The State of the Science in Sport Nutrition

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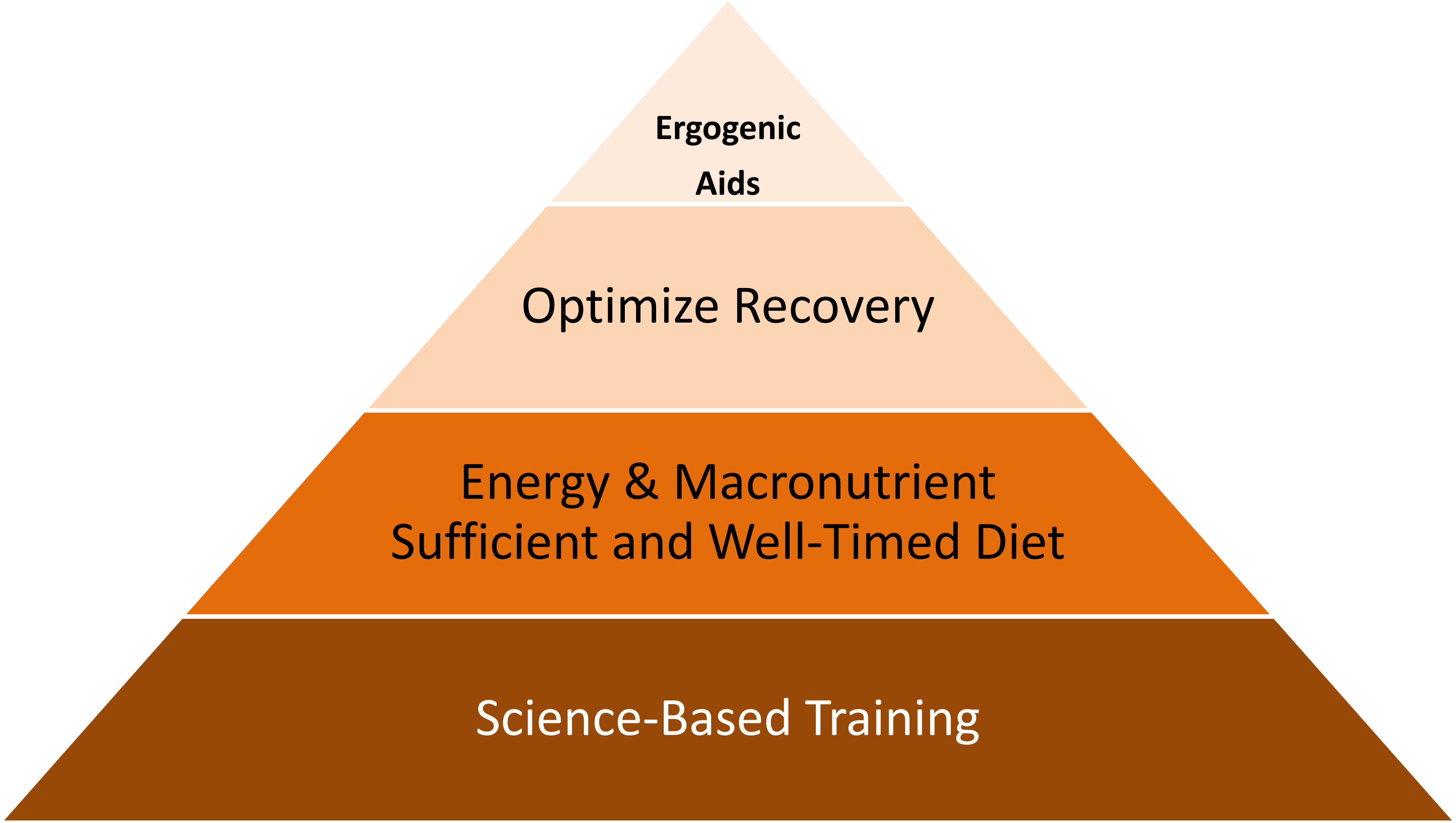
Disclosures: Receive industry sponsored research grants and serve as a scientific and legal consultant.

Performance Enhancement Pyramid



Ergogenic Aid

Kerksick et al., JISSN. 15:38, 2018

Any training technique, mechanical device, nutritional practice, pharmacological method, or psychological technique that can improve exercise performance capacity and/or enhance training adaptations.

Nutritional Ergogenic Aids

Categories

- Strong Evidence to Support Efficacy and Apparently Safe
- Limited or Mixed Evidence to Support Efficacy
- Little to No Evidence to Support Efficacy and/or Safety

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Journal of the International Society of Sports Nutrition

REVIEW Open Access

ISSN exercise & sports nutrition review update: research & recommendations

Chad M. Kerksick[1*], Colin D. Wilborn[2], Michael D. Roberts[3], Abbie Smith-Ryan[4], Susan M. Kleiner[5], Ralf Jäger[6], Rick Collins[7], Mathew Cooke[8], Jaci N. Davis[2], Elfego Galvan[9], Mike Greenwood[10], Lonnie M. Lowery[11], Robert Wildman[12], Jose Antonio[13] and Richard B. Kreider[10*]

Abstract

Background: Sports nutrition is a constantly evolving field with hundreds of research papers published annually. In the year 2017 alone, 2082 articles were published under the key words 'sport nutrition'. Consequently, staying current with the relevant literature is often difficult.

Methods: This paper is an ongoing update of the sports nutrition review article originally published as the lead paper to launch the Journal of the International Society of Sports Nutrition in 2004 and updated in 2010. It presents a well-referenced overview of the current state of the science related to optimization of training and performance enhancement through exercise training and nutrition. Notably, due to the accelerated pace and size at which the literature base in this research area grows, the topics discussed will focus on muscle hypertrophy and performance enhancement. As such, this paper provides an overview of: 1.) How ergogenic aids and dietary supplements are defined in terms of governmental regulation and oversight; 2.) How dietary supplements are legally regulated in the United States; 3.) How to evaluate the scientific merit of nutritional supplements; 4.) General nutritional strategies to optimize performance and enhance recovery; and, 5.) An overview of our current understanding of nutritional approaches to augment skeletal muscle hypertrophy and the potential ergogenic value of various dietary and supplemental approaches.

Conclusions: This updated review is to provide ISSN members and individuals interested in sports nutrition with information that can be implemented in educational, research or practical settings and serve as a foundational basis for determining the efficacy and safety of many common sport nutrition products and their ingredients.

Keywords: Sports nutrition, Performance nutrition, Position stand, Review, Recommendations, Efficacy, Double-blind, Randomized, Placebo-controlled, Dietary supplements, Ergogenic aids, Weight gain, Hypertrophy, Strength, Capacity, Power

Background

Evaluating the scientific merit of articles and advertisements about exercise and nutrition products is a key skill that all sports nutrition professionals must possess. To assist members and other advocates of the International Society of Sports Nutrition (ISSN) in keeping up to date about the latest findings in sports nutrition, the ISSN Exercise & Sports Nutrition Review: Research & Recommendations has been updated. The initial version of this paper was the first publication used to help launch the Journal of the International Society of Sports Nutrition (JISSN, originally called the Sports Nutrition Review Journal). This paper provides a definition of ergogenic aids and dietary supplements and discusses how dietary supplements are legally regulated. Other sections highlight how to evaluate the scientific merit of nutritional supplements and provide general nutritional strategies to optimize performance and enhance recovery. Finally, a brief overview of the efficacy surrounding many supplements commonly touted to

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Nutritional Needs of Active Individuals and Athletes

Energy Needs

- ***General Fitness Training*** (e.g., 30 - 40 min/d; 3 d/wk)
  - Exercise energy expenditure generally 200 – 400 kcals/workout
  - Energy needs can be met on normal diet (e.g., 1,800 – 2,400 kcals/day or about 25 - 35 kcals/kg/day for a 50 – 80 kg individual)
- ***Moderate Training*** (e.g., 2-3 hrs/d; 5-6 d/wk)
  - Exercise energy expenditure generally 600 – 1,200 kcals/hour
  - Caloric needs may approach 40 – 70 kcals/kg/day (2,000 – 7,000 kcals/day for a 50 – 100 kg athlete)
- ***Elite Athletes*** (e.g., 3-6 hrs/d; 5-6 d/wk)
  - Caloric needs are typically 70 – 90 kcals/kg/day (3,500 – 9,000 kcals/day for a 50 – 100 kg athlete) with energy expenditure in Tour de France reported as high as 12,000 kcals/day (150 - 200 kcals/kg/d for a 60 – 80 kg athlete)
  - Caloric needs for large athletes (i.e., 100 – 150 kg) may range between 6,000 – 12,000 kcals/day depending on the volume/intensity of training
  - Often difficult for athletes to eat enough food in order to meet caloric needs

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Nutritional Guidelines

General Fitness / Active Populations

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- Diet focused on goals (maintenance, weight gain/loss)
- ***Carbohydrate*** (45%-55% of calories)
  - 3 – 5 g/kg/d
- ***Protein*** (15%-20% of calories)
  - 0.8 – 1.0 g/kg/d (younger)
  - 1.0 – 1.2 g/kg/d (older)
- ***Fat*** (25-35% of calories)
  - 0.5 – 1.5 g/kg/d
- Make Good Food Choices
- Meal timing can optimize training response

Nutritional Guidelines

Athletes

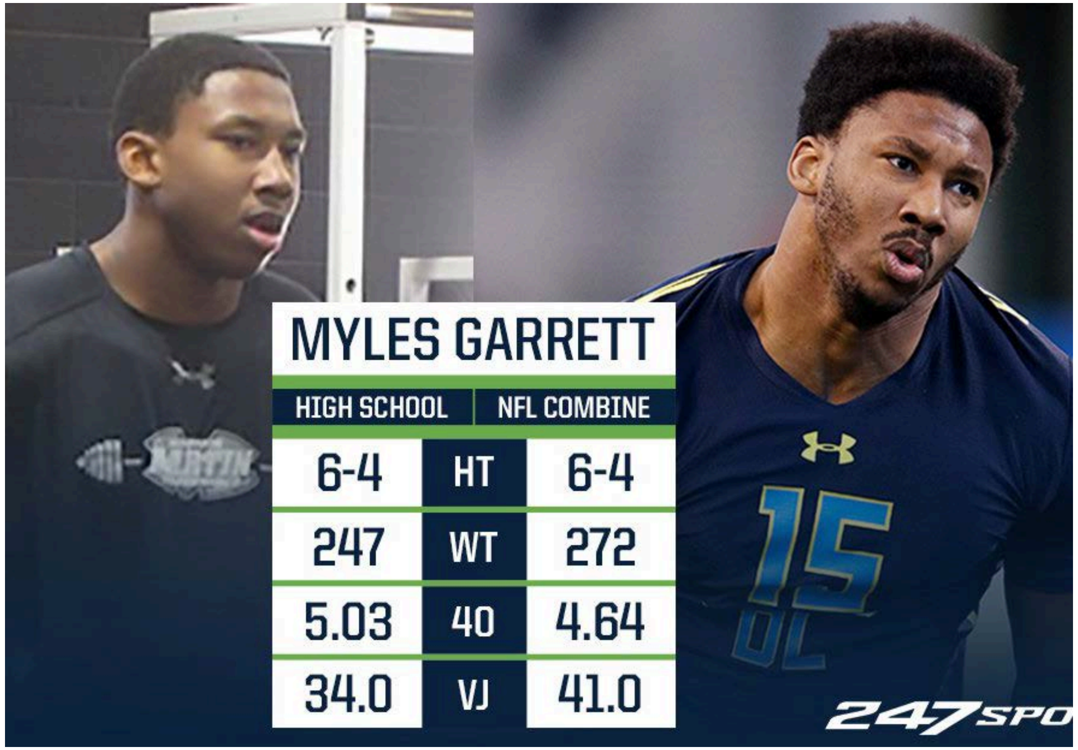
- ***Carbohydrate*** (55%-65% of calories)
  - 3 – 5 g/kg/d – Resistance / Power
  - 5 – 8 g/kg/d – Field / Endurance
  - 8 – 10 g/kg/d – heavy training
- ***Protein*** (15-20% of calories)
  - 0.8 – 1.2 g/kg/d - general fitness
  - 1.2 – 2.0 g/kg/d - moderate training
  - 1.7 – 2.2 g/kg/d - heavy training
- ***Fat*** (25-30% of calories)
  - 0.5 – 1.5 g/kg/d
- Meal Timing Important
- Use of energy supplements helpful

Kerksick et al., JISSN. In press, 2018

Dietary Guidelines

Strength/Power Athletes

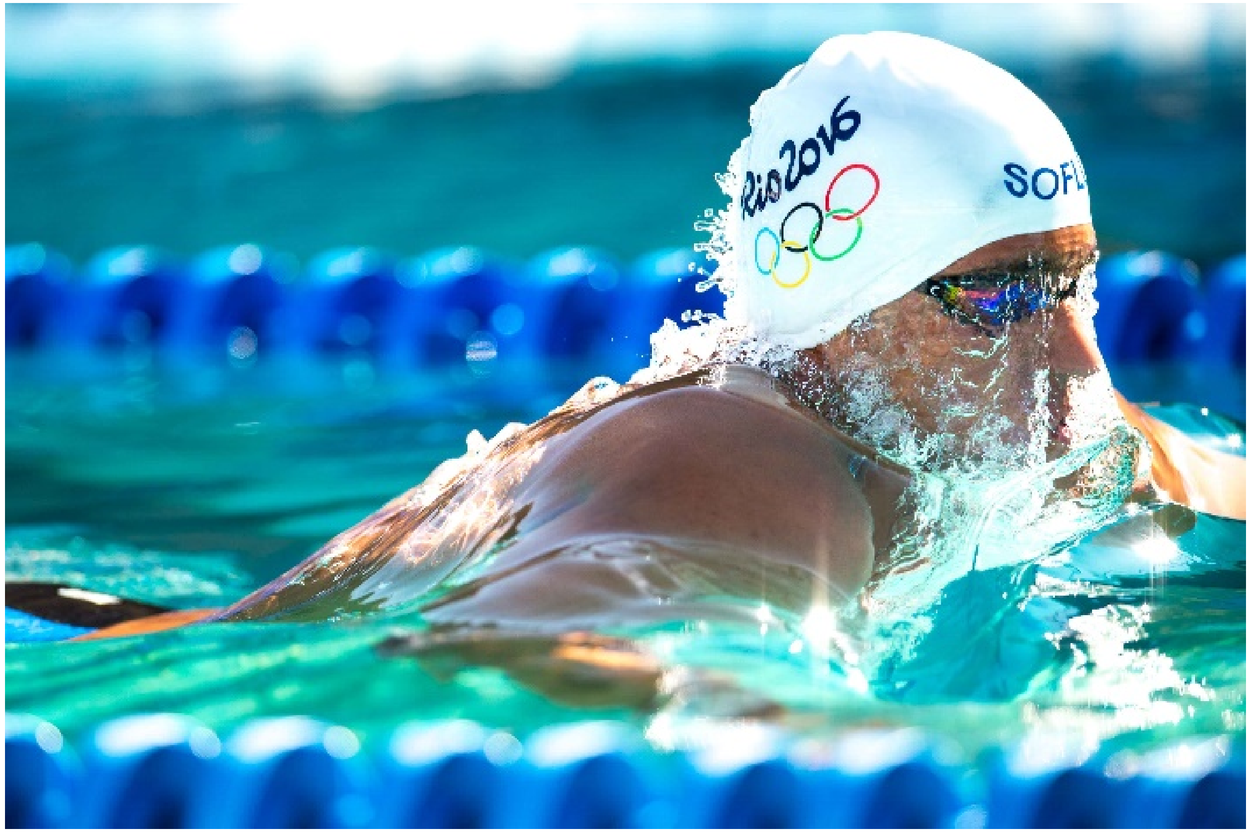
- Caloric needs typically range between 40–70 kcals/kg/day (2000–7000 kcals/day) for a 50–100 kg athlete engaged in moderate training.
- **Carbohydrate** (40-55% of calories)
  - 3 – 5 grams/kg/day typically sufficient
- **Protein** (15-30% of calories)
  - 1.4 – 2.0 grams/kg/day general
  - 1.7 – 2.2 grams/kg/day during heavy training and/or at altitude
- **Fat** (20-30% of calories)
  - 1 – 1.5 grams/kg/day
- Greater emphasis on meal timing
- May need more education about nutritional ergogenic aids



Nutritional Guidelines

Nutrient Timing

- Pre-exercise meals (4-6 h)
- Pre-exercise snack (30-60 min)
  - 40-50 g CHO, 10 g PRO
- Sports drinks during exercise (> 60 min)
  - 6%-8% glucose-electrolyte solution
  - Sports gels/bars at half-time
- Post-exercise snack (within 30 min)
  - 1 g/kg CHO, 0.5 g/kg PRO
- Post-exercise meal (within 2 hrs)
- CHO loading (2-3 days prior to competition)
  - Taper training by 30%-50%
  - Ingest 200-300 extra grams of CHO



Kerksick et al., JISSN. In press, 2018

Sport Supplement Categories

- ***Pre-Workout Supplements***
  - Carbohydrate (30-40 g)
  - Protein / AA (5-10 g)
  - Stimulate metabolism
  - Improve cognitive function
  - Lessen exercise-induced catabolism, inflammation, and/or immunosuppression
  - Ergogenic Nutrients that support training

- ***During Exercise Supplements***
  - Prevent dehydration
  - Maintain blood glucose (20-40 g/hr of CHO, 6-8%)
  - Provide amino acids (BCAA or EAA) to limit exercise-induced protein degradation
  - Minimize exercise-induced inflammation and catabolism
  - Minimize mental fatigue and central fatigue

Sport Supplement Categories

- ***Post-Workout & Training Supplements***
  - CHO for glycogen replenishment
  - Protein / AA to enhance protein synthesis
  - Support immune function
  - Reduce inflammation and promote recovery
- ***Ergogenic Nutrients***
  - Creatine
  - B-alanine
  - HMB
  - Nitrates
  - Sodium Phosphate
  - Glycerol

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Nutritional Ergogenic Aids

Muscle Building Supplements

Strong Evidence to Support Efficacy and Apparently Safe

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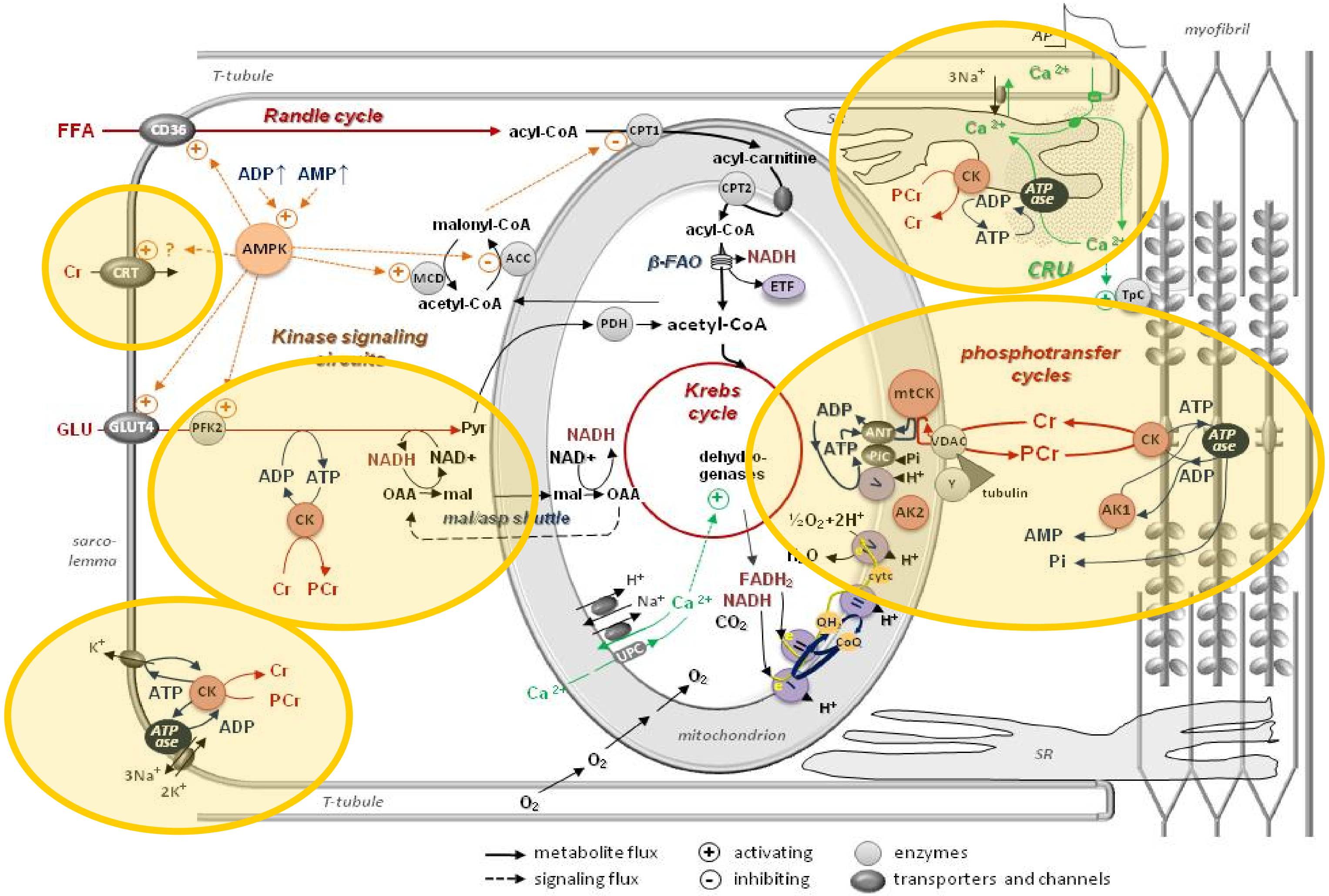
- Creatine monohydrate
- Essential amino acids (EAA)
- Protein
- HMB*

