

## Macronutrients and Exercise-Induced Muscle Damage Recovery

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### Abstract

In recent years, significant advances in molecular biology has facilitated emerging knowledge pertaining to genetics in sport science research. Specific regions of DNA are known to influence genetic polymorphism(s) and partly explain individual variations in response to exercise stimuli and diet. Following exhaustive exercise, certain genetic variations or polymorphisms have been associated with muscle damage indices and may influence muscular recovery. The purpose of this narrative review, also highlight the potential interaction of impact of macronutrients in muscle damage recovery.

**Keywords:** Macronutrients; Exercise-Induced; Muscle Damage Recovery

### Introduction

Muscular adaptations are multifactorial and are primarily determined by exercise stimulus and adequate nutritional support; however, there is large individual variability. As such, genetics are emerging as an important variable to predict responsiveness. Identifying key genotypes and polymorphisms is a critical factor for understanding individual acute exercise performance and physiological responses and adaptations [1].

Exercise is well known to upregulate and signal specific proteins associated with enhancing mitochondrial biogenesis and oxidative power and capacity [2], alter metabolic flexibility, and influence intracellular signaling and transcriptional responses [3]. Molecular adaptations are mediated by stimuli involved in controlling the content of mRNA and these proteins in skeletal muscle, in theory, increase exercise performance.

Some sports require greater muscular stress and eccentric overload leading to increase muscle soreness from 24 to 72 hours after a single exercise bout [4]. Exercise intensity and type of muscular contraction are also associated with muscle injury, leading

to an increased inflammatory response and activation of adjacent pathways, such as muscle protein degradation [3] and changes on circulating muscle-specific proteins [i.e., creatine kinase (CK), myoglobin and  $\alpha$ -actin] [4,5]. Noteworthy, some polymorphisms may modify the proteins which can potentially modulate muscle function or adaptation [6].

The initial phase, which occurs during the exercise session, and the secondary phase, which is linked to the delay in the inflammatory response [6]. These phases are critical to stimulate muscle remodeling [7] and down regulation or blocking this inflammatory response may attenuate adaptations. Appropriate muscle damage caused by exercise provides a positive stimulus for muscle restructuring, hypertrophy and strength gains [5,7].

In elite athletes, the incidence of injuries is higher than the general population, partly due to training exposure, and possibly due to different genetic profiles [8]. It is likely that the ideal genetic profile to enhance performance is dependent on the specific sport [9]. These genetic differences alter muscle recovery, training and responses to nutrition [6].

Adaptations from both aerobic and resistance training are mediated by a complex interaction between genes and nutrients [9] altering signaling pathways and main transcription co-activators associated polymorphisms [10] which are also related to exercise-induced muscle damage [10]. The interactions between diet and genes related to metabolic pathways involved in both health and sports performance are becoming more widely recognized [11,12].

Macronutrient imbalance may alter metabolic, physiological and functional pathways reducing performance [13,14]. Carbohydrates provide an essential fuel [15] for brain and skeletal muscle [16,17] and their consumption affects sport performance predominantly in high intensity exercise [17,18]. Proteins are essential for strength, increases and/or maintenance of lean body mass, in addition to playing an important role in immune function [19,13]. Fat (fatty acids and glycerol) are an important source of energy and play a critical role in the regulation of genes and in the cellular adaptation of skeletal muscles [20]. The aim of this review was to discuss the current scientific interaction with diet/macronutrients in muscle damage recovery.

#### Macronutrients and exercise-induced muscle damage recovery.

Gene expression is a complex process carried out through the activities of different response elements that potentially influence the rate of gene transcription. Nutrients in a diet can act actively to influence the rate of transcription, or passively, by altering specific signaling pathways.

