Acta Scientific NUTRITIONAL HEALTH (ISSN:2582-1423)

Volume 6 Issue 9 September 2022

Review Article

Macronutrients and Exercise-Induced Muscle Damage Recovery

Thais Verdi*

Clinical, Orthomolecular and Sports Nutritionist, Nutritionist in São Paulo, Brazil

***Corresponding Author:** Thais Verdi, Clinical, Orthomolecular and Sports Nutritionist, Nutritionist in São Paulo, Brazil.

DOI: 10.31080/ASNH.2022.06.1114

Received: June 24, 2022

Published: August 17, 2022

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 α-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 adaptions. 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 effects 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 carbo- hydrates 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).4 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 ef- fort (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 inter-val training, ice hockey, soccer, basketball, running, swim- ming, 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-a 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-a 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-a 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 sufficcient 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.

Bibliography

1. Andreassen CS., *et al*. "Accelerated atrophy of lower leg and foot muscles--a follow-up study of long-term diabetic polyneuropathy using magnetic resonance imaging (MRI)". *Diabetologia* 52.6 (2009): 1182-1191.
2. Abreu Phablo., *et al*. "Adaptação do músculo esquelético ao exercício físico: Consideração Moleculares". *Revista Brasileira de Medicina do Esporte (online)* 23 (2017): 60-65.
3. Hyldahl RD and Hubal MJ. "Lengthening our perspective: morphological, cellular, and molecular responses to eccentric exercise". *Muscle Nerve* 49.2 (2014): 155-170.
4. Grobler L., *et al*. "Remodelling of skeletal muscle following exercise-induced muscle damage: review article". *International SportMed Journal* 5.2 (2014): 67-83.
5. Martinez Amat A., *et al*. "Role of alpha-actin in muscle damage of injured athletes in comparison with traditional markers". *British Journal of Sports Medicine* 41.7 (2017): 442-446.
6. Baumert P., *et al*. "Genetic variation and exercise-induced muscle damage: implications for athletic performance, injury and ageing". *Journal of Applied Physiology* 116 (2016): 1595-1625.
7. Macdonald P. "Diversity in translational regulation". *Current Opinion in Cell Biology* 13.3 (2001): 326-331.
8. Aragon AA and Schoenfeld BJ. "Nutrient timing revisited: Is there a post-exercise anabolic window?" *Journal of the International Society of Sports Nutrition* 10 (2013): 5.
9. Muller M and Kersten S. "Genetic". *Nature* (2003): 315-321.
10. COFFEY VG., *et al*. "Effect of consecutive repeated sprint and resistance exercise bouts on acute adaptive responses in human skeletal muscle". *The American Journal of Physiology--Regulatory, Integrative and Comparative Physiology* 297.5 (2009): R1441-1451.
11. El-Sohemy A. "Only DNA-based dietary advice improved adherence to the Mediterranean diet score". *The American Journal of Clinical Nutrition* 105.3 (2017): 770.

12. Kicklighter JR., *et al*. “Visioning Report. A Preferred Path Forward for the Nutrition and Dietetics Profession”. *Journal of the Academy of Nutrition and Dietetics* 117.1 (2017): 110-127.

13. Longland TM., *et al*. “Higher compared with lower dietary protein during an energy deficit combined with intense exercise promotes greater lean mass gain and fat mass loss: a randomized trial”. *The American Journal of Clinical Nutrition* 103.3 (2016): 738-746.

14. Kriger JW., *et al*. “Effects of variation in protein and carbohydrate intake on body mass and composition during energy restriction: a meta-regression”. *The American Journal of Clinical Nutrition* 2 (2006): 260-274.

15. Beelen M., *et al*. “Koolhydraatinname tijdens en na intensieve inspanning [Performance enhancement by carbohydrate intake during sport: effects of carbohydrates during and after high-intensity exercise]”. *Ned Tijdschr Geneeskd* 159 (2015): A7465.

16. Bartolomei S., *et al*. “Comparison of the recovery response from high-intensity and high-volume resistance exercise in trained men”. *European Journal of Applied Physiology* 117.7 (2017): 1287-1298.

17. Goss AM., *et al*. “Effects of diet macronutrient composition on body composition and fat distribution during weight maintenance and weight loss”. *Obesity (Silver Spring)* 21.6 (2013): 1139-1142.

18. Marquet LA., *et al*. “Enhanced endurance performance by periodization of carbohydrate intake: “Sleep Low” strategy”. *Medicine and Science in Sports and Exercise* 48 (2016): 663-672.

19. Naclerio F and Larumbe-Zabala E. “Effects of Whey Protein Alone or as Part of a Multi-ingredient Formulation on Strength, Fat-Free Mass, or Lean Body Mass in Resistance-Trained Individuals: A Meta-analysis”. *Sports Medicine* 46.1 (2016): 125-137.

20. Garaulet M., *et al*. “PPARγ Pro12Ala interacts with fat intake for obesity and weight loss in a behavioural treatment based on the Mediterranean diet”. *Molecular Nutrition and Food Research* 55.12 (2001): 1771-1779.