* Beginners and elderly initiating training

Kerksick et al., JISSN. 15:38, 2018

Metabolic Role of Creatine

Saks et al. (2013) in: Systems biology of metabolic and signalling networks, Springer



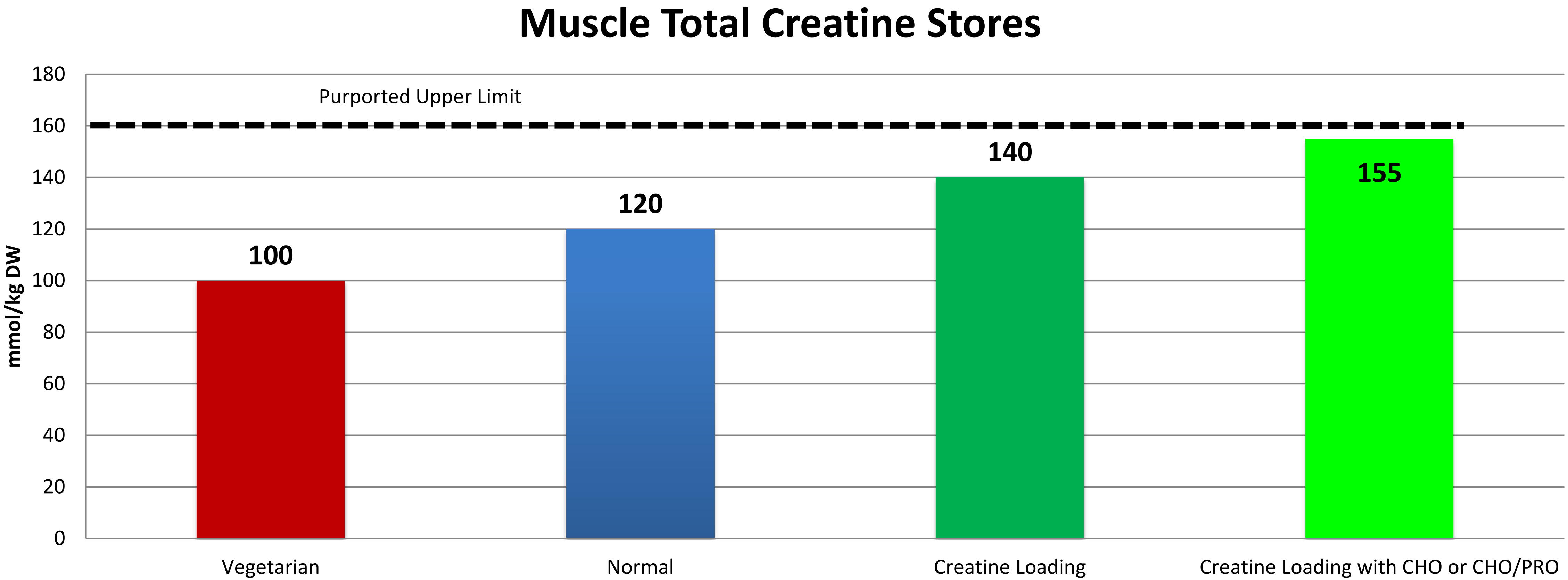
Creatine

Supplementation Protocols

- High Dose Protocol
  - Ingest 15-25 g/d (0.3 g/kg/d) during training
- ***Loading/Maintenance Protocol***
  - ***Ingest 0.3 g/kg/d (15-25 g/d) for 5-7 d***
  - ***Ingest 0.03 g/kg/d (3-5 g/d) to maintain***
- Low Dose Protocol
  - Ingest 0.03 g/kg/d (3-5 g/d)
- Cycling Protocol
  - Load/maintain during training and reduce/abstain between training periods

Takes about 4-6 weeks for muscle creatine levels to return to baseline after loading.

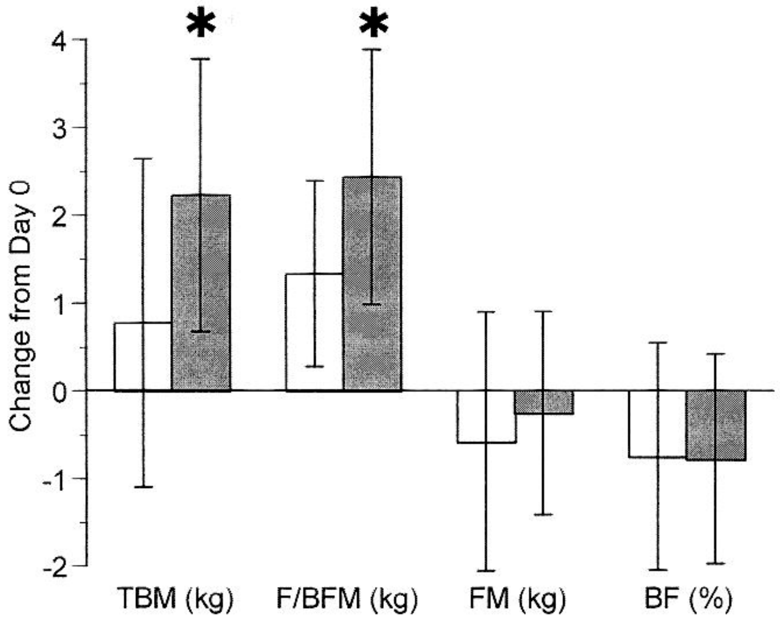
Bioavailability



Approximate muscle total creatine levels in mmol/kg dry weight muscle reported in the literature for vegetarians, individuals following a normal diet, and in response to creatine loading with or without carbohydrate (CHO) or CHO and protein (PRO). From Kreider & Juhn, JENB, 2011.

Effects of Creatine Supplementation on Body Composition, Strength, and Sprint Performance *Kreider et al. MSSE 30:73-82, 1998*

- 25 NCAA division IA football players were matched-paired and assigned to supplement their diet for 28 d during resistance/agility training (8 h·wk-1) with a placebo (P) or supplement 15.75 g/d of CrM.
- Hematological parameters remained within normal clinical limits with no side effects reported.
- DEXA scanned body mass (P 0.77 ± 1.8; CrM 2.22± 1.5 kg) and FFM (P 1.33 ± 1.1; CrM 2.43 ± 1.4 kg) were significantly increased in the CrM group.

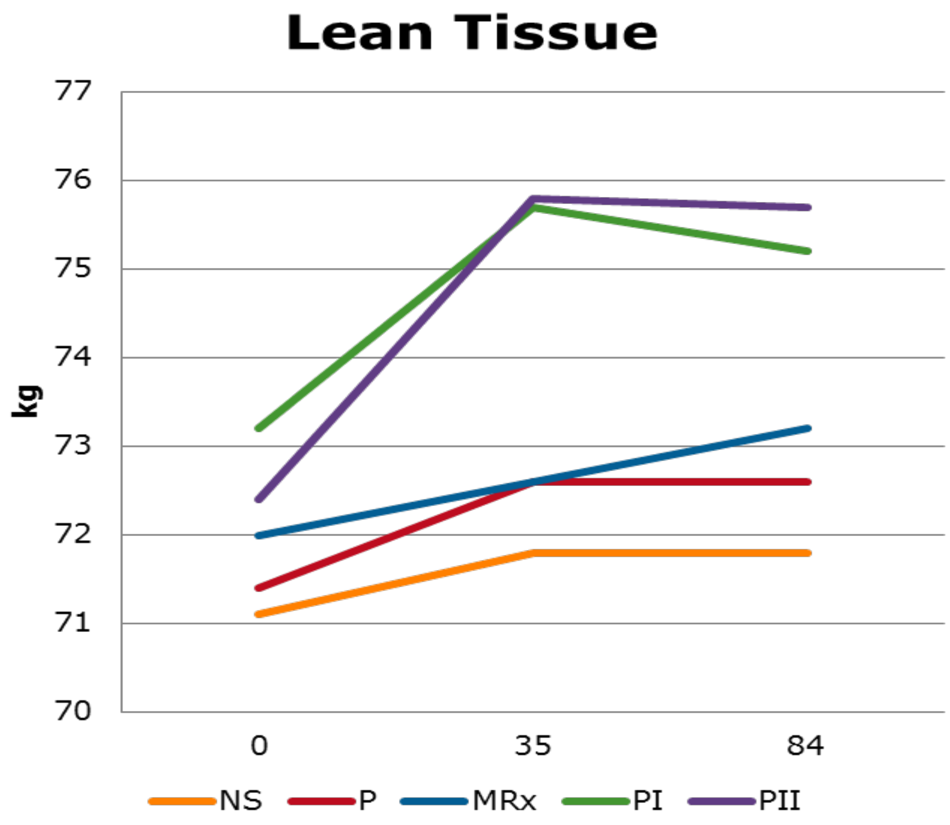


Cited over 750 times

Effects of Nutritional Supplementation During Off-Season College Football Training on Body Composition & Strength

Kreider et al. JEP 2(2):24-39, 1999

- 62 DI American football players
- In a DB-R-P manner, assigned to supplement diet with:
  - Non-Supplemented Control
  - Maltodextrin Placebo
  - MetRx
  - Phosphagain I (20 g/d CM)
  - Phosphagain II (25 g/d CM)
- Greater gains in FFM & strength in CM groups



Creatine

ISSN Position Stand

1. ***Creatine monohydrate is the most effective ergogenic nutritional supplement currently available to athletes with the intent of increasing high-intensity*** exercise capacity and lean body mass during training.
2. Creatine monohydrate supplementation is ***not only safe, but has been reported to have a number of therapeutic benefits in healthy and diseased populations ranging from infants to the elderly***. There is no compelling scientific evidence that the short- or long-term use of creatine monohydrate (up to 30 g/day for 5 years) has any detrimental effects on otherwise healthy individuals or among clinical populations who may benefit from creatine supplementation.
3. If proper precautions and supervision are provided, ***creatine monohydrate supplementation in children and adolescent athletes is acceptable and may provide a nutritional alternative with a favorable safety profile to potentially dangerous anabolic androgenic drugs***. However, we recommend that creatine supplementation only be considered for use by younger athletes who: a.) are involved in serious/competitive supervised training; b.) are consuming a well-balanced and performance enhancing diet; c.) are knowledgeable about appropriate use of creatine; and d.) do not exceed recommended dosages.

Kreider et al. JISSN 14:18, 2017

Creatine

ISSN Position Stand

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4. Label advisories on creatine products that caution against usage by those under 18 years old, while perhaps intended to insulate their manufacturers from legal liability, are likely unnecessary given the science supporting creatine's safety, including in children and adolescents.
5. At present, ***creatine monohydrate is the most extensively studied and clinically effective form*** of creatine for use in nutritional supplements in terms of muscle uptake and ability to increase high-intensity exercise capacity.
6. The ***addition of carbohydrate or carbohydrate and protein to a creatine supplement appears to increase muscular uptake of creatine***, although the effect on performance measures may not be greater than using creatine monohydrate alone.
7. The quickest method of increasing muscle creatine stores may be to consume ***~0.3 g/kg/day of creatine monohydrate for 5–7-days followed by 3–5 g/day thereafter to maintain elevated stores***. Initially, ingesting smaller amounts of creatine monohydrate (e.g., 3–5 g/day) will increase muscle creatine stores over a 3–4 week period, however, the initial performance effects of this method of supplementation are less supported.
8. ***Clinical populations*** have been supplemented with high levels of creatine ***monohydrate (0.3 – 0.8 g/kg/day equivalent to 21–56 g/day for a 70 kg individual) for years*** with no serious adverse events.
9. Further research is warranted to examine the ***potential medical benefits*** of creatine monohydrate and precursors like guanidinoacetic acid on sport, health and medicine.

Kreider et al. JISSN 14:18, 2017

Creatine

ISSN Position Stand

"…it is the view of ISSN that ***government legislatures and sport organizations who restrict and/or discourage use of creatine may be placing athletes at greater risk—particularly in contact sports that have risk of head trauma and/or neurological injury thereby opening themselves up to legal liability.***"

Kreider *et al. Journal of the International Society of Sports Nutrition* (2017) 14:18
DOI 10.1186/s12970-017-0173-z

Journal of the International Society of Sports Nutrition

REVIEW Open Access

International Society of Sports Nutrition position stand: safety and efficacy of creatine supplementation in exercise, sport, and medicine

Richard B. Kreider[1*], Douglas S. Kalman[2], Jose Antonio[3], Tim N. Ziegenfuss[4], Robert Wildman[5], Rick Collins[6], Darren G. Candow[7], Susan M. Kleiner[8], Anthony L. Almada[9] and Hector L. Lopez[4,10]

Abstract

Creatine is one of the most popular nutritional ergogenic aids for athletes. Studies have consistently shown that creatine supplementation increases intramuscular creatine concentrations which may help explain the observed improvements in high intensity exercise performance leading to greater training adaptations. In addition to athletic and exercise improvement, research has shown that creatine supplementation may enhance post-exercise recovery, injury prevention, thermoregulation, rehabilitation, and concussion and/or spinal cord neuroprotection. Additionally, a number of clinical applications of creatine supplementation have been studied involving neurodegenerative diseases (e.g., muscular dystrophy, Parkinson's, Huntington's disease), diabetes, osteoarthritis, fibromyalgia, aging, brain and heart ischemia, adolescent depression, and pregnancy. These studies provide a large body of evidence that creatine can not only improve exercise performance, but can play a role in preventing and/or reducing the severity of injury, enhancing rehabilitation from injuries, and helping athletes tolerate heavy training loads. Additionally, researchers have identified a number of potentially beneficial clinical uses of creatine supplementation. These studies show that short and long-term supplementation (up to 30 g/day for 5 years) is safe and well-tolerated in healthy individuals and in a number of patient populations ranging from infants to the elderly. Moreover, significant health benefits may be provided by ensuring habitual low dietary creatine ingestion (e.g., 3 g/day) throughout the lifespan. The purpose of this review is to provide an update to the current literature regarding the role and safety of creatine supplementation in exercise, sport, and medicine and to update the position stand of International Society of Sports Nutrition (ISSN).

Keywords: Ergogenic aids, Performance enhancement, Sport nutrition, Athletes, Muscular strength, Muscle power, Clinical applications, Safety, Children, Adolescents

Background

Creatine is one of the most popular nutritional ergogenic aids for athletes. Studies have consistently shown that creatine supplementation increases intramuscular creatine concentrations, can improve exercise performance, and/or improve training adaptations. Research has indicated that creatine supplementation may enhance post-exercise recovery, injury prevention, thermoregulation, rehabilitation, and concussion and/or spinal cord neuroprotection. A number of clinical applications of creatine supplementation have also been studied involving neurodegenerative diseases (e.g., muscular dystrophy, Parkinson's, Huntington's disease), diabetes, osteoarthritis, fibromyalgia, aging, brain and heart ischemia, adolescent depression, and pregnancy. The purpose of this review is to provide an update to the current literature regarding the role and safety of creatine supplementation in exercise, sport, and medicine and to update the position stand of International Society of Sports Nutrition (ISSN) related to creatine supplementation.

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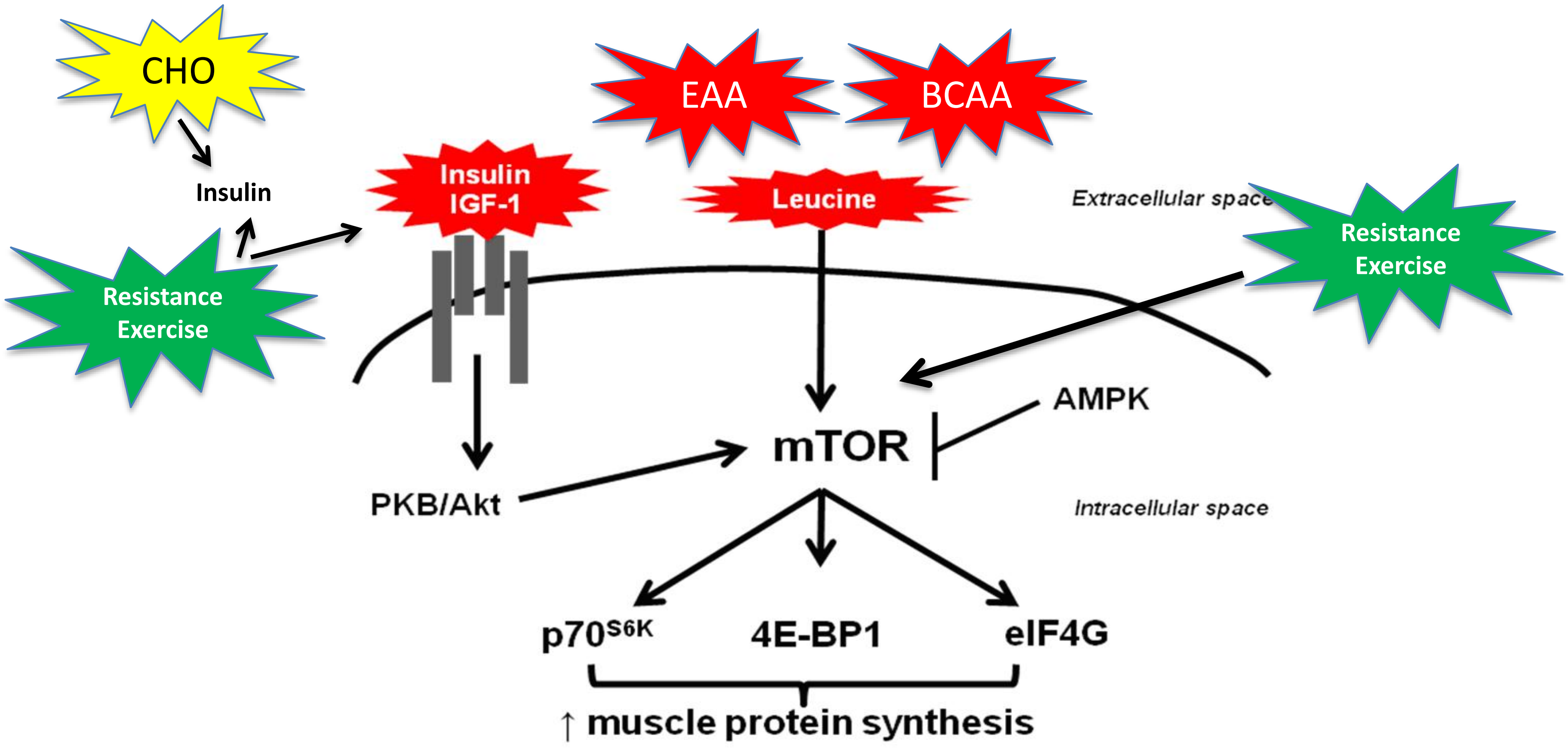
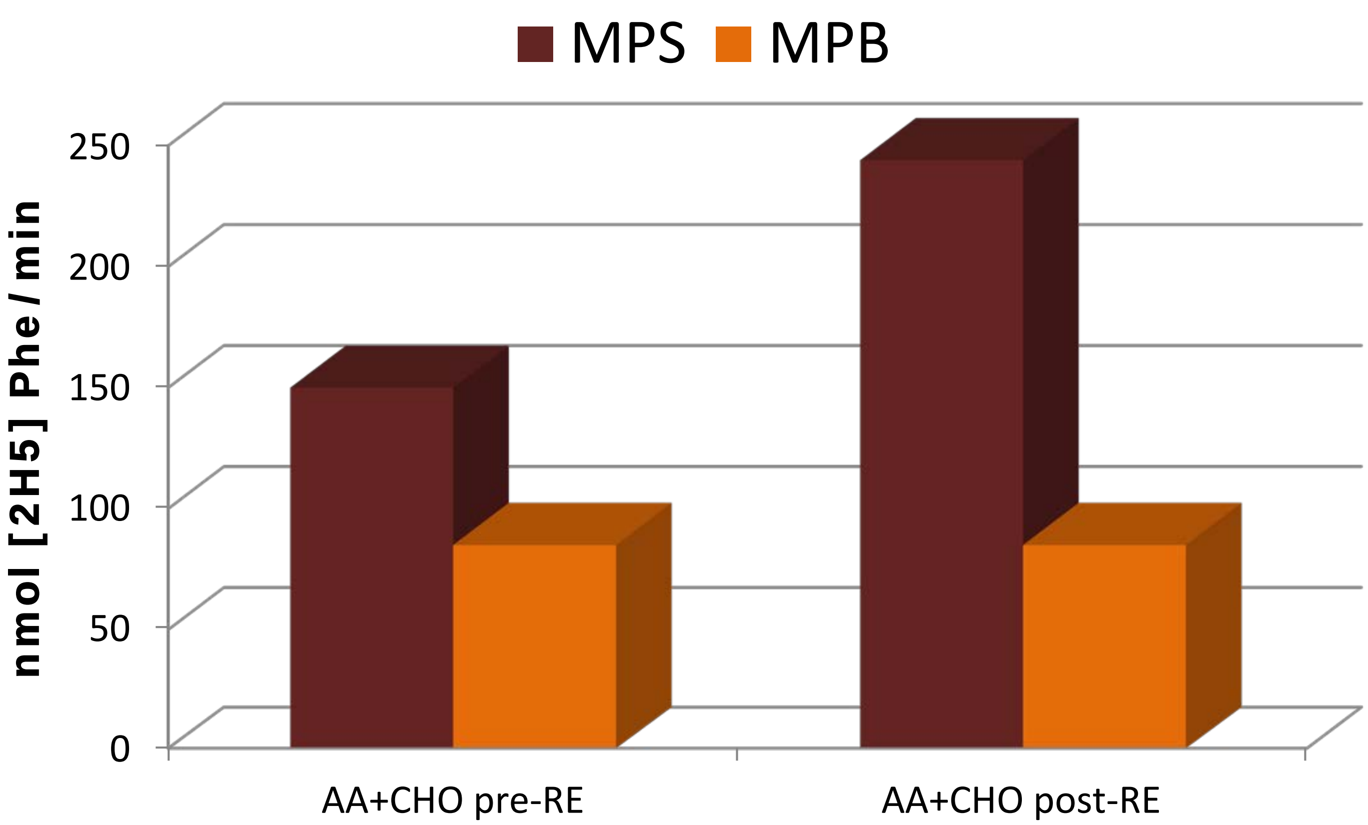
https://jissn.biomedcentral.com/articles/10.1186/s12970-017-0173-z