Nutrients can actively act to influence the rate of transcription, through the alterations of specific signaling pathways and genetic variants relevant to exercise performance [21]. Optimal nutritional strategies are needed to support adaptive responses to enhance performance [22,23]. The macronutrient composition is a critical component of any nutritional plan for optimal recovery, in addition to reducing or recovering from injury and periods of immobilization and reduced activity [24]. The amount of exercise and resting energy expenditure typically dictate total energy expenditure during immobilization [25]. An imbalance in macronutrients can result in metabolic and physiological stress and hinder recovery [26]. An important consideration during injury-induced immobilization is the appropriate energy intake. Recommendations may be considered somewhat counterintuitive.

#### Carbohydrate

Carbohydrate consumption during and after exercise can affect the increased or decreased rate of muscle and liver glycogen synthesis, mainly by insulin-mediated glycogen synthase activation [27]. In addition, exercise-induced muscle damage has been associated with impaired glycogen synthesis [28] and reduced glucose uptake likely due to muscle damage [31] and reduced muscle insulin sensitivity. Insulin signaling influences increased blood flow and protein synthesis at rest and suppresses protein breakdown after resistance exercise, improving the net balance of muscle proteins, in particular with the delivery and availability of amino acids [1,29]. It is now widely accepted that consuming a diet sufficient in carbohydrates, along with ingesting carbohydrates during and following exercise, can improve performance and speed recovery [30].

Immediately after physical activity, muscle cells that have experienced a substantial decrease in glycogen content are metabolically primed for rapid glycogenesis [28]. When carbohydrates are ingested shortly after exercise, insulin release from the pancreas, insulin sensitivity in muscle cells, glucose uptake by muscle cells, and glycogen synthase activity in muscle cells increase [28], responses that may remain elevated for a long time. 48 hours [32]. The timing of carbohydrate intake after physical activity is very important during training and competition versus recovery. Daily carbohydrate intake should reflect the extent of carbohydrate oxidation during training: low on light training days, substantially higher on days of intense or prolonged training [31,32]. Table 3 contains related practical recommendations.

Adapted from Burke., *et al.* (2017).<sup>4</sup> Abbreviations: BW, body weight.

For daily active individuals, energy needs can exceed 3,000 kcal/day, resulting in increased dietary intake of carbohydrates, proteins, and other nutrients. Increasing consumption of high-quality carbohydrate foods such as potatoes, grains, fruits can help ensure adequate consumption of nutrients vital for health, recovery, repair, adaptation, growth and performance [6,9,30]. As is often the case in science, additional research is needed to further clarify the conditions in which consuming high-GI foods benefits glycogen restoration and performance.

Exercise Intensity	Description	Dietary Carbohydrate
Low	Easy activity such as yoga, tai chi, walking, or any exercise done at a light effort (can easily talk or sing during the activity)	3–5 g/kg BW/d
Moderate	One hour or more of activity such as walking, jogging, swimming, bicycling at a modest effort (can carry on a conversation without problem, but cannot sing)	5–7 g/kg BW/d
High	One hour or more hard exercise such as interval training, running, swimming, bicycling at a modest effort (can carry on only very brief conversations)	6–10 g/kg BW/d
Very- high	Very hard exercise for an hour or more or very prolonged exercise such as interval training, ice hockey, soccer, basketball, running, swimming, bicycling at an intense effort (cannot speak during the effort)	8–12 g/kg BW/d

**Table 1:** Recommendations for daily carbohydrate intake for athletes involved in repeated days of strenuous, prolonged physical activity and training.

### Protein

Protein is essential for muscle building and repair. Most of the pleiotropic effects of proteins are mediated by the expression of the target gene [1,31]. The coding genes, such as the insulin-like growth factor system (IGF-3) are highly sensitive to nutritional status [29].

The adaptations induced by exercise are reflected by changes in protein and contractile function, as well as in mitochondrial function, intracellular signaling and transcriptional responses [29]. This suggests that nutritional strategies are able to compensate for the anabolic resistance of physical exercise capable of increasing the rates of muscle protein synthesis and decrease muscle loss during muscle injury or disuse [10,33].