21. Cousins RJ. “Nutritional regulation of gene expression”. *The American Journal of Medicine* 106.1A (1999): 20S-23S.

22. Tipton KD. “Nutrition for acute exercise-induced injuries”. *Annals of Nutrition and Metabolism* 57.2 (2010): 43-53.

23. Tipton KD. “Dietary strategies to attenuate muscle loss during recovery from injury”. *Nestlé Nutrition Institute Workshop Series* 75 (2013): 51-61.

24. Wall BT., *et al*. “Strategies to maintain skeletal muscle mass in the injured athlete: nutritional considerations and exercise mimetics”. *European Journal of Sport Science* 15.1 (2015): 53-62.

25. Bergouignan A., *et al*. “Regulation of energy balance during long-term physical inactivity induced by bed rest with and without exercise training”. *The Journal of Clinical Endocrinology and Metabolism* 95.3 (2010): 1045-1053.

26. Frankenfield D. “Energy expenditure and protein requirements after traumatic injury”. *Nutrition in Clinical Practice* 21.5 (2006): 430-437.

27. Prats C., *et al*. “Dual regulation of muscle glycogen synthase during exercise by activation and compartmentalization”. *Journal of Biological Chemistry* 284 (2009): 15692-15700.

28. Richter EA., *et al*. “Glucose, exercise and insulin: emerging concepts”. *The Journal of Physiology (London)* 535.pt2 (2001): 313-322.

29. Fujita S., *et al*. “Effect of insulin on human skeletal muscle protein synthesis is modulated by insulin-induced changes in muscle blood flow and amino acid availability”. *American Journal of Physiology-Endocrinology and Metabolism* 291.4 (2005): E745-754.

30. Hawley J and Leckey JJ. “Carbohydrate dependence during prolonged, intense en- durance exercise”. *Sports Medicine* 45.1 (2015): S5-12.

31. Verdi and Thais. “Nutrição esportiva: Modulação da expressão genética e estratégias na performance física”. *Ed Metha* 1.3 (2020): 43-63.

32. Burke LM., *et al*. “Postexercise muscle glycogen resynthesis in humans”. *Journal of Applied Physiology* 122 (2017): 1055-1067.

33. Sharples AP., *et al*. “Longevity and skeletal muscle mass: the role of IGF signalling, the sirtuins, dietary restriction and protein intake”. *Aging Cell* 14.4 (2015): 511-523.

34. Zhou P., *et al*. "Effects of Dietary Crude Protein Levels and Cysteamine Supplementation on Protein Synthetic and Degradative Signaling in Skeletal Muscle". *PLoS One* 10.9 (2015): e0139393.

35. Cluberton LJ., *et al*. "Effect of carbohydrate ingestion on exercise-induced alterations in metabolic gene expression". *Journal of Applied Physiology* 99.4 (2005): 1359-1363.

36. Schrauwen P., *et al*. "Fiber type dependent upregulation of human skeletal muscle UCP2 and UCP3 mRNA expression by high-fat diet". *International Journal of Obesity and Related Metabolic Disorders* 4 (2011): 449-456.

37. Bonen A., *et al*. "Skeletal muscle fatty acid transport and transporters". *Advances in Experimental Medicine and Biology* 441 (1998): 193-205.

38. Jump DB and Clarke SD. "Regulation of gene expression by dietary fat". *Annual Review of Nutrition* 19 (1999): 63-90.

39. Fritsche KL. "The Science of Fatty Acids and Inflammation". *Advances in Nutrition* 6.3 (2015): S293-301.

40. Babcock TA., *et al*. "Modulation of lipopolysaccharide- stimulated macrophage tumor necrosis factor-α production by ω-3 fatty acid is associated with differential cyclooxygenase-2 protein expression and is independent of interleukin-10". *Journal of Surgical Research* 107 (1 (2002): 135-139.

41. Forbes SC., *et al*. "Supplements and Nutritional Interventions to Augment High-Intensity Interval Training Physiological and Performance Adaptations-A Narrative Review". *Nutrients* 12.2 (2020): 10.

42. Galli C and Calder PC. "Effects of fat and fatty acid intake on inflammatory and immune responses: a critical review". *Annals of Nutrition and Metabolism* 55 (2009): 123-139.

43. Goodpaster BH., *et al*. "The effects of pre-exercise starch ingestion on endurance performance". *International Journal of Sports Medicine* 17 (1996): 366-372.

44. Babraj JA., *et al*. "Collagen synthesis in human musculoskeletal tissues and skin". *American Journal of Physiology-Endocrinology and Metabolism* 289 (2005): E864-E869. 1.

45. Rieu I. "Leucine supplementation improves muscle protein synthesis in elderly men in- dependently of hyperaminoacidaemia". *The Journal of Physiology* 575 (2006): 305-315.

46. Andersen MB., *et al*. "Interleukin-6: a growth factor stimulating collagen synthesis in human tendon". *Journal of Applied Physiology* 110.6 (2011): 1549-1154.

47. Thomas TD., *et al*. "Nutrition and athletic performance". *Medicine and Science in Sports and Exercise* 48 (2016): 543-568.

48. Bartolomei S., *et al*. "Comparison of the recovery response from high-intensity and high-volume resistance exercise in trained men". *European Journal of Applied Physiology* 117.7 (2017): 1287-1298.

49. Katsanos CS., *et al*. "A high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly". *American Journal of Physiology-Endocrinology and Metabolism* 291 (2006): E381-E387.