Essential Amino Acids



Postexercise net protein synthesis in human muscle from orally administered amino acids

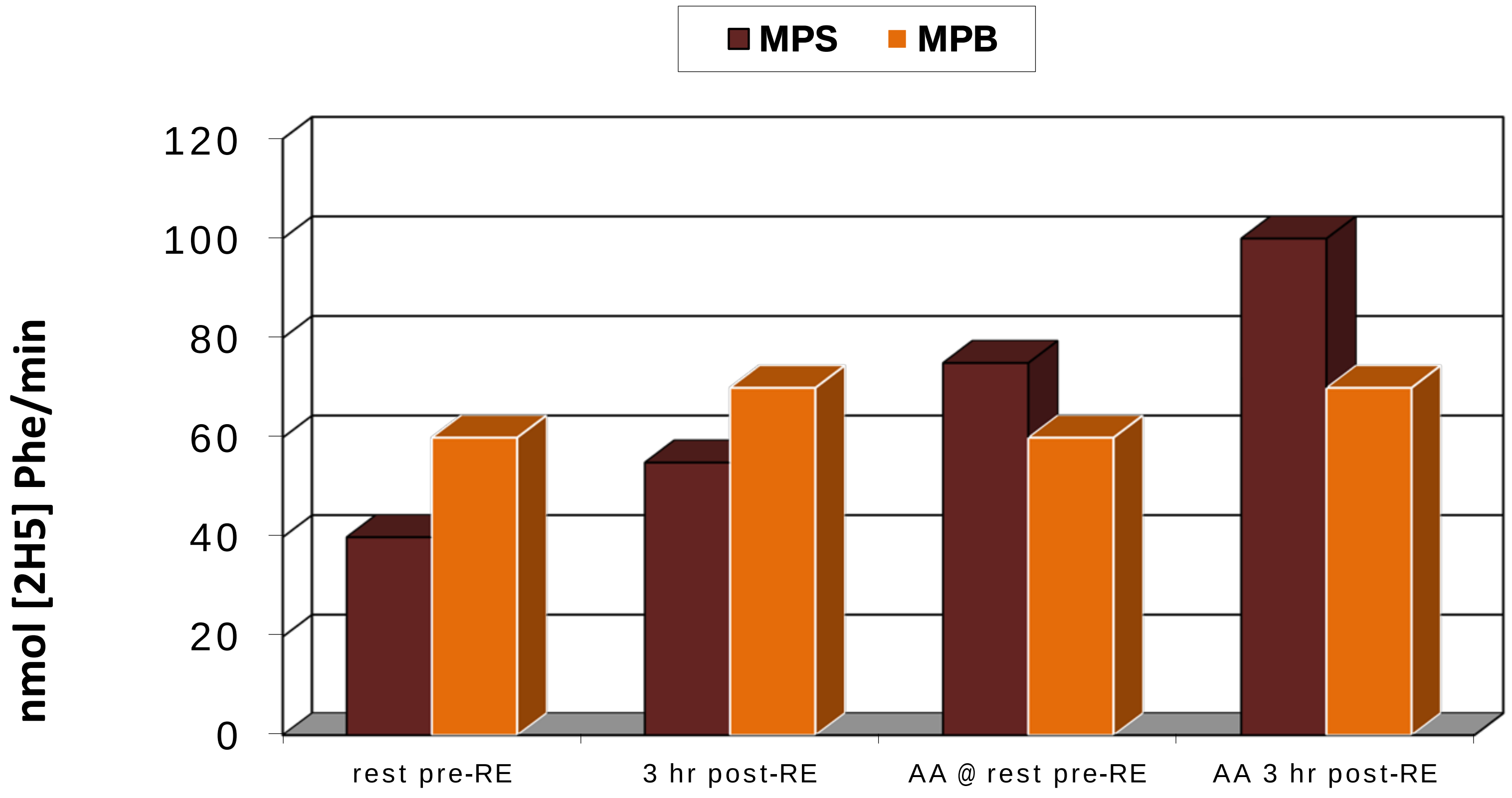
Tipton et al. Am J. Physiol. 276:E628-34, 1999



40 grams infused mixed AA + 40 grams infused CHO

An oral essential amino acid-carbohydrate supplement enhances muscle protein anabolism after resistance exercise

Rasmussen & Phillips. J Appl Physiol. 88(2):386-92, 2000.



6 grams oral EAA + 35 grams oral CHO

Essential Amino Acids

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- Ingesting 6 – 12 grams of the EAAs in the fasted and prior to and/or following resistance exercise stimulates protein synthesis.
- Theoretically, this would lead to gains in fat-free mass during resistance-training.
- However, there is actually limited evidence to demonstrate that supplementation with EAAs alone during resistance-training increases muscle mass.
- There is also evidence that acute changes in muscle protein synthesis may not correlate with adaptations to resistance-exercise training.
- Leucine (or BCAA with sufficient leucine) has been suggested to be the primary amino acid responsible for stimulating muscle protein synthesis.
- While there is strong rationale, there is no direct evidence that ingesting EAAs and/or leucine alone during training promotes greater gains in FFM than protein containing a sufficient amount of EAA.
- Some evidence that EAAs need other amino acids to maximize protein synthesis.

Protein

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- People undergoing intense training designed to build muscle should consume between 1.4 – 2.0 grams/kg/day of protein in their diet.
- The type of protein ingested and digestion rates influence the release of EAAs into the blood and thereby protein synthesis.
- Ensuring that amino acid availability is maintained throughout the day as well as timing fast and slow proteins around exercise and/or upon retiring at night may influence protein synthesis and/or catabolism.
- Moreover, different types of protein may offer advantages over one another depending on the population targeted and/or outcome desired.
- Significant interest in combining different types of vegetable sources and/or fortifying vegetable proteins with deficient amino acids to improve quality.

Protein

ISSN Position Stand

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1. An acute exercise stimulus, particularly resistance exercise, and protein ingestion both stimulate muscle protein synthesis and are synergistic when protein consumption occurs before or after resistance exercise.
2. For building muscle mass and for maintaining muscle mass through a positive muscle protein balance, an overall daily protein intake in the range of ***1.4 – 2.0 grams/kg/day*** is sufficient for most exercising individuals, a value that falls in line within the Acceptable Macronutrient Distribution Range published by the Institute of Medicine for protein.
3. There is novel evidence that suggests higher protein intakes (>3.0 grams/kg/day) may have positive effects on body composition in resistance-trained individuals (i.e., promote loss of fat mass).
4. Recommendations regarding the optimal protein intake per serving for athletes to maximize muscle protein synthesis are mixed and are dependent upon age and recent resistance exercise stimuli. General recommendations are ***0.25 grams/kg*** of a high-quality or an absolute dose of ***20 – 40 grams***.

Jager et al. JISSN 14:18, 2017

Protein

ISSN Position Stand

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5. Acute protein doses should strive to contain 700–3,000 mg of leucine and/or a higher relative leucine content, in addition to a balanced array of the essential amino acids.
6. These protein doses should ideally be evenly distributed, every 3 – 4 hours, across the day.
7. The optimal time period during which to ingest protein is likely a matter of individual tolerance, since benefits are derived from pre- or post-workout ingestion; however, the anabolic effect of exercise is long-lasting (at least 24-hours), but likely diminishes with increasing time post-exercise.
8. While it is possible for physically active individuals to obtain their daily protein requirements through the consumption of whole foods, supplementation is a practical way of ensuring intake of adequate protein quality and quantity, while minimizing caloric intake, particularly for athletes who typically complete high volumes of training.

Jager et al. JISSN 14:18, 2017

Protein

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9. Rapidly digested proteins that contain high proportions of essential amino acids and adequate leucine, are most effective in stimulating muscle protein synthesis.
10. Different types and quality of protein can affect amino acid bioavailability following protein supplementation.
11. Athletes should consider focusing on whole food sources of protein that contain all of the essential amino acids (i.e., it is the essential amino acids that are required to stimulate muscle protein synthesis.
12. Endurance athletes should focus on achieving adequate carbohydrate intake to promote optimal performance; the addition of protein may help to offset muscle damage and promote recovery.
13. Pre-sleep casein protein intake (30–40 grams)

Jager et al. JISSN 14:18, 2017

β-HMB

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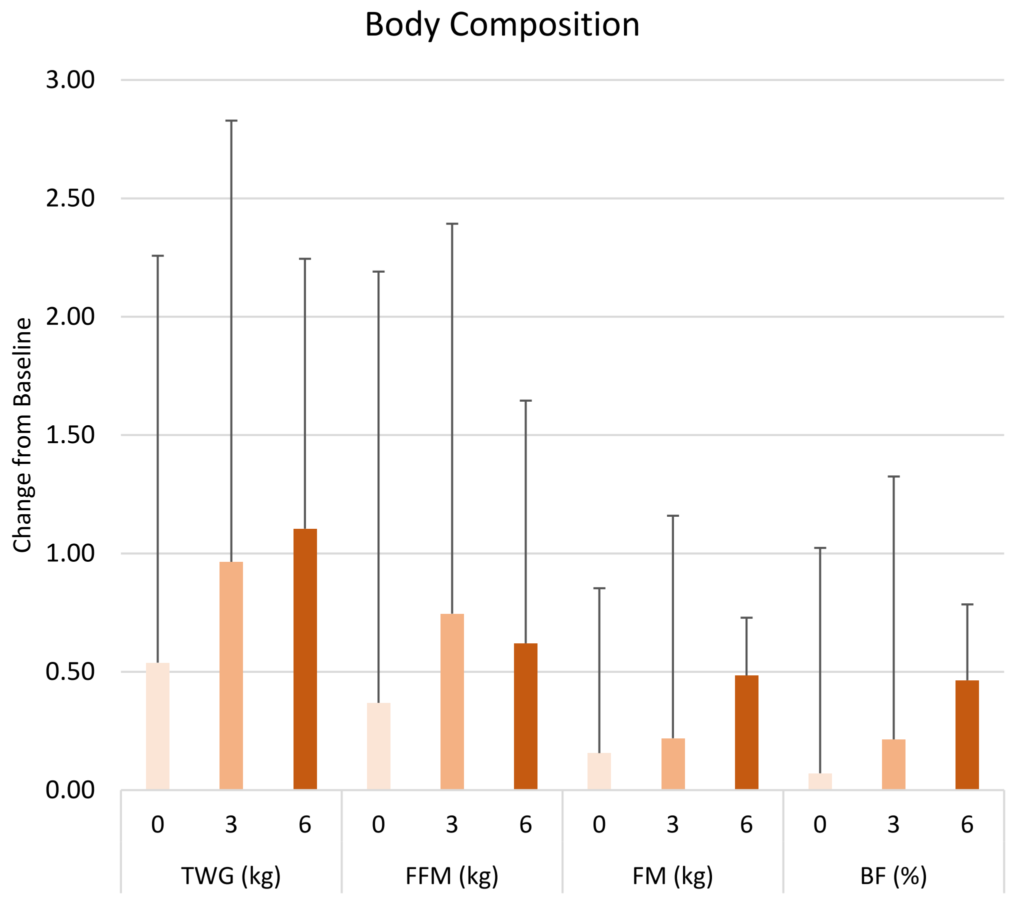
- Leucine, α-ketoisocaproate (KIC) and β-HMB have been reported to inhibit protein degradation
- Ingestion of 1.5 to 3 g/d of HMB reported to increase FFM and strength in untrained subjects initiating training
- Gains in muscle mass typically 0.5 – 1 kg greater than controls during 3 – 6 weeks of training
- Consistent results observed in untrained and older subjects initiating training.
- Greater effects as an anticatabolic nutrient during intense training and in elderly to reduce muscle mass loss
- Extraordinary results reported in two studies with Free Acidic-HMB have not been replicated to date.

Effects of Calcium β-Hydroxy-β-methylbutyrate (HMB) Supplementation During Resistance-Training on Markers of Catabolism, Body Composition and Strength

Kreider et al. Int J Sports Med. 20(8):503-9, 1999

- 40 resistance-trained athletes were matched and assigned to supplement their diet for 28 d with a fortified carbohydrate/ protein powder containing either 0, 3 or 6 g/d of calcium HMB.
- Fasting venous blood and urine samples, DEXA determined body composition, and isotonic bench press and leg press 1 RMs were determined prior to and following 28 d.
- HMB supplementation resulted in significant increases in serum and urinary HMB concentrations.
- No statistically significant differences were observed in general markers of whole body anabolic/catabolic status, muscle and liver enzyme efflux, fat/bone-free mass, fat mass, percent body fat, or 1 RM strength.
- 28 d of HMB supplementation (3 to 6 g/d) during resistance-training does not reduce catabolism or affect training-induced changes in body composition and strength in experienced resistance-trained males.



Effects of 4 Weeks of High-Intensity Interval Training and Beta-Hydroxy-Beta-Methylbutyric Free Acid Supplementation on the Onset of Neuromuscular Fatigue

Miramonti et al. J Strength Cond Res. 30(3):626-34, 2016

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- 37 participants completed PWC at the onset of neuromuscular fatigue threshold (PWC(FT)) tests while EMG's were recorded.
- Participants ingested a PLA or HMB or were assigned to a CON group during 4-wks of HIIT.
- HIIT training increased PWC(FT).
- ***HMB group experienced greater changes in PWC(FT) compared to PLA and CON***.
- Adding HMB supplementation with HIIT in untrained men and women may further improve endurance performance measures.

β-HMB

ISSN Position Stand

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1. HMB can be used to enhance recovery by attenuating exercise induced skeletal muscle damage in trained and untrained populations.
2. If consuming HMB, an athlete will benefit from consuming the supplement in close proximity to their workout/
3. HMB appears to be most effective when consumed for 2 weeks prior to an exercise bout.
4. 38 mg/kg daily of HMB has been demonstrated to enhance skeletal muscle hypertrophy, strength, and power in untrained and trained populations when the appropriate exercise prescription is utilized.

http://www.jissn.com/content/10/1/6

B-HMB

ISSN Position Stand

5. Currently, two forms of HMB have been used: Calcium HMB (HMB-Ca) and a free acid form of HMB (HMB-FA). HMB-FA may increase plasma absorption and retention of HMB to a greater extent than HMB-CA. However, research with HMB-FA is in its infancy, and there is not enough research to support whether one form is superior.
6. HMB has been demonstrated to increase LBM and functionality in elderly, sedentary populations.
7. HMB ingestion in conjunction with a structured exercise program may result in greater.
8. HMB's mechanisms of action include an inhibition and increase of proteolysis and protein synthesis, respectively.
9. Chronic consumption of HMB is safe in both young and old populations.

http://www.jissn.com/content/10/1/6

Muscle Building Supplements

Limited or Mixed Evidence to Support Efficacy

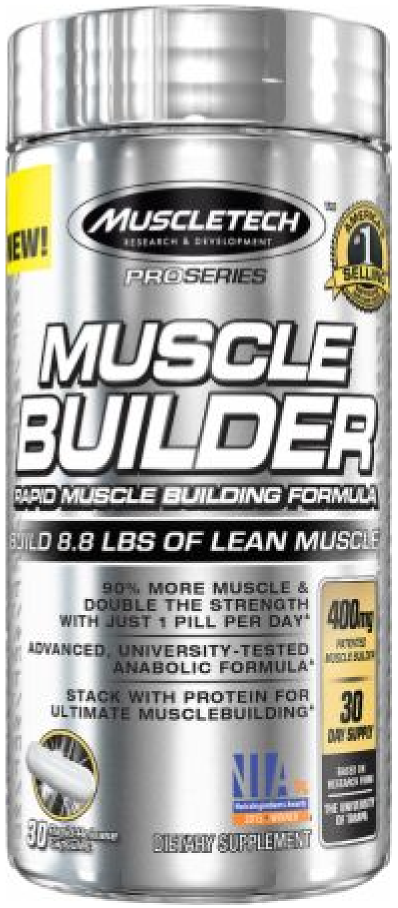
- Adenosine-5’-Triphosphate (ATP)
- BCAA
- HMB*
- Phosphatidic acid

* Trained populations

Kerksick et al., JISSN. 15:38, 2018

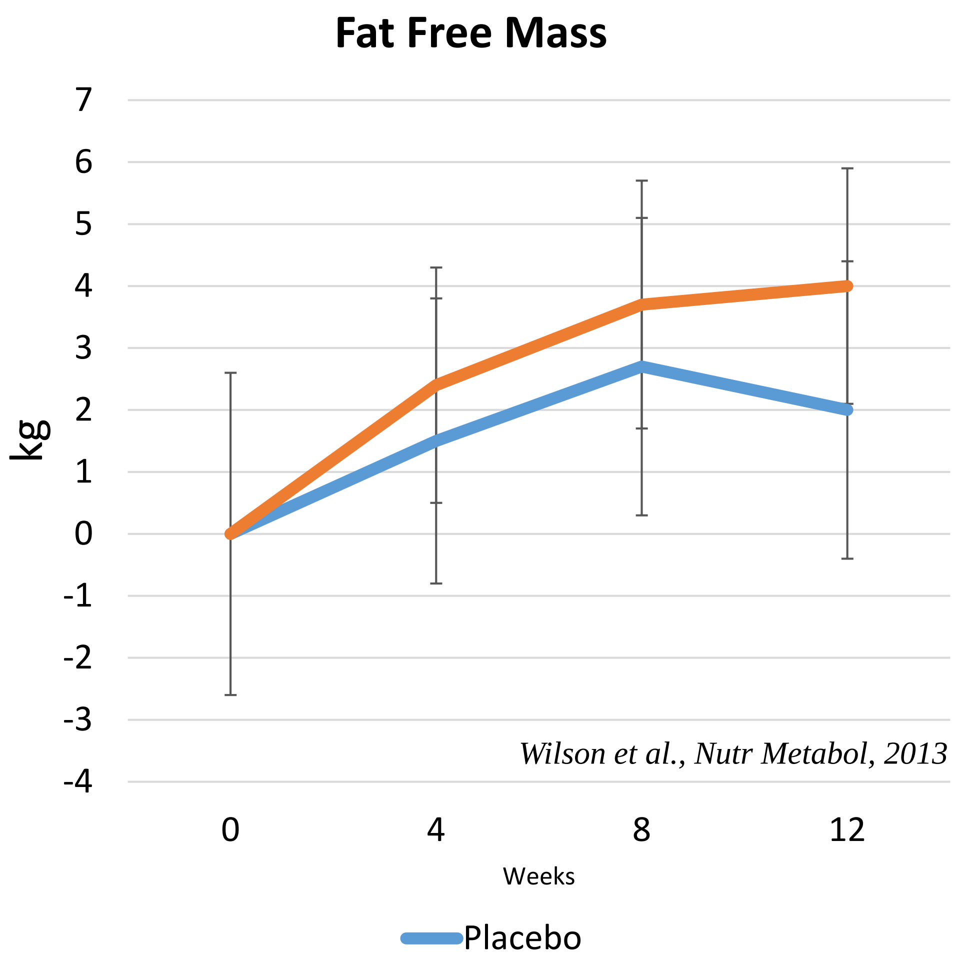
Adenosine-5'-Triphosphate

- While intravenous administration of ATP is bioavailable, several studies have shown that oral ATP is not systematically bioavailable.
- However, several recent studies indicate that chronic supplementation with ATP may increase the capacity to synthesize ATP within the erythrocytes without increasing resting concentrations in the plasma, thereby minimizing exercise-induced drops in ATP levels.
- Oral ATP has demonstrated ergogenic properties, after a single dose, improving total weight lifted and total number of repetitions (*Purpura et al. JACN. 2017*, *Freitas et al., JSCR, 2017*).
- ATP may increase blood flow to the exercising muscle (*Jager et al., JISSN, 2014*) and may reduce fatigue and increase peak power output during later bouts of repeated bouts exercise (*Purpura et al. JACN. 2017*).