Undoubtedly, sufficient protein intake is necessary to support wound and/or fracture healing. However, there does not seem to be much support for increasing protein intake to enhance recovery or to slow muscle loss with immobilization [22,23]. These increases in muscle protein turnover will contribute to increased energy requirements during recovery [33,34]. So, with increased activity and metabolism, energy expenditure is almost certain to increase during rehabilitation [22-24]. Clearly, since synthesis of muscle and other proteins is critical, energy intake should not be restricted much. It suggested that daily protein intake typically ranges from 1.2 to 2.0g/kg body mass per day. However, no specific recommendation or comparison was made in regard to the most appropriate macronutrient intake that can benefit exercise recovery [22,23,33].

### Fatty acids

Fatty acids regulate the expression of many genes, in addition to their role as an important oxidative substrate [35]. Studies show that the actions of fatty acids in skeletal muscle have a significant effect on the expression of the gene encoding the de-coupling protein 3 (UPC-3). UPC-3 in the muscle plays an important role in homeostasis and oxidation of lipids and carbohydrates [36,37]. Studies provide strong evidence of the role of fatty acids in the regulation of gene expression (Macdonald, 2001) with a step in the cellular adaptation of skeletal muscles that can contribute to the prevention of injuries [38]. The relative contribution of these fuels to the energy demands of skeletal muscle is associated with a complex regulation at multiple levels, including availability of substrate, hormonal concentrations, and regulation of enzymatic activities by intracellular metabolic intermediates [35], in addition to exercise intensity and duration [36]. The inflammatory response occurs after the morphological damage caused by eccentric contraction. Cytokines are released into injured muscle when inflammatory cells such as neutrophils and macrophages are most active. Inflammatory mediators are released, namely pro-inflammatory cytokines such as TNF- $\alpha$  and IL-6 and anti-inflammatory cytokines such as IL-10. The acute effect of n-3 PUFAs has been shown to reduce the level of TNF- $\alpha$  without decreasing the level after anaerobic exercise [39]. n-3 PUFAs are known for their anti-inflammatory properties. n-3 PUFAs can inhibit inflammation by blocking TNF- $\alpha$  signaling by activating protein responses in muscle [40].

### Other nutrients

During rehabilitation and recovery following immobilization, it is likely that energy needs will increase due to the restoration of physical activity and increased protein turnover. During this stage, there is a rationale to increase protein intake, but not at the expense of sufficient carbohydrate to support renewed training [48]. Ultimately, a balanced diet with sufficient energy, ample carbohydrate, protein and micronutrient intakes is always the best approach. Other supplements to aid in muscle recovery. Creatine supplementation may help increase the rate of muscle hypertrophy; success of creatine supplementation may depend on the type of injury and the length of immobilization [41]. Moreover, recent preliminary evidence suggests that omega-3 fatty acid supplementation most associated with injury are the omega-3 fatty acids. These fatty acids are widely associated with anti-inflammatory and immunomodulatory properties [19,20]. Thus, there are wide-ranging recommendations for omega-3 supplementation during recovery from injuries [22,23,42,43].

Collagen synthesis rates in tendon and muscle do not respond to increased amino acid levels, suggesting that protein feeding would have little impact on tendon healing [44]. Bone collagen synthesis, an important aspect of bone healing, on the other hand, does respond to increased amino [44]. Leucine may help overcome the resistance of muscle protein synthesis to anabolic stimuli [49]. There is some theoretical rationale for increasing leucine intake, but direct evidence for these injury situations is not forthcoming [45].

### Conclusion

Sports performance is multifactorial, having been implicated in several aspects of skeletal muscle remodeling. Individuals with specific genotypes experience changes in induced muscle damage and recovery rates after exercise. The contribution of heritability to a specific phenotype is likely dependent and specific to exercise modality, intensity and duration. Future research will allow the assessment of the multigenetic traits needed to provide a deeper molecular understanding of recovery, adaptation and nutrition that may allow for the identification of individuals with a greater genetic predisposition, or at greater risk of developing muscle injuries. Macronutrients play an important role in muscle remodeling, repair and recovery.

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