aspects of fatigue. When taken together, it is clear that those competition nutrition strategies that focus on sufficient macronutrient intake and ergogenic aids to promote energy availability and delay the biochemical determinants of fatigue are now largely based on sound scientific evidence.

However, in the last decade of research, accumulating data have now demonstrated a potent role of both macro- and micro-nutrient availability in regulating those exercise-induced cell-signalling pathways that are thought to regulate skeletal muscle adaptations to exercise training. As such, both researchers and practitioners alike are now beginning to treat "competition nutrition" and "training nutrition" as two separate entities, the former having an obvious performance focus but the latter having an adaptive focus. For example, in the case of endurance exercise, emerging data suggest that deliberate periods of reduced carbohydrate availability (and potentially, high fat availability) can enhance those adaptations fundamental to endurance performance including mitochondrial biogenesis, increased lipid oxidation and increased fatigue resistance. Similarly, many novel compounds are also emerging (albeit from rodent studies) that can also regulate those signalling pathways inherent to endurance training adaptations. In the context of resistance exercise, it is also now well known that increased dietary protein is a necessary nutrient to promote muscle growth by providing those necessary amino acids to both activate and promote muscle protein synthesis.

In the present paper, we review the current developments in sports nutrition by providing a narrative that simultaneously

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discusses traditional and novel strategies that serve to enhance exercise performance and training adaptations. We begin by providing an overview of the molecular regulation of skeletal muscle adaptations to endurance and resistance training and discuss where appropriate, the role of carbohydrate, fat and protein in modulating performance and training adaptations. We then proceed to review our latest thinking on evidence-based supplements that can promote performance. Finally, we close by outlining a variety of potential novel compounds that may also regulate training adaptations.

2. Nutrition gene interactions

Multiple molecular pathways are activated by exercise and these pathways have been shown to contribute to the adaptive remodelling of skeletal muscle [1,2]. These same pathways are shared with a number of the nutrient sensing mechanisms [3,4]. This cross-talk between nutrient sensitive and exercise sensitive pathways opens up the possibility that nutrient provision strategies could influence not only acute exercise performance through fuelling the activity, but also the magnitude of the adaptive response following a period of structured exercise training. In the following sections we will discuss some of these nutrient–gene interactions and the potential for exploiting these interactions through strategically delivered or withheld nutrition to enhance the adaptive stimulus and ultimately to improve exercise and athletic performance.

2.1. The molecular regulation of endurance training adaptation

Endurance training is typically defined by rhythmically performing relatively low intensity contractions for a relatively long period of time [5], however recent studies show that short duration high intensity interval training may in fact result in similar adaptations to typical endurance exercise [6]. Structured endurance training leads to improvements in fatigue resistance partly by altering the phenotype of the skeletal muscle performing the work [7]. At the level of the muscle a period of endurance training leads to improvements in blood flow, mitochondrial content and an improved ability to extract and utilise oxygen during exercise [7]. These adaptive processes are driven by

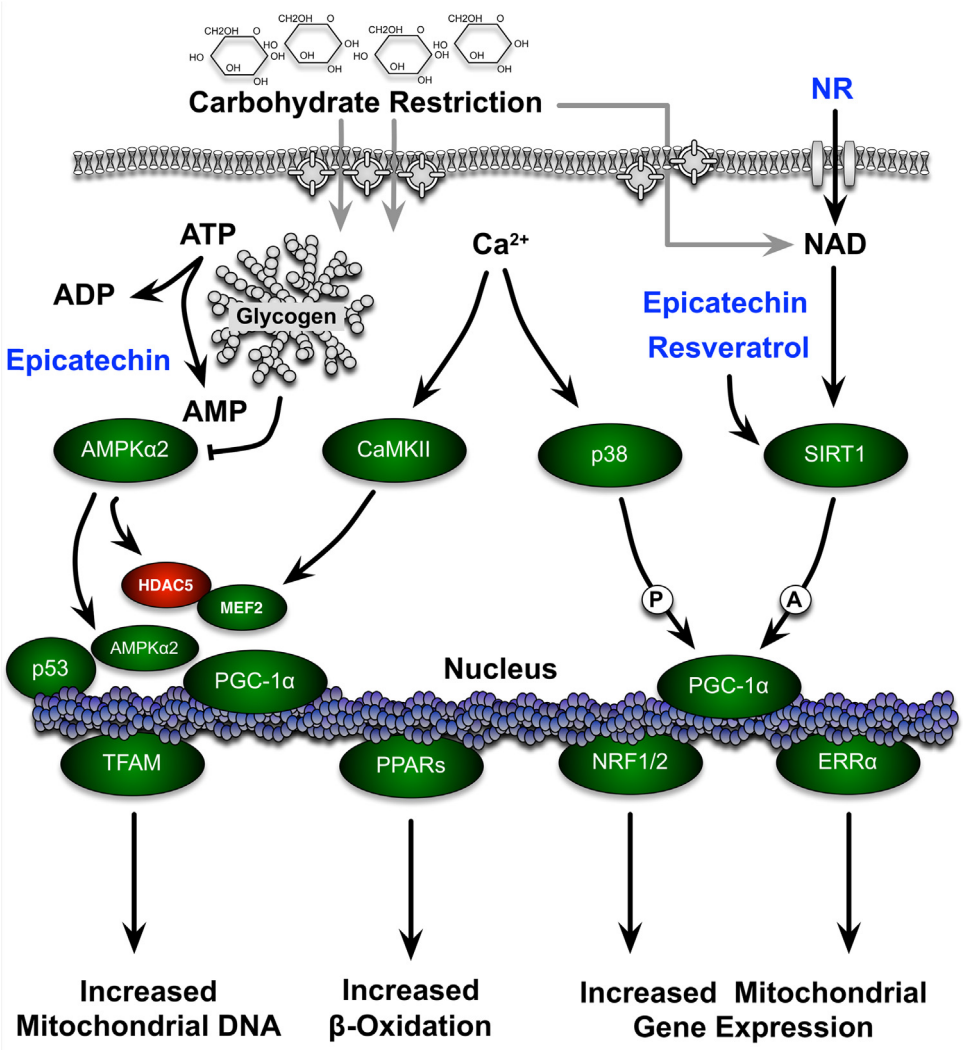

Fig. 1. Overview of the molecular signalling pathways activated in skeletal muscle in response to endurance exercise. Contraction results in alterations in AMP, Ca2+ and NAD which activate numerous cellular energy sensing proteins (AMPK, CaMKII, p38MAPK, SIRT1). These signalling proteins converge on the transcriptional co-activator PGC-1α which leads to increases in mitochondrial biogenesis through the activation of numerous nuclear transcription factors (TFAM, PPARs, NRF1/2, ERRα). Carbohydrate restriction and/or glycogen depletion during exercise leads to further enhances in mitochondrial biogenesis through increased activity of AMPK, p38 and SIRT1. In addition, the small compounds epicatechins, nicotinamide riboside (NR) and resveratrol have all been suggested to enhance endurance-training responses in skeletal muscle through a number of signalling pathways (blue).