Adenosine-5'-Triphosphate

- ATP may also support greater recovery and lean mass maintenance under high volume training (*Wilson et al., Nutr Metabol, 2013*).
- ATP has been shown to improve strength, reduce pain after knee surgery, and reduce the length of the hospital stay in clinical populations (*Long et al., J Arthroplasty, 2014*).
- Given the limited number of human studies of ATP on increasing exercise-induced gains in muscle mass, more chronic human training studies are warranted.



BCAA

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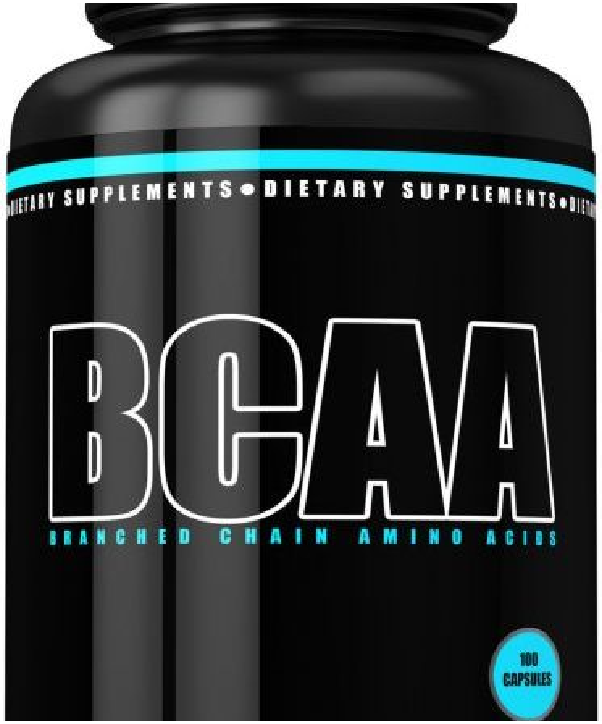
- Theoretically, BCAA supplementation during intense training may help minimize protein degradation and thereby lead to greater gains in or limit losses of fat-free mass.
- Schena and colleagues (*EJAPOP, 1992*)reported that BCAA supplementation (~10 g/d) during 21-days of trekking at altitude increased fat free mass (1.5%) while subjects ingesting a placebo had no change in muscle mass.
- Bigard and associates (*IJSN, 1996*) reported that BCAA supplementation appeared to minimize loss of muscle mass in subjects training at altitude for 6-weeks.
- Candeloro and coworkers (*Minerva Endocrinol, 1995*) reported that 30-days of BCAA supplementation (14 grams/day) promoted a significant increase in muscle mass (1.3%) and grip strength (+8.1%) in untrained subjects.



BCAA

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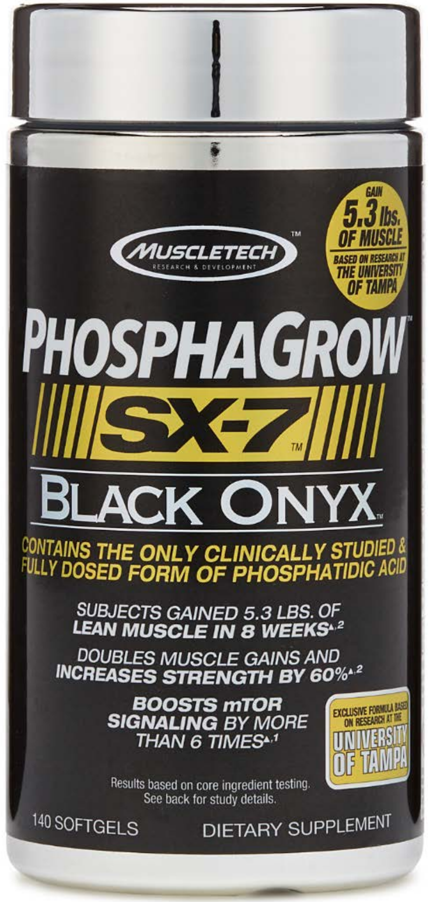
- Spillane and colleagues (*Nutr Health, 2012*) reported that 8-weeks of resistance training while supplementing with either 9 grams/day of BCAAs or placebo did not impact body composition or muscle performance.
- Jackman et al. (*Front Phyiol, 2017*) examined the ability of an acute dose of BCAA to stimulate increases in muscle protein synthesis. While acute ingestion of BCAAs promoted a 22% greater increase in muscle protein synthesis when compared to a placebo, the rates were 50% lower than what has typically been reported when a dose of whey protein containing similar amounts of BCAAs was ingested.
- Wolfe (*JISSN, 2017*) concluded that it is likely the ***other EAAs are needed to promote protein synthesis*** and that claims that BCAA alone stimulates MPS or produces an anabolic response to exercise is unwarranted.

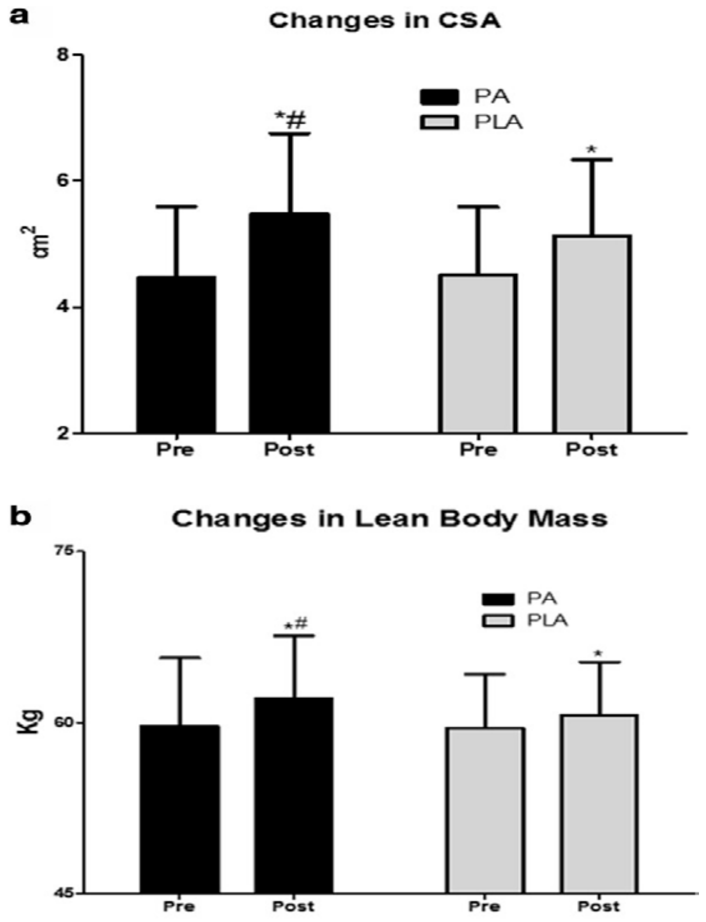
Phosphatidic Acid

- Phosphatidic acid (PA) is a diacyl-glycerophospholipid that is enriched in eukaryotic cell membranes and it can act as a signalling lipid (*Shad et al., Appl Physiol Nutr Metab, 2015*).
- PA has been shown to activate the mammalian target of rapamycin (mTOR) signalling in muscle with ultimately leads to increases in muscle protein synthesis.
- Fang et al. (*Science, 2001*) demonstrated that PA activates mTOR in vitro.
- Hornberger et al. (*PNAS, 2006*) found that mechanical stretching of skeletal muscle in situ promotes an increase in intramuscular PA levels and this effect was associated with the activation of mTOR signalling.



Phosphatidic Acid

- Hoffman and colleagues (*JISSN, 2012*) reported that PA supplementation (750 mg/d) increased whole-body lean body mass by 1.7 kg, whereas the placebo group demonstrated no relative change in lean body mass (0.1 kg).
- Joy et al. (*Nutr Metab, 2014*) performed an 8-week study and reported that PA supplementation significantly increased lean body mass by 2.4 kg compared to 1.2 kg in placebo group.
- Escalante et al. (*JISSN, 2015*) confirmed the beneficial effects of PA on exercise-induced gains in lean body mass.
- Andre et al. (*J Sports Sci Med, 2016*) reported that 250 and 375 mg/d of PA did not affect FFM.



Joy et al. Nutr Metab, 2014)

Muscle Building Supplements

Little to No Evidence to Support Efficacy and/or Safety

- Agmatine sulfate
- Alpha-ketoglutarate
- Arginine
- Boron
- Chromium
- Conjugated linoleic acids (CLA)
- D-Aspartic acid
- Ecdysterones
- Fenugreek extract
- Gamma oryzanol (Ferulic acid)
- Glutamine
- Growth-hormone releasing peptides and Secretogogues
- Isoflavones
- Ornithine-alpha-ketoglutarate
- Prohomones (Illegal for sale in USA)
- Sulfo-polysaccharides
- Tribulus terrestris
- Vanadyl sulfate
- Zinc-magnesium aspartate

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Performance Enhancement Supplements

Exercise & Sports Nutrition Review

Strong Evidence to Support Efficacy and Apparently Safe

- β-alanine
- Caffeine
- Carbohydrate
- Creatine Monohydrate
- Sodium Bicarbonate
- Sodium Phosphate
- Water and Sports Drinks

* Beginners and elderly initiating training

Kerksick et al., JISSN. 15:38, 2018

Performance Enhancing Supplements

Strength/Power Athletes

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- β-alanine
- β-HMB
- Creatine
- Nitrates *
- Sodium Bicarbonate

* Classified by ISSN as Limited / Mixed Efficacy

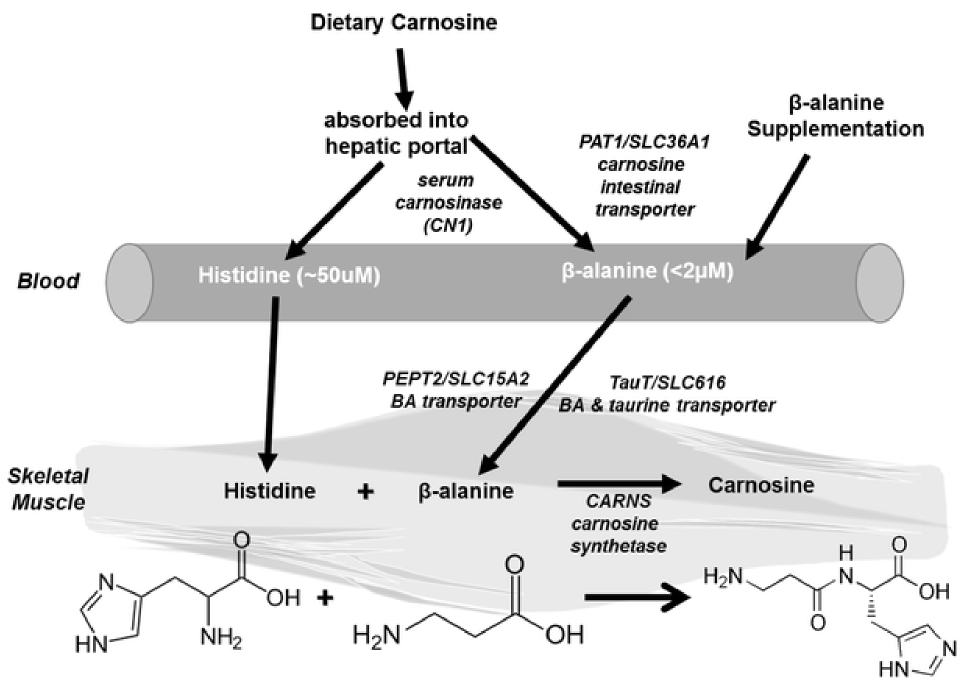
Performance Enhancing Supplements

Endurance Athletes

- Caffeine
- Carbohydrate
- Creatine Monohydrate
- Sodium Phosphate
- Water and Sports Drinks

B-Alanine

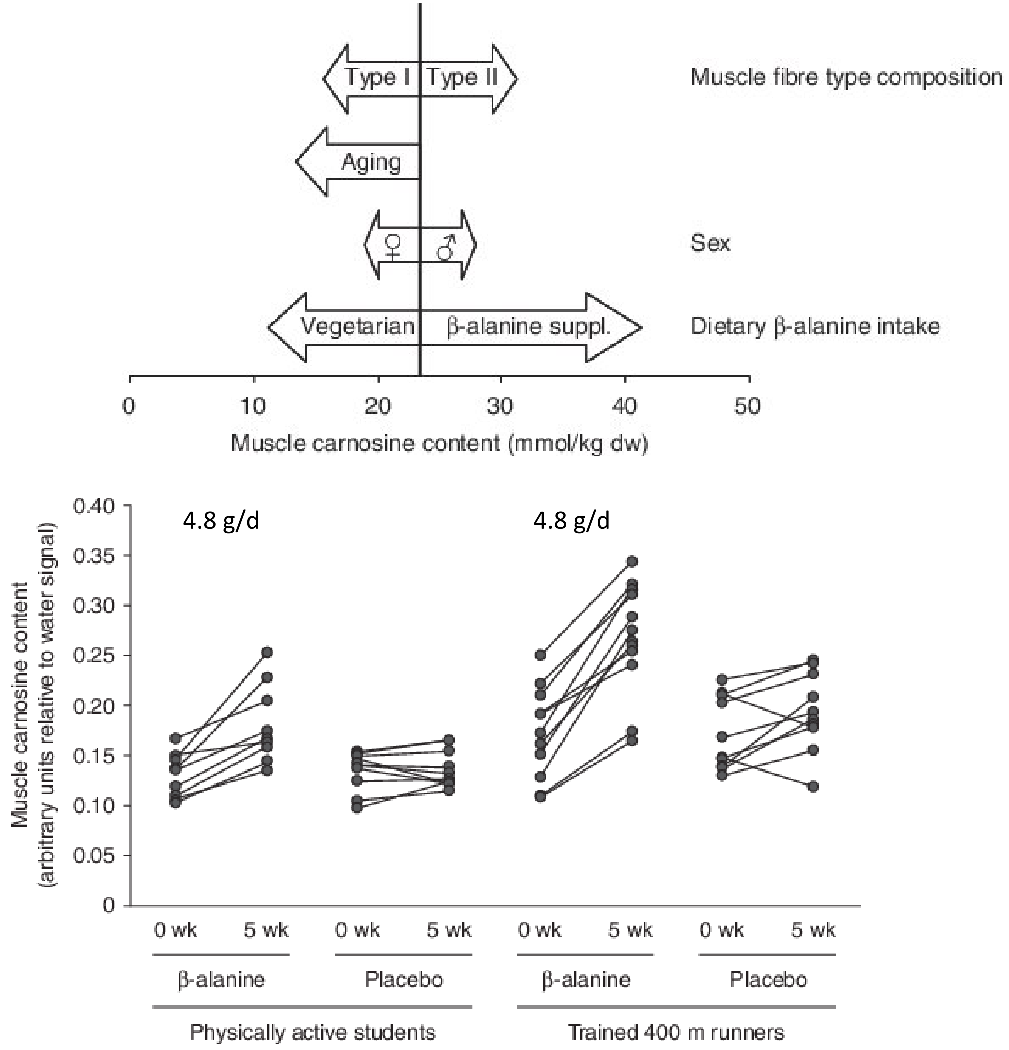
- ß-alanine, a non-essential amino acid, has ergogenic potential based on its role in carnosine synthesis
- Carnosine is a dipeptide comprised of the amino acids, histidine and ß-alanine, that naturally occur in large amounts in skeletal muscles.
- Carnosine is believed to be one of the primary muscle-buffering substances available in skeletal muscle.
- Studies have demonstrated that taking 4 to 6 g of ß-alanine orally, in divided doses, over a 28-day period is effective in increasing carnosine levels, while more recent studies have demonstrated increased carnosine and efficacy up to 12 g/day.



From Stellinwerff et al. Amino Acids, 43(1): 57-65, 2012

B-Alanine

- Consuming 4 to 6 g/d in divided doses of 2 g or less, for a minimum of two weeks results in a 20-30 % increase in muscle carnosine concentrations.
- Ingesting 2–6 g/d for more than 4-wks increases muscle carnosine concentrations by 20–80%. (*Culbertson et al, 2010*).
- There does not appear to be an upper ceiling to muscle carnosine levels.
- Single large boluses of BA have been reported to induce paraesthesia (i.e. tingling).
- Most studies use a sustained release form of BA to reduce paresthesia.



Derave et al. Sports Med. 40(3), 247-63, 2010

β-Alanine supplementation slightly enhances repeated plyometric performance after high-intensity training in humans

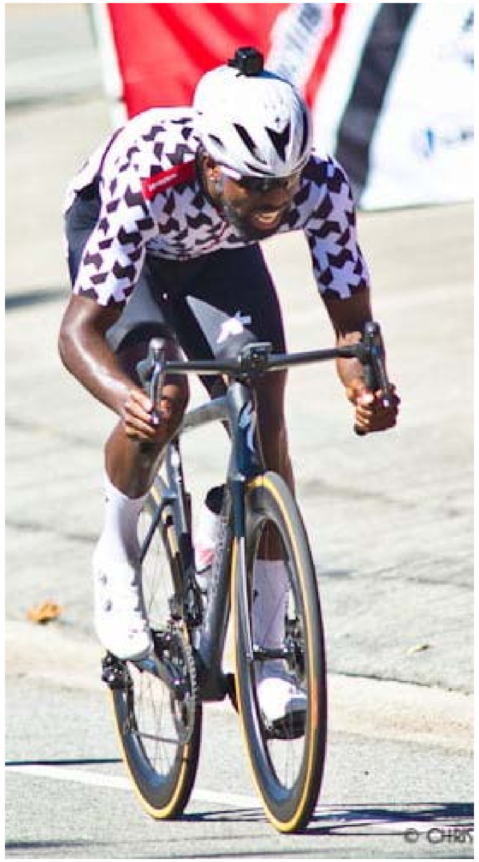
Belinger et al. Amino Acids 47:1479-1483, 2015

- 14 cyclists performed a supramaximal cycling test, 4- and 10-km TT's, and 4 x 1-km sprints prior to and following 28 d of loading (***6.4 g/d***) with BA or a PLA and after a 5-wk of HIT (repeated 1-km sprints – 2 x/ wk) while taking (1.2 g/d) of BA or a PLA.
- BA loading improved sprint 3 and 4 of the 4 x 1-km sprints (4.5 +/- 3.4% and 7.0 +/- 4.0%).
- After HIT, training intensity increased to a greater degree with BA (9.9 +/- 5.0% vs. 4.9 +/- 5.0).
- BA improved maximal cycling time to exhaustion (14.9 +/- 9.2% vs. 9.0 +/- 6.9%) and anaerobic capacity (5.5 +/- 4.2%)
- ***BA enhances training intensity during HIT and provides benefits to exhaustive supramaximal cycling compared to HIT alone.***

Metabolic consequences of beta-alanine supplementation during exhaustive supramaximal cycling and 4000-m time-trial performance

Belinger et al. Appl Physiol Nutr Metab 41(8):864-71, 2016

- 17 cyclists ingested ***6.4 g/d*** of BA or PLA for ***4-wks***
- Participants performed a supramaximal cycling tests to exhaustion and a 4k TT before and after supplementation
- BA increased time to exhaustion (+12.8 +/- 8.2 s) and anaerobic capacity (+1.1 +/- 0.7 kJ)
- 4000-m TT performance was improved with BA (-6.3 +/- 4.6 s) and the mean anaerobic power output was greater (+6.2 +/- 4.5 W).
- ***BA supplementation increased time to exhaustion concomitant with an augmented anaerobic capacity during supramaximal intensity cycling***, which was also mirrored by a meaningful increase in the anaerobic contribution to power output during a 4000-m cycling TT, resulting in an enhanced overall performance.



The effects of beta alanine plus creatine administration on performance during repeated bouts of supramaximal exercise in sedentary men

Okudan et al. J Sports Med Phys Fitness 55(11):1322-8, 2015

- 44 untrained men were assigned to one of four treatment groups randomly:
  - P (10 g maltodextrose)
  - Cr (5 g creatine plus 5 g maltodextrose);
  - BA (1,6 g BA plus 8.4 g maltodextrose); or,
  - BA + Cr (,6 g BA + 5 g creatine plus 3.4 g maltodextrose).
- Supplements were taken twice a day for 22 days, then four times a day for the following 6 days.
- Prior to and following 28 days, peak power (PP), mean power (MP), and fatigue index (FI) was determined.
- PP increased in the Cr (from 642.7+/-148.6 to 825.1+/-205.2 in PP2 and from 522.9+/-117.5 to 683.0+/-148.0 in PP3, respectively). MP was increased in BA+Cr
- ***BA and BA+Cr have strong performance enhancing effect by increasing mean power and delaying fatigue Index during the repeated WAnT*.**

β-Alanine

Non-Controlled Release of β-Alanine

- Most initial studies on β-alanine were performed on an immediate release version using oral doses of 10 - 40 mg/kg (800 mg to 3.2 g per dose for an 80 kg individual)
- Initial pharmacokinetic studies indicated that β-alanine typically peaks in the blood about 30-45-mins after ingestion.
- Ingestion of multiple doses of β-alanine promotes corresponding peaks in blood β-alanine levels.
- Most β-alanine supplements introduced on the market in the mid 2000's were immediate release formulations.

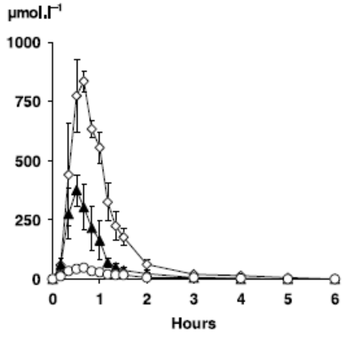


Fig. 2. Mean plasma β-alanine concentration with time following ingestion of 10 (○), 20 (▲) or 40 (◇) mg · kg^{-1} bwt β-alanine. For reasons of clarity the SE of the means is shown only for measurements following 20 and 40 mg · kg^{-1} bwt

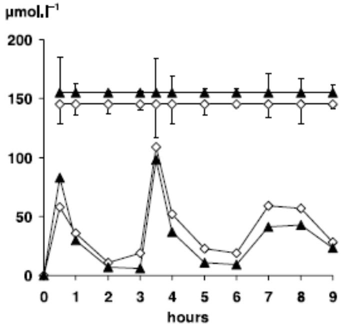


Fig. 6. Plasma β-alanine over 9 h following the oral ingestion of 10 mg · kg^{-1} bwt of β-alanine at 0, 3 and 6 h on days 1 (▲) and 15 (◇) whilst dosing at 3 × 10 mg · kg^{-1} bwt per day. For reasons of clarity the SE of the means are shown separately above the main trend line

Harris et. al., Amino Acids. 30:279-89, 2006

B-Alanine

ISSN Position Stand

1. Four weeks of beta-alanine supplementation (4–6 g daily) significantly augments muscle carnosine concentrations, thereby acting as an intracellular pH buffer.
2. Beta-alanine supplementation currently appears to be safe in healthy populations at recommended doses
3. The only reported side effect is paranesthesia (tingling), but studies indicate this can be attenuated by using divided lower doses (1.6 g) or using a sustained-release formula.
4. Daily supplementation with 4 to 6 g of beta-alanine for at least 2 to 4 weeks has been shown to improve exercise performance, with more pronounced effects in open end-point tasks/time trials lasting 1 to 4 min in duration.

Trexler et al. JISSN. 12:30, 2015

β-Alanine

ISSN Position Stand

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5. Beta-alanine attenuates neuromuscular fatigue, particularly in older subjects, and preliminary evidence indicates that beta-alanine may improve tactical performance.
6. Combining beta-alanine with other single or multi-ingredient supplements may be advantageous when supplementation of beta-alanine is high enough (4–6 g daily) and long enough (minimum 4 weeks);
7. More research is needed to determine the effects of beta-alanine on strength, endurance performance beyond 25 min in duration, and other health-related benefits associated with carnosine.

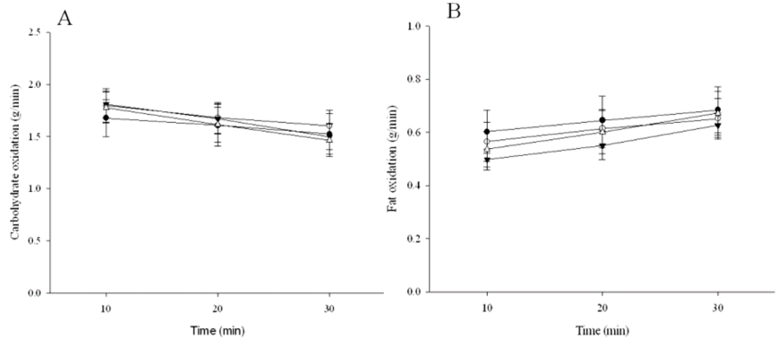
Trexler et al. JISSN. 12:30, 2015

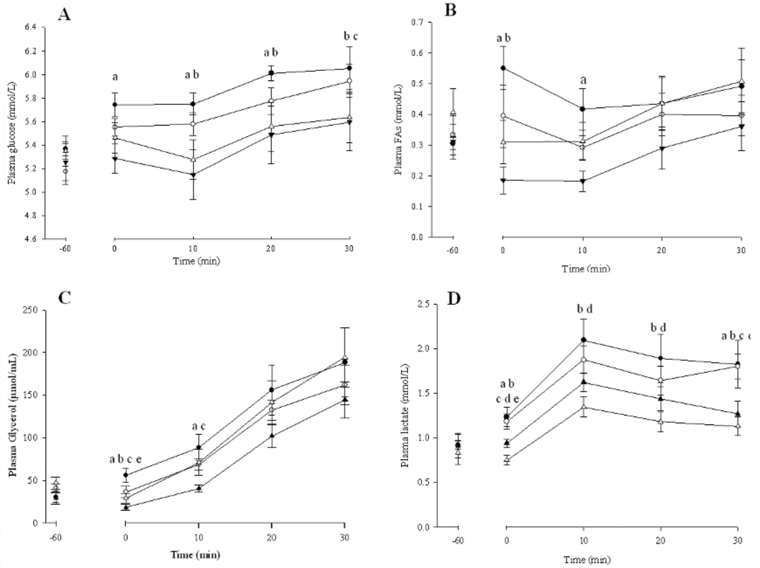
Caffeine

- Caffeine is a naturally derived stimulant found in many nutritional supplements typically as guarana, bissey nut, or kola.
- Caffeine can also be found in coffee, tea, soft drinks, energy drinks, and chocolate.
- Caffeine has been shown to be an effective ergogenic aid for aerobic and anaerobic exercise.
- Studies indicate that ingestion of caffeine (e.g., 3-9 mg/kg taken 30 – 90 minutes before exercise) can spare carbohydrate use during exercise and thereby improve endurance exercise capacity.
- The effects of caffeine on maximal strength and muscular endurance (repetitions) is mixed.
- Caffeine doses above 9 mg/kg can result in urinary caffeine levels that surpass the doping threshold for many sport organizations.

The metabolic and performance effects of caffeine compared to coffee during endurance exercise *Hodgson et al. PLoS One. 8(4): e59561, 2016*

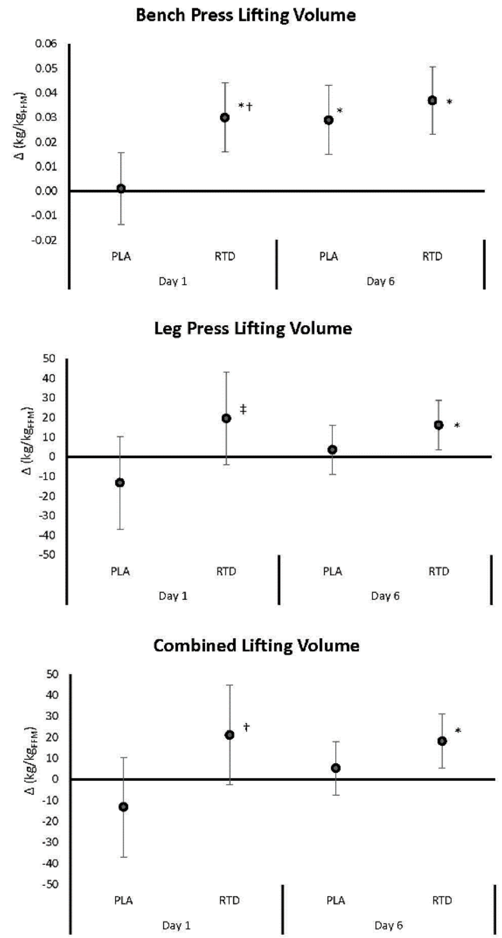
- In a SBCOR study, 8 trained male cyclists/triathletes completed 30 min of steady-state (SS) cycling at approximately 55% VO_{2max} followed by a 45 min energy based target time trial (TT).
- 1 hr prior to exercise, participants consumed drinks consisting of CAF (5 mg CAF/kg BW), instant coffee (5 mg CAF/kg BW), instant decaffeinated coffee or PLA.
- Performance times during the TT were significantly faster (~5.0%) for both caffeine and coffee when compared to PLA and decaf (38.35±1.53, 38.27±1.80, 40.23±1.98, 40.31±1.22 min respectively, $p<0.05$).
- Average power for CAF and coffee during the TT was significantly greater when compared to PLA and decaf (294±21 W, 291±22 W, 277±14 W, 276±23 W respectively, $p<0.05$).
- Both caffeine (5 mg/kg/BW) and coffee (5 mg/kg/BW) consumed 1 h prior to exercise can improve endurance exercise performance.





Short-term effects of a ready-to-drink pre-workout beverage on exercise performance and recovery *Collins et al. Nutrients. 8(4):9(8), 823, 2017.*

- In a DBRCO manner, 25 RT participants ingested a placebo (PLA) containing or (RTD) containing caffeine (200 mg), β-alanine (2.1 g), arginine nitrate (1.3 g), niacin (65 mg), folic acid (325 mcg), and Vitamin B12 (45 mcg) for 7-days, separated by a 7–10-day.
- On day 1 and 6, participants donated a fasting blood sample and completed a hemodynamic challenge test, 1-RM and muscular endurance tests (3 × 10 repetitions at 70% of 1-RM with the last set to failure on the bench press (BP) and leg press (LP)) followed by ingesting the assigned beverage.
- After 15 min, participants repeated the hemodynamic test, 1-RM tests, and performed a repetition to fatigue (RtF) test at 70% of 1-RM.
- On day 2 and 7, participants donated a fasting blood sample, ingested the assigned beverage, rested 30 min, and performed a 4 km TT.
- Acute RTD ingestion better maintained LP 1-RM, increased LP RtF repetitions, increased BP LV, and, increased TLV.
- Short-term RTD ingestion maintained baseline LP 1-RM , LP RtF repetitions, and LP TLV to a greater degree than PLA.
- No significant differences were observed between treatments in cycling TT performance, hemodynamic assessment, fasting blood panels, or self-reported side effects.



Caffeine

ISSN Position Stand

- Caffeine is effective for enhancing sport performance in trained athletes when consumed in low-to-moderate dosages (***3-6 mg/kg***)
- Caffeine can enhance vigilance during bouts of extended exhaustive exercise, as well as periods of sustained sleep deprivation.
- Caffeine is ergogenic for sustained maximal endurance exercise, and has been shown to be highly effective for time-trial performance.
- Caffeine supplementation is beneficial for high-intensity exercise, including team sports such as soccer and rugby, both of which are categorized by intermittent activity within a period of prolonged duration.

Goldstein et al. JISSN. 7:5, 2010

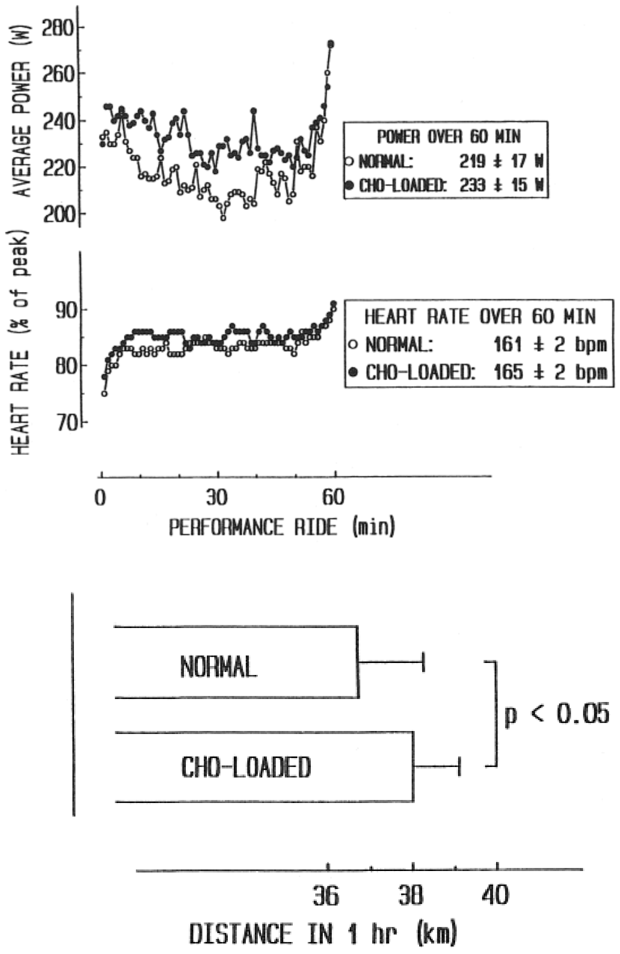
Carbohydrate

- Intramuscular and hepatic glycogen stores are best maximized by consumption of a high-CHO diet (5–8 g/kg/d during moderate training and 8–12 g/kg/d during heavy training).
- Athletes undergoing prolonged bouts (2–3 h) of exercise training can oxidize CHO at a rate of 1–1.1 g per minute or about 60 g/hr.
- Several reviews advocate the ingestion of 0.7 g of carbohydrate/kg/hr. during exercise in a 6–8% solution (i.e., 6–8 g per 100 ml of fluid).
- CHO feedings (> 8 g/kg/d or 1.2 g/kg/hour) during the first 4-hours following exercise that favor high-glycemic CHO (> 70) promote rapid restoration of glycogen stores.
- Athletes should emphasize CHO ingestion during the first 4 hrs after intense exercise.

Kerksick et al., JISSN. 15:38, 2018

The effects of carbohydrate loading on muscle glycogen content and cycling performance *Rauch et al. In J Sport Nutr. 5(1):25-36, 1995.*

- 8 endurance-trained cyclists ingested in random order either their normal CHO intake of 6.15±0.23 g/kg/d or a high-CHO diet of 10.52±0.57 g/kg/d.
- Participants cycled for 2 hr at approximately 75% of VO_{2peak} with five 60-s sprints at 100% VO_{2peak} at 20-min intervals, followed by a 60-min performance ride.
- Increasing CHO intake by 72±9% for 3 days prior to the trial elevated pre-exercise muscle glycogen contents, improved power output, and extended the distance covered in 1 hr.
- Muscle glycogen contents were similar at the end of the 3-hr trial, indicating a greater utilization of glycogen when subjects were CHO loaded, which may have been responsible for their improved cycling performance.

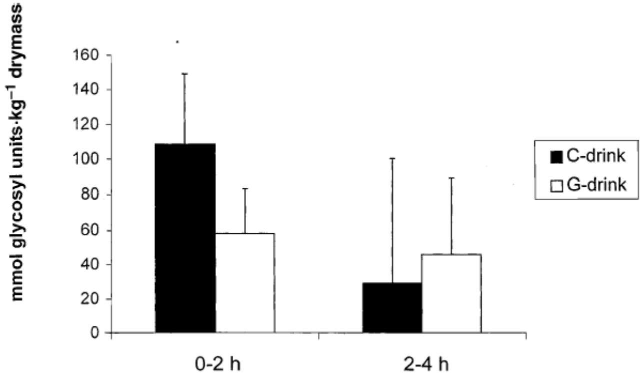


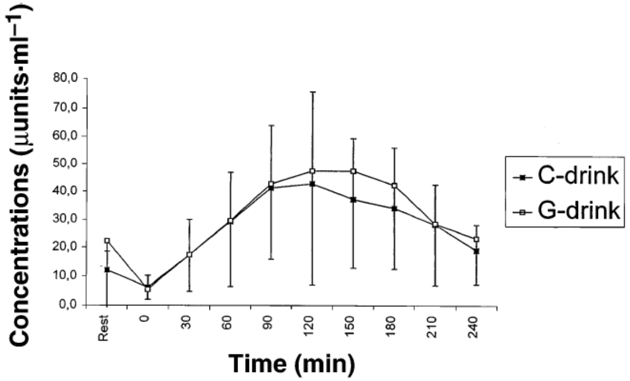
Muscle glycogen resynthesis rate in humans after supplementation of drinks containing carbohydrates with low and high molecular masses. *Piehl et al. Eur J Appl Physiol. 81(4):346-51, 2000*

- 13 healthy well-trained men performed a glycogen depleting exercise bout followed by ingesting drinks containing 4.2 g/kg of CHO (75 g in 500 ml water) at 0, 30, 60 ad 90-min post exercise.
- One drink contained a polyglucoside with a mean molecular mass (MMM) of 500 000±700 000 (C drink) and the other contained monomers and oligomers of glucose with a MMM of approximately 500 (G drink).
- Mean glycogen synthesis rate was significantly higher during the initial 2 h for the C drink compared to the G drink: 50.2±13.7 mmol/kg/h in the C group and 29.9±12.5 mmol/kg/hr in the G group.
- During the last 2 h the mean synthesis rate was 18.8±33.3 and 23.3±22.4) mmol/kg/h in the C and G group, respectively.
- Mean blood glucose and insulin concentrations did not differ between the two drinks.
- Our data indicted that the osmolality of the carbohydrate drink may influence the rate of resynthesis of glycogen in muscle after its depletion by exercise.

	Glycogen, mmol · kg^{-1} (dry mass)			Synthesis rate, mmol · kg^{-1} (dry mass) · h^{-1}	
	0 h	2 h	4 h	0–2 h	2–4 h
C group	52.9 (27.4)	153.3 (27.4)*	190.8 (61.5)	50.2 (13.7)#	18.8 (33.3)
G group	58.3 (35.4)	118.1 (38.9)*	164.7 (49.9)	29.9 (12.5)	23.3 (22.4)

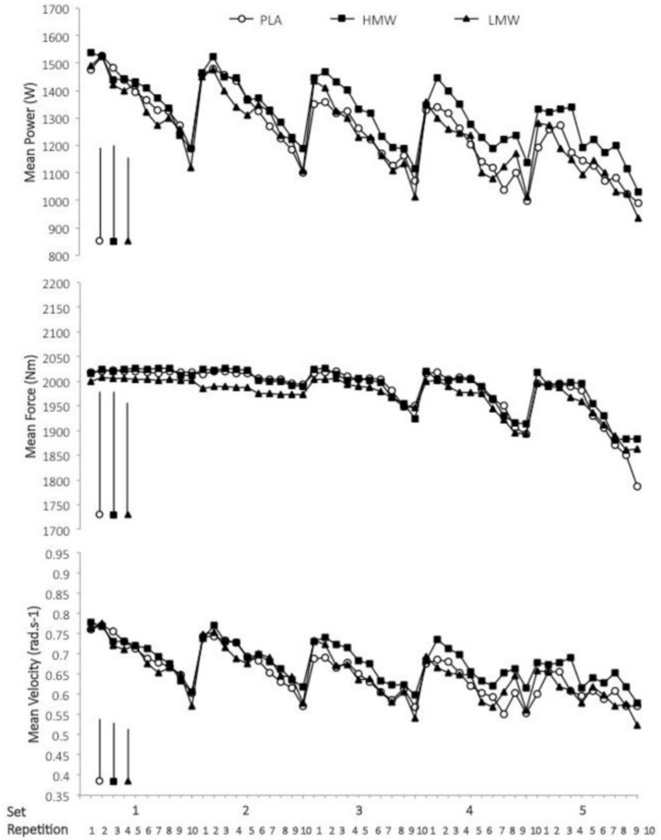
$^{*}P < 0.06$, $^{\#}P < 0.06$





Ingestion of high molecular weight carbohydrate enhances subsequent repeated maximal power: a randomized controlled trial *Oliver et al. PLoS One. 16;11(9), 2016*

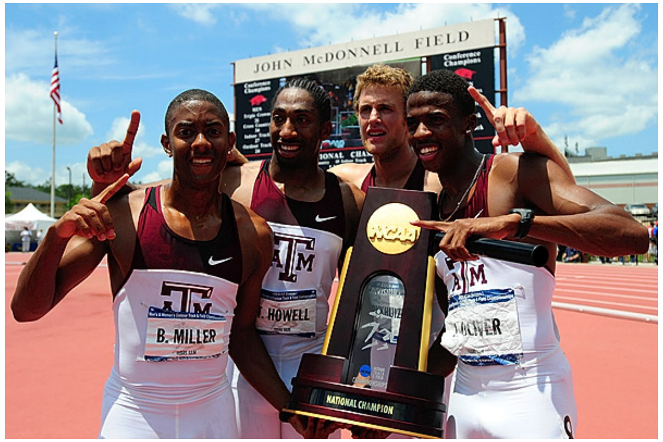
- 16 RT men participated in a DBPCRCO study comprising a muscle-glycogen depleting cycling exercise followed by ingestion of placebo (PLA), or 1.2 g/kg of LMW or HMW carbohydrate solution (10%).
- Participants then performed 5 sets x 10 maximal explosive repetitions of back squat @ 75% of 1RM.
- Compared to PLA, ingestion of HMW (4.9%, 90%CI 3.8%, 5.9%) and LMW (1.9%, 90%CI 0.8%, 3.0%) CHO solutions substantially increased power output during resistance exercise, with the 3.1% (90% CI 4.3, 2.0%) additional gain in power after HMW-LMW ingestion attributed to higher movement velocity after force kinematic analysis (HMW-LMW 2.5%, 90%CI 1.4, 3.7%).
- Both CHO solutions increased post-exercise plasma glucose, glucoregulatory and gut hormones compared to PLA.
- Ingestion of a HMW carbohydrate following prolonged intense endurance exercise provides superior benefits to movement velocity and power output during subsequent repeated maximal explosive resistance exercise.



Creatine

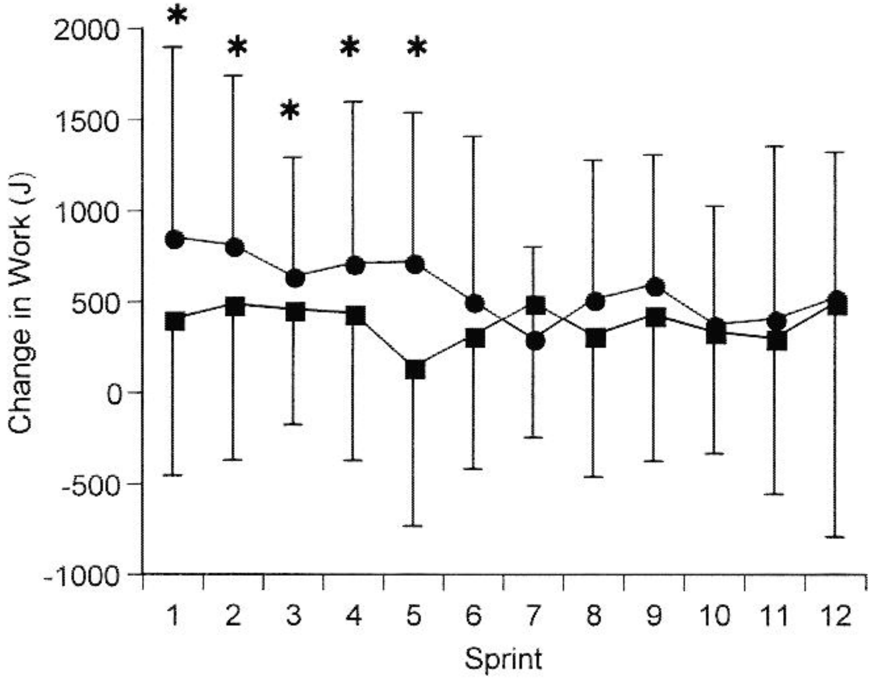
Performance

- Increased single and repetitive sprint performance
- Increased work performed during sets of maximal effort muscle contractions
- Increased muscle mass & strength adaptations during training
- Enhanced glycogen synthesis
- Increased anaerobic threshold
- Possible enhancement of aerobic capacity via greater shuttling of ATP from mitochondria
- Increased work capacity
- Enhanced recovery
- Greater training tolerance



Effects of Creatine Supplementation on Body Composition, Strength, and Sprint Performance *Kreider et al. MSSE 30:73-82, 1998*

- 25 NCAA division IA football players were matched-paired and assigned to supplement their diet for 28 d during resistance/agility training (8 h·wk-1) with a placebo (P) or supplement 15.75 g/d of CrM.
- Hematological parameters remained within normal clinical limits with no side effects reported.
- Gains in bench press lifting volume (P -5 ± 134; CrM 225 ± 246 kg), the sum of bench press, squat, and power clean lifting volume (P 1,105 ± 429; CrM 1,558± 645 kg), and total work performed during the first five 6-s sprints were greater in the CrM group.
- CrM promoted greater gains in FFM, isotonic lifting volume, and sprint performance during intense training.



Cited over 750 times

Creatine Supplementation and Upper Limb Strength Performance: A Systematic Review and Meta-Analysis *Lanthers et al. Sports Med. June 21, 2016*

- Conducted a meta-analysis on 53 studies (563 individuals in the creatine supplementation group and 575 controls).
- Results did not differ at T0, while, at T1, the effect size (ES) for bench press and chest press were 0.265 (95 % CI 0.132-0.398; $p < 0.001$) and 0.677 (95 % CI 0.149-1.206; $p = 0.012$), respectively.
- Overall, pectoral ES was 0.289 (95 % CI 0.160-0.419; $p = 0.000$), and global upper limb ES was 0.317 (95 % CI 0.185-0.449; $p < 0.001$).
- Meta-analysis of changes between T0 and T1 gave similar results.
- The meta-regression showed no link with characteristics of population or supplementation, demonstrating the efficacy of creatine independently of all listed conditions.
- ***Creatine supplementation is effective in upper limb strength performance for exercise with a duration of less than 3 min, independent of population characteristics, training protocols, and supplementary doses or duration.***

Creatine

Other Uses

- Other Applications in Sport
  - Enhanced Recovery
  - Injury Prevention
  - Enhance Tolerance to Exercise in the Heat
  - Enhanced Rehabilitation from Injury
  - Brain and Spinal Cord Neuroprotection
- Potential Medical Uses
  - Creatine Synthesis Deficiencies
  - Neurodegenerative Diseases
  - Ischemic Heart Disease
  - Aging (Sarcopenia and Cognitive Function)
  - Pregnancy

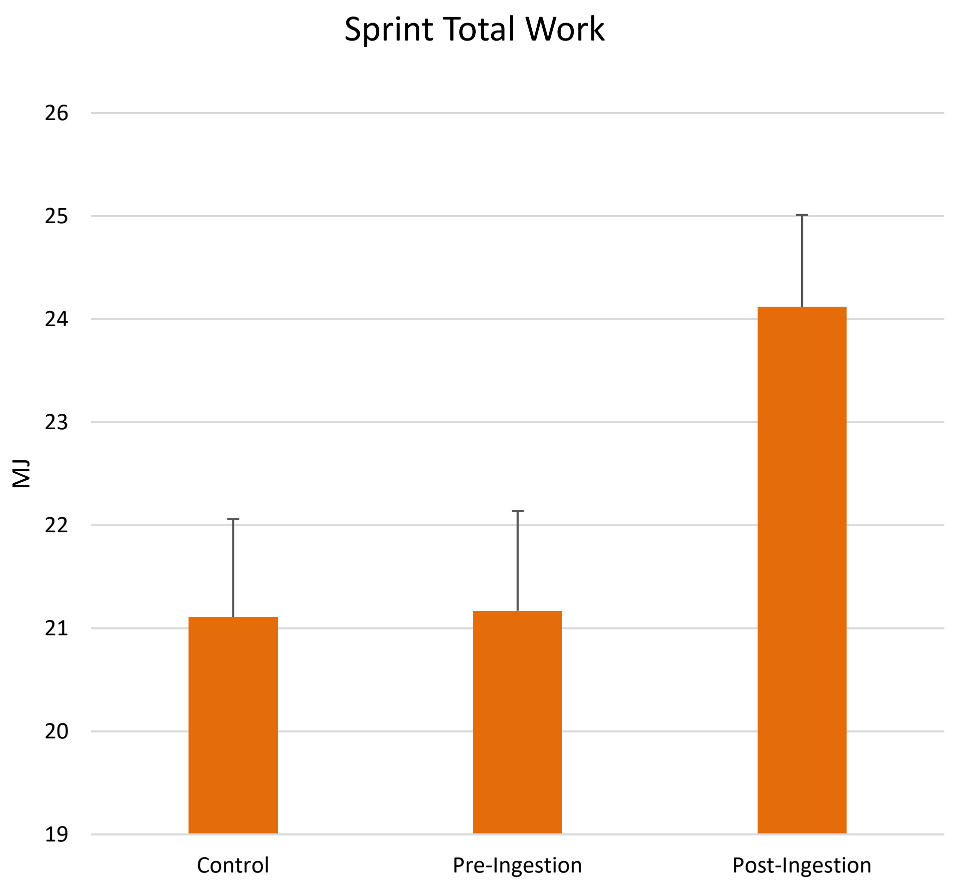
Kreider et al. JISSN 14:18, 2017

Sodium Bicarbonate

- Supplementation Protocols:
  - 0.3 g/kg of baking soda 1 to 2 hours before competition
  - 10 g/d for 5-d
- Reported to buffer acidity and improve high intensity exercise performance (1 - 3 min)
- Possible GI distress
- Start out with a small amount during training to build up tolerance

Effects of chronic bicarbonate ingestion on performance of high intensity work *McNaughton et al. EJAP, 80:333-6. 1999*

- 8 subjects performed a 60-s sprint on a CE prior to and following 5-d of supplementation of SB (0.5 g/kg/d) and following 1 month cessation
- SB significantly increased blood bicarbonate levels and pH levels
- SB increased work by 14% and peak power



Ergogenic effects of caffeine and sodium bicarbonate supplementation on intermittent exercise performance preceded by intense arm cranking

Marriott et al. JISSN, 12:13, 2015

- 12 male team-sports athletes (n = 12) ingested sodium bicarbonate ($NaHCO_3$; 0.4 g/kg), caffeine (CAF; 6 mg/kg) or placebo (PLA) on three different occasions.
- Participants engaged in intense arm exercise prior to the Yo-Yo intermittent recovery test level-2 (Yo-Yo IR2).
- CAF and $NaHCO_3$ elicited a 14 and 23% improvement ($P < 0.05$), respectively, in Yo-Yo IR2 performance, post arm exercise compared to PLA.
- RPE was lower ($P < 0.05$) during the Yo-Yo IR2 test in the $NaHCO_3$ trial in comparison to CAF and PLA, while no difference in heart rate was observed between trials.
- ***Caffeine and sodium bicarbonate administration improved Yo-Yo IR2 performance and lowered perceived exertion after intense arm cranking exercise, with greater overall effects of sodium bicarbonate intake.***

Separate and Combined Effects of Caffeine and Sodium-Bicarbonate Intake on Judo Performance *Felippe et al. Int J Sports Physiol Perform, 11(2):221-6, 2016*

- 10 judo athletes performed 4 supplementation protocols-NaHCO3, CAF, NaHCO3 + CAF, and placebo (PLA) followed by 3 Special Judo Fitness Tests (SJFTs) interspaced with 5 min rest.
- The combined supplement (NaHCO3 + CAF) resulted in a higher number of throws than with PLA (24.4 +/- 0.9 and 23.2 +/- 1.5 throws, respectively, P = .02) during the first SJFT.
- In the 3rd SJFT, NaHCO3 and NaHCO3 + CAF resulted in more throws than with PLA (23.7 +/- 1.6, 24.4 +/- 1.0, and 22.0 +/- 1.6 throws, P = .001 and P = .03, respectively).
- Sum of throws performed in the 3 SJFTs were higher than PLA only for NaHCO3 + CAF (68.8 +/- 4.4 and 72.7 +/- 3.1 throws, respectively, P = .003).
- ***Combined supplementation of NaHCO3 + CAF increased judo performance compared with PLA.***

Sodium Phosphate

- Involved in acid-base balance, energy metabolism, and heart function.
- 4 gm/d x 3 to 6-d of sodium phosphate
- Increases VO_2 max & AT by 5 -10%.
- Effective aid primarily for endurance athletes but may also be helpful for short-duration and/or intermittent high intensity exercise.
- May cause stomach upset and stool softening.

Kerksick et al., JISSN. 15:38, 2018

Sodium Phosphate

Study	Findings
Cade et al. MSSE, 1984	Trained runners – 9% ↑ in VO_2max; ↓ submaximal lactate
Kreider et al. MSSE, 1990	Trained runners - 9% ↑ in VO_2max; 12% ↑ in VANT; NS but 14-s faster 5-mile run time
Stewart et al. Res Q, 1990	Trained cyclists - 9% ↑ in VO2max; 20% ↑ in time to exhaustion
Kreider et al. IJSN, 1992	Trained cyclists & triathletes - 9% ↑ in VO_2max; 10% ↑ in VANT; 17% ↑ in 40km time trial cycling power output; 13% ↑ in Ejection Fraction; 24% ↑ myocardial fractional shortening (2D Echo)

Kerksick et al., JISSN. 15:38, 2018

Effect of sodium phosphate supplementation on repeated high-intensity cycling efforts *Brewer et al. J Sports Sci. 33(11):1109-16, 2015*

- Trained male cyclists were randomized to 6 days of SP supplementation (50 mg/kg FFM/d) or PLA.
- Performance was assessed at baseline and 1 and 4 days post-supplementation on an air-braked cycle ergometer.
- Compared with baseline, the SP group recorded significantly improved ($P < 0.05$) work and mean power output values in both the sprint (baseline, 259 kJ/719 W; day 1, 271 kJ/754 W; day 4, 271 kJ/753 W) and time-trial (baseline, 225 kJ/374 W; day 1, 235 kJ/398 W; day 4, 236 kJ/393 W) aspects of the performance test post-loading.
- No differences were seen in total work or power output in the PLA group.
- ***SP supplementation improved repeated-sprint and time-trial cycling efforts both 1 and 4 days post-loading in trained cyclists.***

Effects of sodium phosphate and caffeine loading on repeated-sprint ability

Buck et al. J Sports Sci. 33(19):1971-9, 2015

- 12 female, team-sport players participated in four trials: 1) SP and CAF; 2) SP and PLA; 3) CAF and PLA; and 4) PLA + PLA with ~21 days separating each trial.
- Participants performed a simulated team-game circuit (4 x 15 min quarters) with 6 x 20-m repeated-sprints performed once before (Set 1), at half-time (Set 2), and after (Set 3).
- Total sprint times were faster after SP and CAF compared with PLA (Set 1: P = 0.003; Set 2: d = -0.51; Set 3: P < 0.001; overall: P = 0.020), CAF (Set 3: P = 0.004; overall: P = 0.033) and SP (Set 3: d = -0.67).
- Total sprint times were faster after SP supplementation compared with PLA (Set 1: d = -0.52; Set 3: d = -0.58).
- Best sprint results were faster after SP and CAF compared with PLA (Set 3: P = 0.007, d = -0.90) and CAF (Set 3: P = 0.024, d = -0.73).
- Best sprint times were also faster after SP compared to PLA d = -0.54 to -0.61 for all sets).
- ***Sodium phosphate and combined sodium phosphate and caffeine loading improved repeated-sprint ability.***

Effects of sodium phosphate and caffeine ingestion on repeated-sprint ability in male athletes *Kopec et al. J Sci Med Sport. 19(3):272-6, 2016*

- 11 team-sport males participated in four trials: 1) SP (50 mg/kg FFM / d for 6-d) and CAF (6 mg/kg FFM / d) ingested 1h before exercise); 2) SP and PLA; 3) CAF and PLA; and 4) PLA + PLA.
- Participants performed a simulated team-game circuit (STGC) consisting of 2x30min halves, with 6x20-m repeated-sprint sets performed at the start, half-time and end of the STGC.
- SP resulted in the fastest times for all sprints, as supported by moderate to large effect sizes (ES; d=0.51-0.83) and 'likely' to 'very likely' chances of benefit, compared with PLA.
- Compared with CAF, SP resulted in 'possible' to 'likely' chances of benefit for FS, BS and TS for numerous sets and a 'possible' chance of benefit compared with SP+C for BS (set 2).
- Compared with PLA, SP+C resulted in moderate ES (d=0.50-0.62) and 'possible' to 'likely' benefit for numerous sprints, while caffeine resulted in a moderate ES (d=0.63; FS: set 3) and 'likely' chances of benefit for a number of sets.
- Results suggest that ***SP supplementation may improve repeated-sprint performance when compared with PLA.***

Water/Glucose Electrolyte Solutions

- Performance can be impaired when ≥ 2% of body weight is lost through sweat. Fluid loss of > 4% of body weight may lead to heat illness, exhaustion, stroke, or death.
- High intensity (> 70% VO_{2Max}) exercise bouts > 90 min challenge fuel supply and fluid regulation.
- It is advisable to consume CHO at a rate of 30–60 g of carbohydrate/hour in a 6–8% GES (6–12 fluid ounces) every 10–15 min during exercise.
- Addition of 0.5 - 1 g/L of salt in athletes with high sweat rate (>2 L/hr) can help maintain hydration in hot & humid environments.
- Use of GES during prolonged exercise has been reported to maintain BG, attenuate dehydration, improve performance, and lessen the immunosuppressive effects of exercise.

Kerksick et al., JISSN. 15:38, 2018

Glucose Electrolyte Solutions

- The general consensus in the scientific literature is the body can oxidize 1 – 1.1 gram of CHO per minute of carbohydrate or about 60 grams per hour.
- The ACSM recommends ingesting 0.7 g/kg/hr during exercise in a 6-8% solution (i.e., 6-8 grams per 100 ml of fluid).
- Harger-Domitrovich et al (*MSSE, 2007*) reported that 0.6 g/kg/h of maltodextrin optimized carbohydrate utilization (30 - 70 grams of carbohydrate per hour for a 50 – 100 kg individual).
- Jeukendrup et al (*Scan J Med Sci Sports, 2008*), reported that ingesting a glucose and fructose beverage in a 2:1 ratio during exercise enhanced carbohydrate oxidation (1.8 g/min) better than glucose alone as well as helped promote greater fluid retention.

Glucose Electrolyte Drinks

GI of Common Sugars

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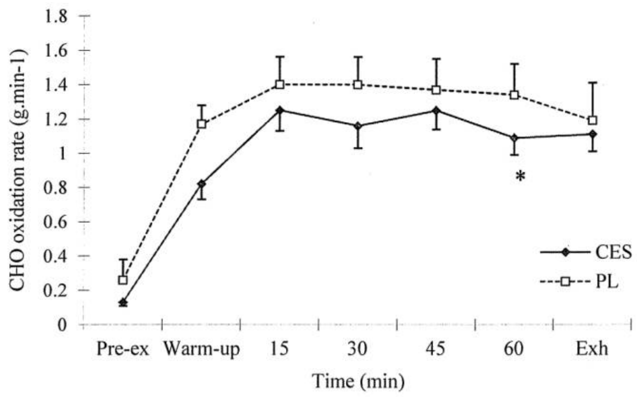
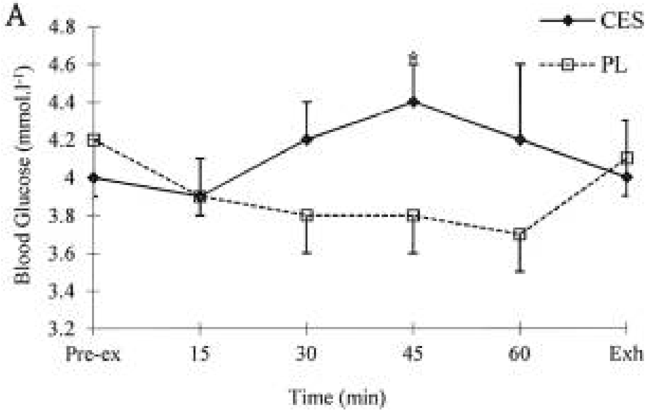
Type of Carbohydrate	Glycemic Index
Sugar Alcohols (e.g., mannitol, erythritol, lactitol, sorbitol, isomalt, xylitol)	0-15
Fructose	19
Galactose	20
Isomaltulose	32
Lactose	46
Honey	55
Trehalose	67
Sucrose	68
Dextrose	93
Glucose	99
Maltose	105
Maltodextrin	137

- Oxidation rates of sucrose, maltose, and maltodextrins are high while fructose, galactose, trehalose, and isomaltulose are lower.
- Combinations of glucose-sucrose or maltodextrin-fructose have been shown to maximize exogenous carbohydrate utilization during exercise but have short lived effects on blood glucose.
- Adding lower GI carbohydrates like fructose, trehalose, or galactose to a mixture of carbohydrate given prior or during exercise can spare glycogen depletion and have less of an effect on insulin.

Carbohydrate electrolyte solutions enhance endurance capacity in active females *Sun et al. Nutrients. 2015 May; 7(5): 3739–3750.*

- In a DBPCCO manner, 8 healthy active females performed a run to exhaustion at 70% VO_{2Max} on a TM during the follicular phase of their menstrual cycle on two occasions.
- During each run, the subjects consumed either ***3mL/kg of a 6% GES*** or a PLA every 20 min during exercise.
- She subjects ingested similar volumes of fluid in the two trials (GES: 644 ± 75 mL vs. PLA: 593 ± 66 mL, $p > 0.05$).
- The ***time to exhaustion was 16% longer during the GES trial (106.2 ± 9.4 min) than during the PAL trial (91.6 ± 5.9 min) (p < 0.05).***
- At 45 min during exercise, the BG in the GES trial was higher than that in PLA.
- No differences were observed in the plasma lactate level, RER, HR, RPE, sensation of thirst, or abdominal discomfort.





Kerksick et al., JISSN. 15:38, 2018

Exercise & Sports Nutrition Review

Limited or Mixed Evidence to Support Efficacy

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- L-Alanyl-L-Glutamate
- Arachidonic acid
- BCAA
- Citrulline
- Essential amino acids (EAA)
- Glycerol
- HMB
- Nitrates
- Post-exercise CHO and PRO
- Quercetin
- Taurine

Kerksick et al., JISSN. 15:38, 2018

The effects of amino acid supplementation on hormonal responses to resistance training overreaching *Kraemer et al. Metabolism. 55(3):282-91, 2006*

- 17 RT men were randomly assigned to either an amino acid (AA) or a placebo (P) group and underwent 4 weeks of total-body RT designed to induce a state of overreaching.
- The protocol consisted of two 2-week phases (phase 1, 3 sets of 8 exercises performed for 8-12 repetitions; phase 2, 5 sets of 5 exercises performed for 3-5 repetitions).
- Muscle strength and resting blood samples were determined before (T1) and at the end of each training week (T2-T5).
- ***AA supplementation attenuated muscle strength loss during initial high-volume stress, possibly by reducing muscle damage by maintaining an anabolic environment.***

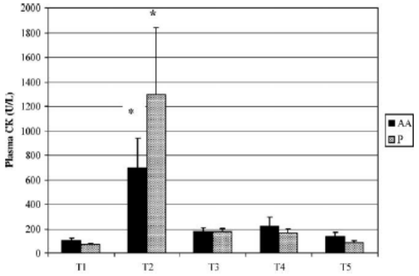


Fig. 1. Resting serum CK concentrations during 4 weeks of resistance training overreaching. Data presented are means ± SEM. *P < .05 from corresponding point T1.

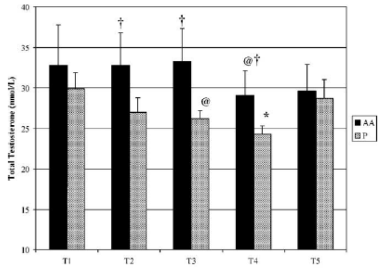


Fig. 2. Resting serum total testosterone concentrations during 4 weeks of resistance training overreaching. †P < .05 from corresponding value for P group. Data presented are means ± SEM. *P < .05 from corresponding point T1. @P = .08 from corresponding time point T1.

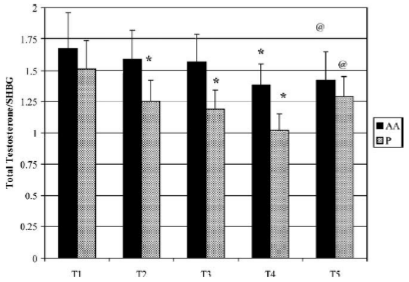


Fig. 4. Resting ratio of total testosterone to SHBG concentrations during 4 weeks of resistance training overreaching. Data presented are means ± SEM. *P < .05 from corresponding point T1. @P = .07 from corresponding time point T1.

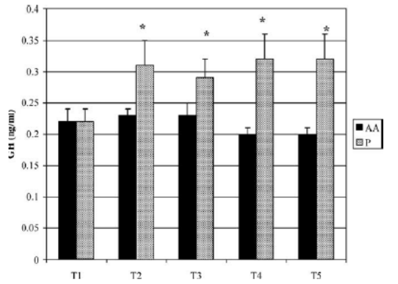
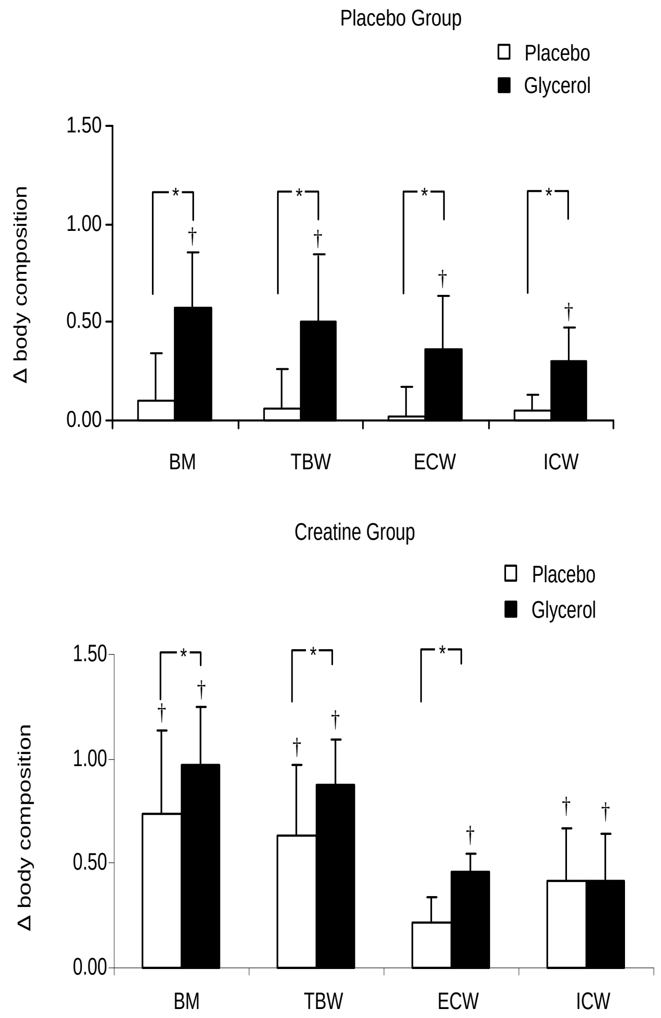


Fig. 5. Resting serum 22-kd GH concentrations during 4 weeks of resistance training overreaching. Data presented are means ± SEM. *P < .05 from corresponding point T1.

Creatine and glycerol hyperhydration in trained subjects before exercise in the heat *Easton et al. Int J Sport Nutr Exerc Metab. 17(1):70-91, 2007.*

- 24 subjects ingested 11.4 g/d of CrM or placebo (PLA) twice daily for 7-d with and without 1 g of Gly/kg (twice daily)
- Exercise trials were conducted pre- and post-supplementation at 30°C and 70% RH.
- In the Pl group, total body water (TBW) increased by 0.50 +/- 0.28 L after Gly and in the Cr group by 0.63 +/- 0.33 L after Pl and by 0.87 +/- 0.21 L after Gly.
- Both Cr/Pl and Cr/Gly resulted in significantly attenuated heart rate, rectal temperature, and perceived effort during exercise, although no regimen had any effect on performance.
- The addition of Gly to Cr significantly increased TBW more than Cr alone (P=0.02) but did not further enhance the attenuation in HR, Tre, and RPE during exercise.
- These data suggest that combined Cr and Gly is an effective method of hyperhydration capable of reducing thermal and cardiovascular responses.



The effects of beta alanine plus creatine administration on performance during repeated bouts of supramaximal exercise in sedentary men

Okudan et al. J Sports Med Phys Fitness 55(11):1322-8, 2015

- 44 untrained men were assigned to one of four treatment groups randomly:
  - P (10 g maltodextrose)
  - Cr (5 g creatine plus 5 g maltodextrose);
  - BA (1,6 g BA plus 8.4 g maltodextrose); or,
  - BA + Cr (,6 g BA + 5 g creatine plus 3.4 g maltodextrose).
- Supplements were taken twice a day for 22 days, then four times a day for the following 6 days.
- Prior to and following 28 days, peak power (PP), mean power (MP), and fatigue index (FI) was determined.
- PP increased in the Cr (from 642.7+/-148.6 to 825.1+/-205.2 in PP2 and from 522.9+/-117.5 to 683.0+/-148.0 in PP3, respectively). MP was increased in BA+Cr
- ***BA and BA+Cr have strong performance enhancing effect by increasing mean power and delaying fatigue Index during the repeated WAnT*.**

Beet Root Juices / Nitrates

- Dietary intake of food or juices with high nitrate levels has been reported to promote healthy blood pressure due to a vasodilatory effect
- Studies show consuming BRJ prior to exercise (e.g., 300-500 ml) improves aerobic endurance efficiency
- Some studies suggest nitrate supplementation can also enhance intermittent exercise performance and/or recovery

Beet Root Juice/Nitrates

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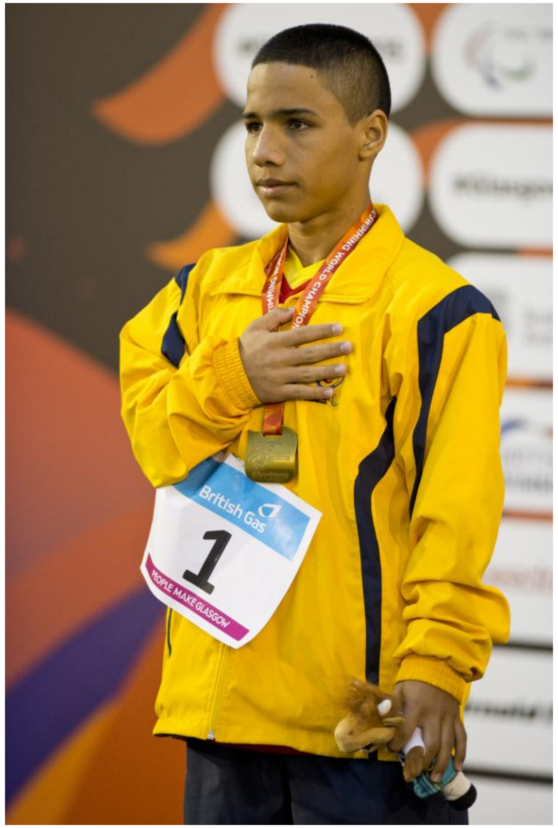
- Larsen et al. (*Acta physiologica. 2007;191:59–66*) reported a ***reduction in maximal oxygen consumption***; and a trend for improvement in time-to-exhaustion accompanying the ingestion of sodium nitrate intake at 0.1 mmol/kg/day for three days.
- Larsen et al. (*Free Radic Biol Med. 2010;48:342–7*) reported a *significant reduction in oxygen consumption and improvement in gross efficiency at sub-maximal workloads* using the same ingestion schema.
- Bescos et al., (*Med Sci Sports Exerc. 2011;43:1979–86*) found that the consumption of 10 mg/kg of sodium nitrate prior to a cycle ergometer test ***reduced VO_2peak without influencing time to exhaustion or maximal power output in highly trained cyclist and triathletes.***



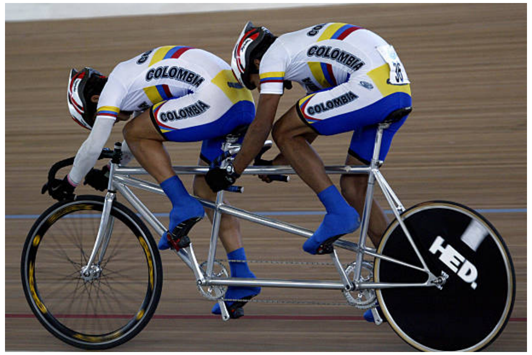
Inorganic nitrate supplementation improves muscle oxygenation, O(2) uptake kinetics, and exercise tolerance at high but not low pedal rates

Bailey et al. J Appl Physiol. 118(11):1396-405, 2015

- 7 subjects completed ***severe-intensity step cycle tests at pedal cadences of 35 rpm and 115 rpm*** during separate 9-d supplementation periods with NO_3- rich beetroot juice (BR) (providing 8.4 mmol NO_3-/d) and PLA.
- Compared with PLA, ***plasma nitrite concentration increased 178% with BR*** ($P < 0.01$).
- There were no significant differences in muscle oxyhemoglobin concentration ([O_2Hb]), phase II Vo_2 kinetics, or Tlim between BR and PLA when cycling at 35 rpm ($P > 0.05$).
- ***When cycling at 115 rpm, muscle [O_2Hb] was higher at baseline and throughout exercise, phase II Vo_2 kinetics was faster*** (47 +/- 16 s vs. 61 +/- 25 s; $P < 0.05$), and ***Tlim was greater*** (362 +/- 137 s vs. 297 +/- 79 s; $P < 0.05$) with BR compared with PLA.
- Results suggest that ***short-term BR supplementation can increase muscle oxygenation, expedite the adjustment of oxidative metabolism, and enhance exercise tolerance when cycling at a high, but not a low, pedal cadence.***

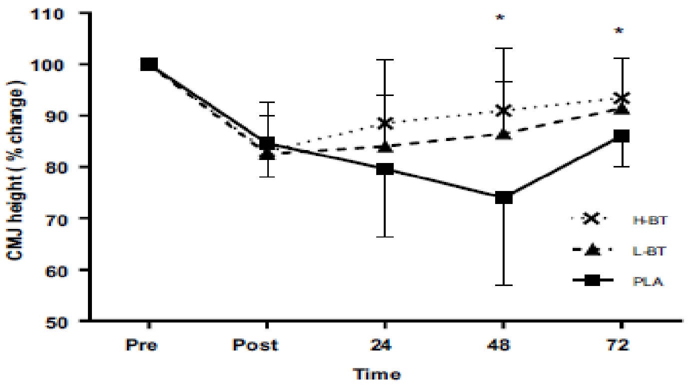
Nitrate intake promotes shift in muscle fiber type composition during sprint interval training in hypoxia *De Smet et al. Front Physiol. 7: 233, 2016*

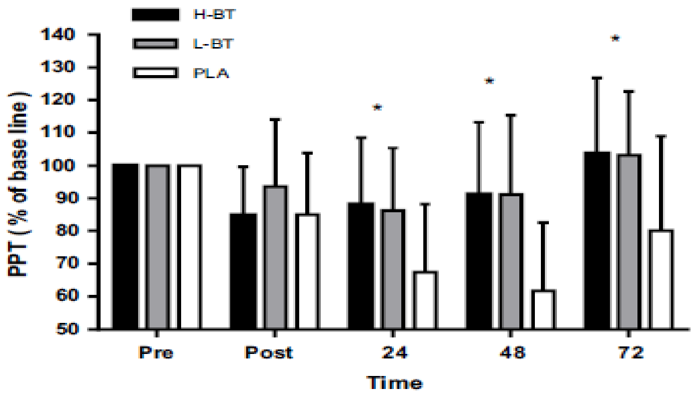
- ***27 moderately-trained participants*** were allocated to one of three experimental groups: ***Sprint Interval Training (SIT) in normoxia (20.9% FiO_2) + PLA (N), SIT in hypoxia (15% FiO_2) + PLA (H), or SIT in hypoxia + nitrate (HN).***
- All participated in 5 weeks of SIT on a cycle ergometer (30-s sprints interspersed by 4.5 min recovery-intervals, 3 weekly sessions, 4-6 sprints per session).
- Nitrate (6.45 mmol $NaNO_3$) or placebo capsules were administered ***3 h before each session***.
- SIT decreased the proportion of type IIx muscle fibers in all groups ($P < 0.05$).
- The relative number of type IIa fibers increased ($P < 0.05$) in HN ($P < 0.05$ vs. H), but not in the other groups.
- Compared with H, SIT tended to enhance 30-s sprint performance more in HN than in H ($P = 0.085$).
- ***SIT in hypoxia combined with nitrate supplementation increases the proportion of type IIa fibers in muscle, which may be associated with enhanced performance in short maximal exercise.***



The effects of beetroot juice supplementation on indices of muscle damage following eccentric exercise *Clifford et al. EJAP. 116(2): 2016*

- 30 males consumed ***high-dose BRJ (H-BT; 250 ml), a lower dose of BRJ (L-BT; 125 ml), or PLA immediately (x3 servings), 24 (x2 servings) and 48 h (x2 servings) following completion of 100-drop jumps.***
- Maximal isometric voluntary contractions (MIVC), countermovement jumps (CMJ), pressure pain threshold (PPT), creatine kinase (CK), interleukin-6 (IL-6), interleukin-8 (IL-8) and tumor necrosis factor-alpha (TNF-alpha) were measured pre, post, 2 (blood indices only), 24, 48 and 72 h following the drop jumps.
- ***Acute BRJ supplementation attenuated muscle soreness and decrements in CMJ performance induced by eccentric exercise*** while MIVC, CK, IL-6, TNF-alpha and IL-8 were not affected.



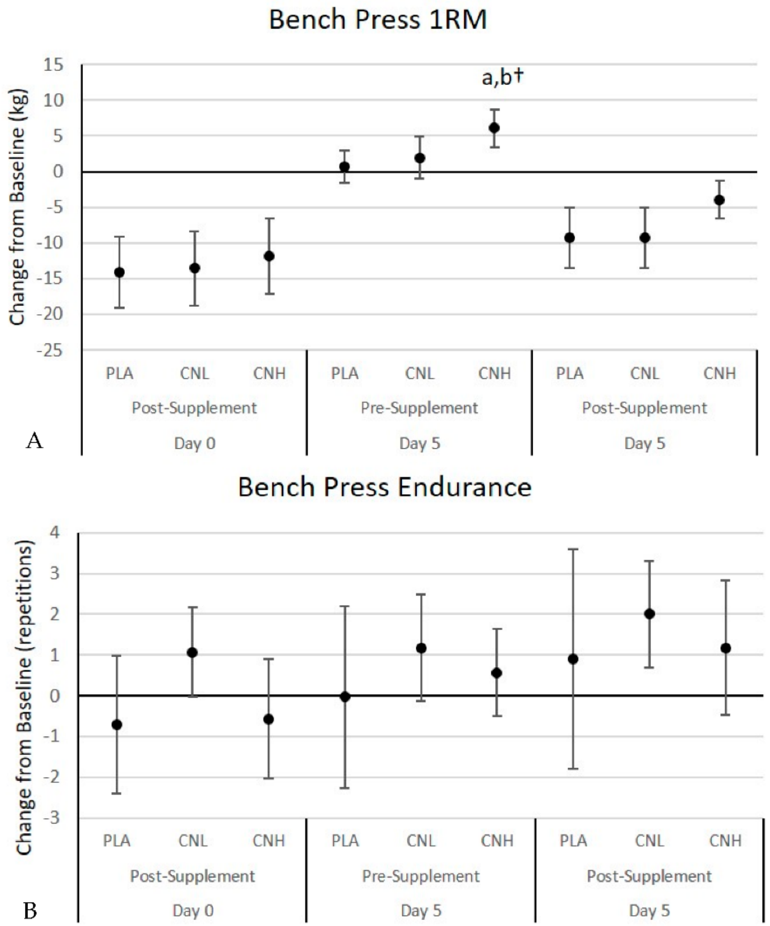


Ingestion of a nitric oxide enhancing supplement improves resistance exercise performance *Mosher et al. J Strength Cond Res. e-pub, April 2, 2016*

- 12 resistance trained males ingested either ***70 ml of "BEET It Sport" nitrate shot containing 6.4 millimoles (mmol/L) or 400 mg of nitrate; or a blackcurrant placebo drink.***
- Participants completed a resistance exercise session, consisting of bench press exercise at an intensity of 60% of their established 1 repetition maximum (1-RM), for three sets until failure with 2 minute rest interval between sets.
- ***Results showed a significant difference in repetitions to failure ($p < 0.001$) and total weight lifted ($p < 0.001$).***
- No significant differences were seen in lactate, local, or general indicators of fatigue.
- ***Nitrate supplementation before exercise improved resistance training performance and work output.***

Hematological and Hemodynamic Responses to Acute and Short-Term Creatine Nitrate Supplementation *Dalton et al. Nutrients. 9(12):1359, 2017*

- 28 men and women ingested a PLA, 3 g of creatine nitrate (CNL), and 6 g of creatine nitrate (CNH) for 6-d in a repeated measures crossover manner with a 7-d washout.
- Hemodynamic responses to a postural challenge, fasting blood samples, and bench press, leg press, and cycling time trial performance and recovery were assessed
- No significant differences were found among treatments for hemodynamic responses, clinical blood markers or self-reported side effects.
- After 5-d of supplementation, *1RM BP improved significantly for CNH (6.1 [3.5, 8.7] kg)* but not PLA (0.7 [−1.6, 3.0] kg or CNL (2.0 [−0.9, 4.9] kg, CNH, $p = 0.01$).
- CNL treatment promoted an increase in BP repetitions at 70% of 1RM during recovery on day 5 (PLA: 0.4 [−0.8, 1.6], CNL: 0.9 [0.35, 1.5], CNH: 0.5 [−0.2, 0.3], $p = 0.56$), greater LP endurance prior to supplementation on day 5 (PLA: −0.2 [−1.6, 1.2], CNL: 0.9 [0.2, 1.6], CNH: 0.2 [−0.5, 0.9], $p = 0.25$) and greater LP endurance during recovery on day 5 (PLA: −0.03 [−1.2, 1.1], CNL: 1.1 [0.3, 1.9], CNH: 0.4 [−0.4, 1.2], $p = 0.23$).
- Cycling time trial performance (4 km) was not affected.
- ***Benefits related to nitrate supplementation.***



The effects of nitrate-rich supplementation on neuromuscular efficiency during heavy resistance exercise *Flanagan et al. J Am Coll Nutr. 35(2):100-7, 2016*

- ***14 resistance-trained men consumed an nitrate-rich (NR) or nitrate-poor (NP) supplement for 3 d, performed a bout of heavy resistance exercise, completed a washout, and then repeated the procedures with the remaining supplement***.
- Before, during, and after exercise, individual and gross motor unit efficiency was assessed during isometric and dynamic muscle contractions and physical performance, heart rate, lactate, and oxygen consumption (VO_2) were determined.
- ***NR lowered initial muscle firing rates at rest and lower mean and maximum firing rates over the course of fatiguing exercise.***
- NP was accompanied by increased mean and maximum firing rates by the end of exercise and lower initial firing rates.
- Nitrate supplementation resulted in higher mean peak electromyography (EMG) amplitudes.
- ***Supplementation with an NR beetroot extract-based supplement provided neuromuscular advantages during metabolically taxing resistance exercise.***

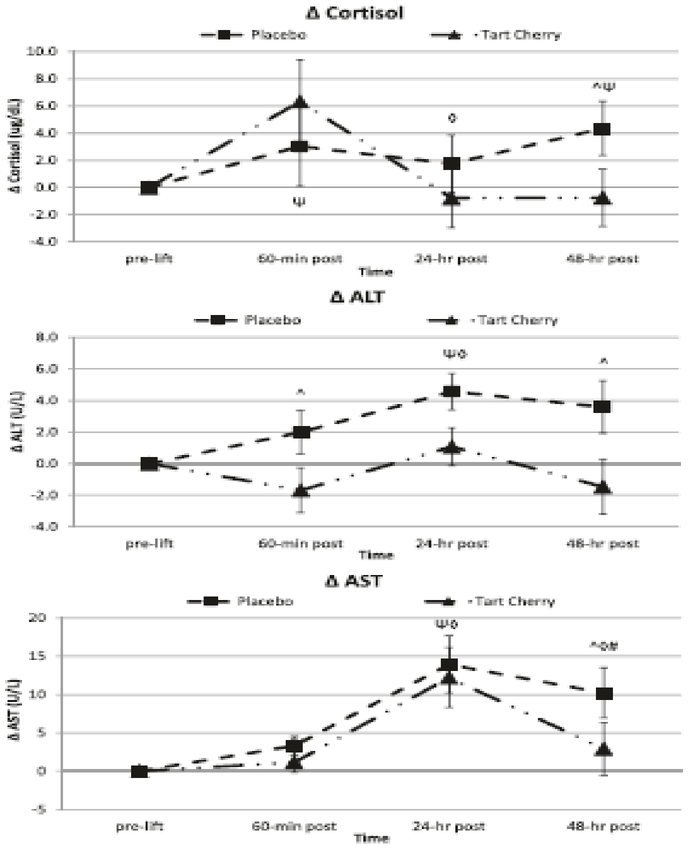
Montmorency Tart Cherries

- Consumption of foods high in polyphenols, particularly anthocyanins, have been associated with improved health
- Tart cherry juice and powders have antioxidant properties and is thought to activate antioxidant response genes.
- Use of tart cherry juice/concentrates theorized to reduce exercise-induced oxidative stress and muscle damage.
- Some evidence of improved weight loss in animals
- Long-term supplementation theorized to enhance recovery and training tolerance

Effects of powdered Montmorency tart cherry supplementation on an acute bout of intense lower body strength exercise in resistance trained males

Levers et al. JISSN. 12:41, 2015

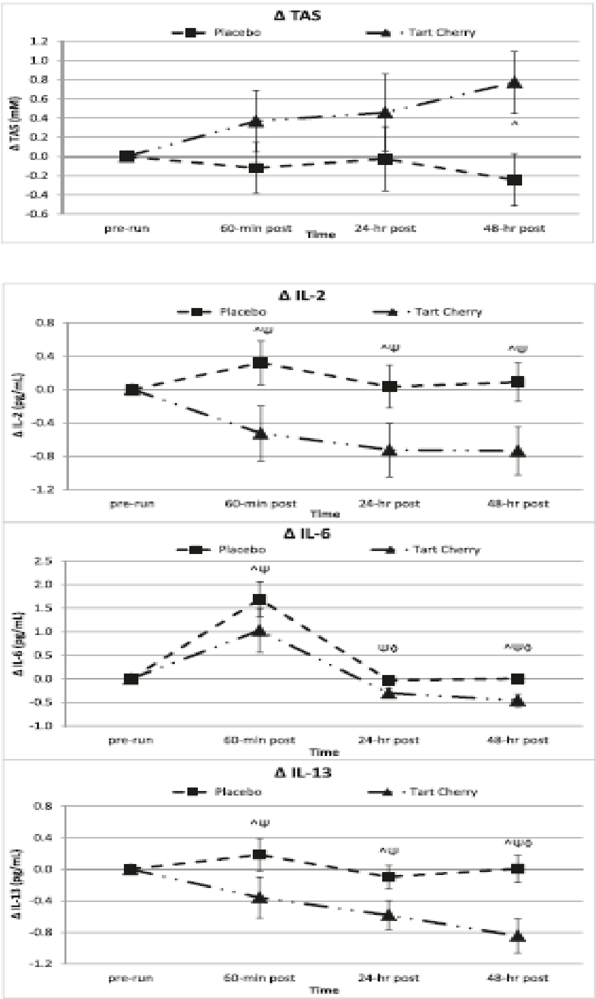
- 23 resistance-trained men were randomly assigned to ingest, in a double blind manner, capsules containing 480 mg/d of a PL or powdered tart cherries (TC) for 10-d prior to and for 48-h post-exercise.
- Subjects performed 10 sets of 10 reps at 70% of a 1-RM back squat exercise after 10-d of supplementation.
- Fasting blood samples, isokinetic MVCs, and quadriceps muscle soreness ratings were taken pre-lift, 60-min, 24-h, and 48-h post-lift.
- ***TC supplementation attenuated muscle soreness, strength decrement during recovery, and markers of muscle catabolism in resistance trained individuals.***



Effects of powdered Montmorency tart cherry supplementation on acute endurance exercise performance in aerobically trained individuals

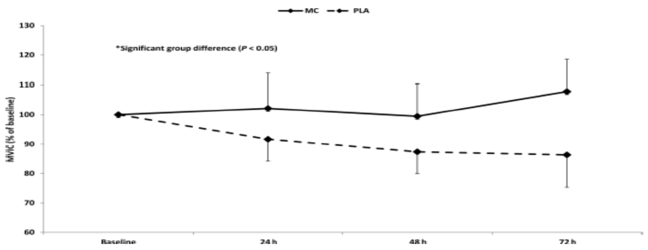
Levers et al. JISSN. 13:22, 2016

- 27 endurance-trained athletes ingested, in a double-blind manner, capsules containing 480 mg of PL or powdered TC for 10-d prior to performing a half marathon and for 48-hr post-run.
- Fasting blood samples and quadriceps muscle soreness ratings were taken pre-run, 60-min, 24 and 48-h post-run.
- ***TC supplementation attenuated markers of muscle catabolism, reduced immune and inflammatory stress, better maintained redox balance, and increased performance in aerobically trained individuals.***



Recovery facilitation with Montmorency cherries following high-intensity, metabolically challenging exercise *Bell et al. Appl Physiol Nutr Metab. 40(4):414-23, 2015*

- 16 trained cyclists consumed 30 mL of PL or MC twice per day for 8-d.
- On day 5. participants completed a 109-min cycling trial designed to replicate road race demands.
- Functional performance (MVIC) cycling efficiency, 6-s peak cycling power) and DOM were assessed at baseline, 24, 48, and 72 h post-trial.
- Blood samples collected at baseline, immediately pre- and post-trial, and at 1, 3, 5, 24, 48, and 72 h post-trial.
- MVIC (P < 0.05) did not decline in the MC group (vs. PLA) across the 72-h post-trial period and economy (P < 0.05) was improved in the MC group at 24 h.
- IL-6 (P < 0.001) and hsCRP (P < 0.05) responses to the trial were attenuated with MC (vs. PLA).
- ***MC concentrate can be an efficacious functional food for accelerating recovery and reducing exercise-induced inflammation following strenuous cycling exercise..***



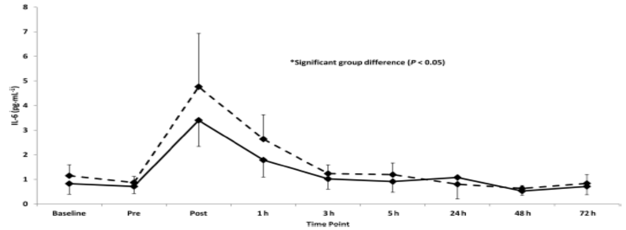
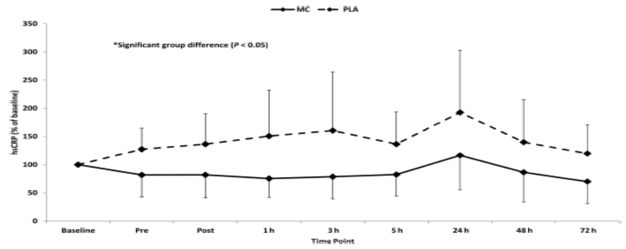


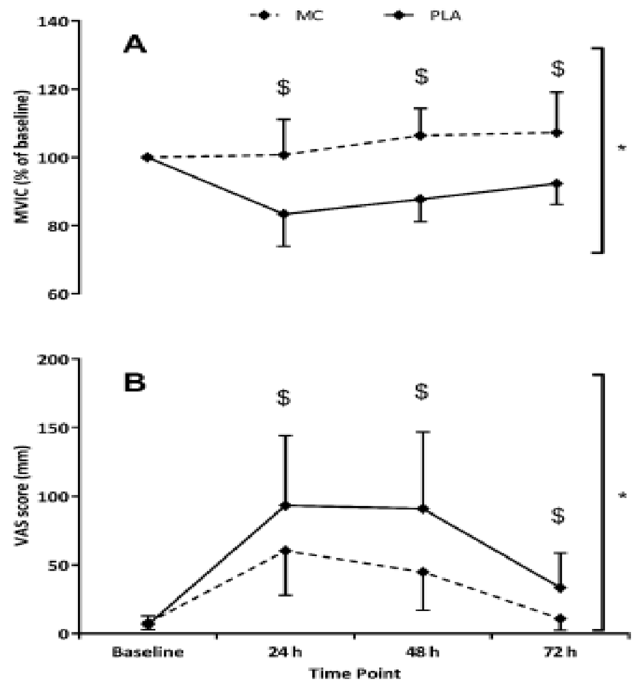
Fig. 5. High-sensitivity C-reactive protein (hsCRP) responses (% of baseline) to Montmorency cherry concentrate (MC) and isoenergetic placebo (PLA). *, Significant group effect (P < 0.05); values are means ± SD.



The effects of Montmorency tart cherry concentrate supplementation on recovery following prolonged, intermittent exercise

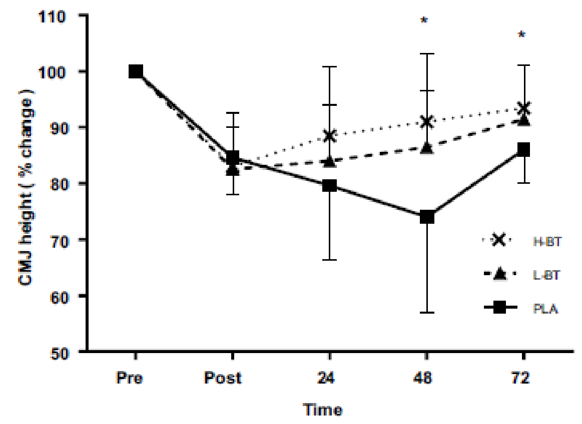
Bell et al. Nutrients. (7): 2016

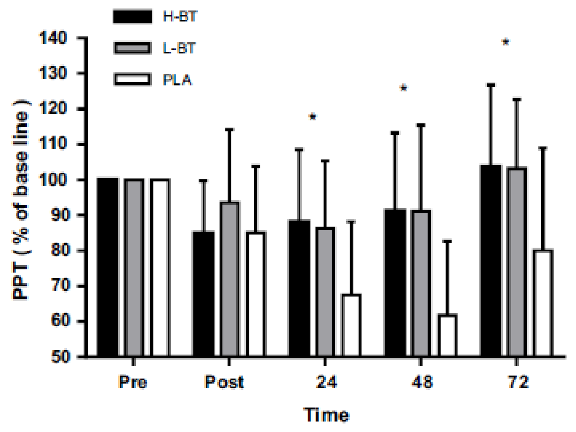
- 16 semi-professional, male soccer players consumed either MC or PLA supplements for 8-d (30 mL x 2/d).
- On day 5, participants completed an adapted version of the Loughborough Intermittent Shuttle Test (LISTADAPT).
- MVIC, 20 m Sprint, counter movement jump (CMJ), agility and muscle soreness (DOMS) were assessed at baseline, and 24, 48 and 72 h post-exercise while measures of inflammation (IL-1-beta, IL-6, IL-8, TNF-alpha, hsCRP), muscle damage (CK) and oxidative stress (LOOH) were analyzed at baseline and 1, 3, 5, 24, 48 and 72 h post-exercise.
- Performance indices (MVIC, CMJ and agility) recovered faster and muscle soreness (DOMS) ratings were lower in the MC group ($p < 0.05$).
- Acute inflammatory response (IL-6) was attenuated by MC.
- ***MC is efficacious in accelerating recovery following prolonged, repeat sprint activity, such as soccer and rugby.***



The effects of beetroot juice supplementation on indices of muscle damage following eccentric exercise *Clifford et al. EJAP. 116(2): 2016*

- 30 males consumed high-dose BRJ (H-BT; 250 ml), a lower dose of BRJ (L-BT; 125 ml), or PLA immediately (x3 servings), 24 (x2 servings) and 48 h (x2 servings) following completion of 100-drop jumps.
- Maximal isometric voluntary contractions (MIVC), countermovement jumps (CMJ), pressure pain threshold (PPT), creatine kinase (CK), interleukin-6 (IL-6), interleukin-8 (IL-8) and tumour necrosis factor-alpha (TNF-alpha) were measured pre, post, 2 (blood indices only), 24, 48 and 72 h following the drop jumps.
- Acute BRJ supplementation attenuated muscle soreness and decrements in CMJ performance induced by eccentric exercise while MIVC, CK, IL-6, TNF-alpha and IL-8 were not affected.





Exercise & Sports Nutrition Review

Little to No Evidence to Support Efficacy and/or Safety

- Arginine
- Carnitine
- Glutamine
- Inosine
- MCTs
- Ribose

Kerksick et al., JISSN. 15:38, 2018

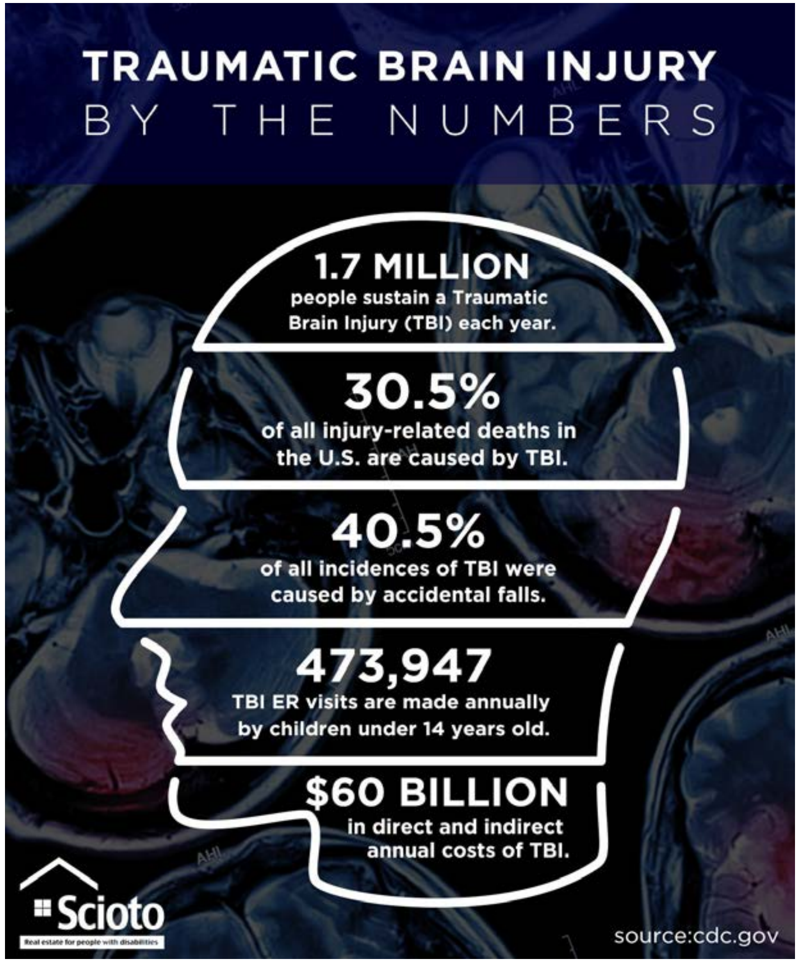
Recovery Nutrition

international society of sports nutrition
The ISSN – Why Go Anywhere Else?!

- Rehydrate
- Replenish Glycogen
- Promote Anabolism and Reduce Catabolism
- Manage Inflammation
- Support the Immune System
- Pre-Sleep Nutrition

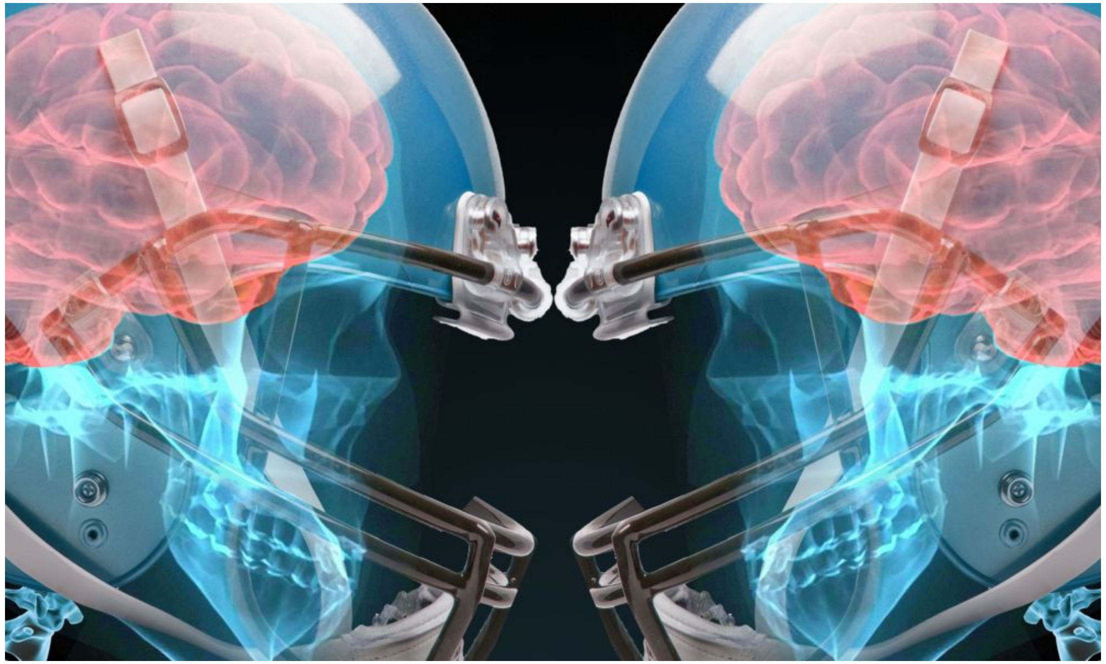
Neuroprotection

- TBI, concussion & CTE are significant concerns in sport.
- Sports-related concussions (SRC) or mild TBI are generally more related to blunt force trauma as a result of blows to the head that cause short-term impairment and incrementally greater damage with reoccurrence.
- Individuals who experience a SRC are more susceptible for subsequent and more serious concussions that can often end an athletic career.
- Exposure to repetitive head trauma over time has been associated with Chronic Traumatic Encephalopathy (CTE), neurodegenerative disease, and suicide.



Nutritional Interventions

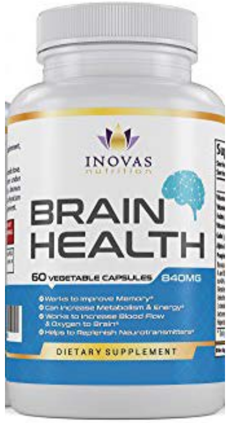
- Increase energy capacity to handle ischemia/injury
- Reduce oxidative stress
- Reduce inflammation
- Maintain cell integrity

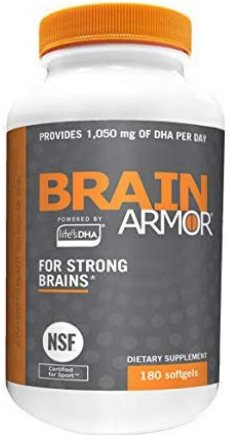


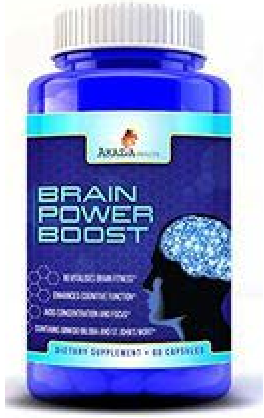
Nutritional Interventions

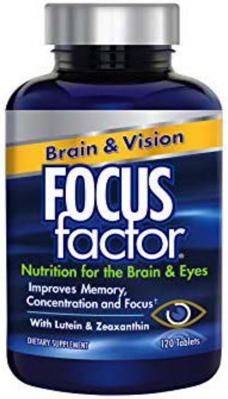
- Creatine
- Citicoline
- Omega 3-Fatty Acids
- Natural Antioxidants
- Natural Anti-inflammatories

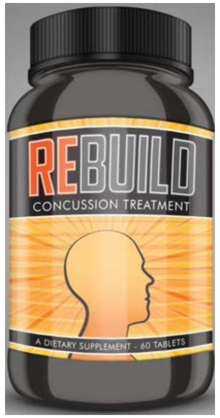
Nutrition & Functional Food Opportunities











Performance Enhancement Nutrition

Summary

- ***Strength/Power/Sprint Athletes***
  - Moderate to High CHO/PRO diet
  - Water/GES
  - Post-Exercise PRO
  - Creatine
  - β-alanine
  - Sodium Bicarbonate
  - Nitrates (Beet Root Juice)
- ***Endurance Athletes***
  - High CHO diet/CHO loading
  - Water/GES
  - Caffeine
  - Sodium Phosphate
  - Nitrates (Beet Root Juice)
  - Creatine
- ***Recovery Nutrition***
  - Rehydrate
  - Carbohydrate
  - Post-Exercise PRO/EAA
  - Creatine
  - Tart Cherry
  - Omega-3 Fatty Acids
- ***Neuroprotection***
  - Creatine
  - Citicoline
  - Omega-3 Fatty Acids
  - Natural Antioxidants
  - Natural Anti-inflammatories

The State of the Science in Sport Nutrition

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Disclosures: Receive industry sponsored research grants and serve as a scientific and legal consultant.