Nutritional Strategies to Optimize Performance



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HEALTH & KINESIOLOGY
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Dedicated to evaluating the interaction between exercise and nutrition on health, disease, and human performance

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ESNL Research

- Endurance / Overtraining
- Ergogenic Aids
  - Carbohydrate
  - Inosine
  - Phosphate
  - BCAA/glutamine
  - Creatine
  - HMB
  - Calcium Pyruvate
  - CLA
  - Protein/EAA
  - CHO Gels (Honey)
  - Ribose
  - Green Tea / Caffeine
  - Meal Timing
  - Colostrums
  - D-Pinitol
  - Coleus Forskohlii
  - ZMA
  - Methoxyisoflavones
  - Ecdysterones
  - Sulfo-Polysaccharides "Myostatin Inhibitor"
  - Calcium
  - Glucosamine and Chondroitin
  - Aromatase Inhibitors
  - BCAA, CHO, Leucine – Protein Synthesis
  - Melatonin
  - Arachidonic Acid
  - Novel Milk Peptides
  - CoQ10
  - Soy Protein
  - Beta Alanine
  - Russian Tarragon
  - Creatine Forms
  - Acai Juice
  - Tart Cherry Powder
  - Pre-workout Supplements
- Weight Loss & Maintenance

Exercise & Sport Nutrition

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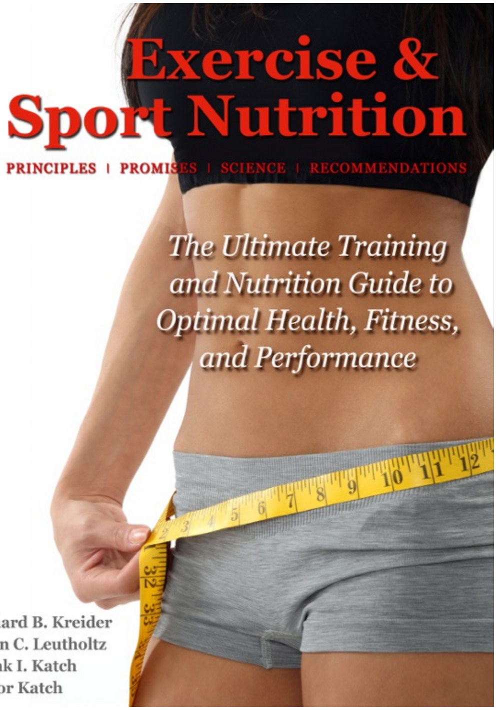

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Review

Highly accessed Open Access

ISSN exercise & sports nutrition review: research & recommendations

Richard B Kreider, Colin D Wilborn, Lem Taylor, Bill Campbell, Anthony L Almada, Rick Collins, Mathew Cooke, Conrad P Earnest, Mike Greenwood, Douglas S Kalman, Chad M Kerksick, Susan M Kleiner, Brian Leutholtz, Hector Lopez, Lonnie M Lowery, Ron Mendel, Abbie Smith, Marie Spano, Robert Wildman, Darryn S Willoughby, Tim N Ziegenfuss and **Jose Antonio**

Journal of the International Society of Sports Nutrition 2010, **7**:7 doi:10.1186/1550-2783-7-7

Published: 2 February 2010

Abstract (provisional)

Sports nutrition is a constantly evolving field with hundreds of research papers published annually. For this reason, keeping up to date with the literature is often difficult. This paper is a five year update of the sports nutrition review article published as the lead paper to launch the JISSN in 2004 and presents a well-referenced overview of the current state of the science related to how to optimize training and athletic performance through nutrition. More specifically, this paper provides an overview of: 1.) The definitional category of ergogenic aids and dietary supplements; 2.) How dietary supplements are legally regulated; 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 the ergogenic value of nutrition and dietary supplementation in regards to weight gain, weight loss, and performance enhancement. Our hope is that ISSN members and individuals interested in sports nutrition find this review useful in their daily practice and consultation with their clients.

The complete article is available as a provisional PDF. The fully formatted PDF and HTML versions are in production.

Journal of the International Society of Sports Nutrition
Volume 7

Viewing options:
- **Abstract**
- PDF (534KB)

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Ergogenic Aid

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

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Ergogenic Aid

Analysis

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- Does the theory make sense?
- Is there any scientific evidence supporting the ergogenic value?
- Is it legal and/or safe?

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Ergogenic Aids

Scientific Evidence?

- Studies on athletes or trained subjects?
- Employed a double blind, repeated measures, placebo controlled, randomized clinical design?
- Appropriate statistical interpretation?
- Do claims match results?
- Data presented at reputable scientific meeting and/or published in peer-reviewed journal?
- Results replicated by others?
- Disclosures and competing interest declared?

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Ergogenic Aids

Categories

I. ***Apparently Effective*.** Supplements that help meet general caloric needs and/or the majority of research studies show is effective and safe.
II. ***Possibly Effective*.** Supplements with initial studies supporting the theoretical rationale but requiring more research.
III. ***Too Early To Tell*.** Supplements with sensible theory but lacking sufficient research to support its current use.
IV. ***Apparently Ineffective*.** Supplements that lack a sound scientific rationale and/or research has clearly shown to be ineffective.

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What are 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 50 – 80 kcals/kg/day (2,500 – 8,000 kcals/day for a 50 – 100 kg athlete)
- ***Elite Athletes*** (e.g., 3-6 hrs/d; 5-6 d/wk)
  - 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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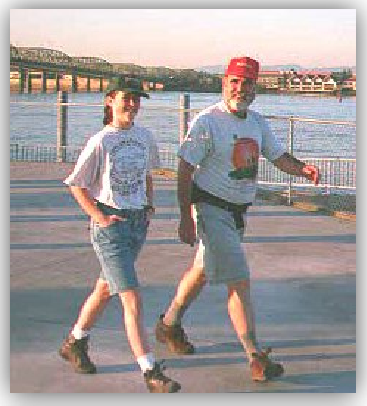

- Diet focused on goals (maintenance, weight gain, weight loss)
- **Carbohydrate** (45%-55% of calories)
  - 3 – 5 g/kg/d
- **Protein** (10-15% of calories)
  - 0.8 – 1.0 g/kg/d (younger)
  - 1.0 – 1.2 g/kg/d (older)
- **Fat** (25-35% of calories)
  - 0.5 – 1.5 g/kg/d
- Make Good Food Choices
- Meal timing can optimize training response

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Nutritional Guidelines

Athletes

- Diet focused on goals (maintenance, weight gain, weight loss)
- **Carbohydrate** (55%-65% of calories)
  - 5 – 8 g/kg/d – moderate training
  - 8 – 10 g/kg/d – heavy training
- **Protein** (15-20% of calories)
  - 1.0 – 1.5 g/kg/d moderate training
  - 1.5 - 2.0 g/kg/d during heavy training
- **Fat** (25-30% of calories)
  - 0.5 – 1.5 g/kg/d
- Meal Timing Important
- Use of energy supplements helpful

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Nutritional Guidelines

Meal 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)
- Carbohydrate loading (2-3 days prior to competition)
  - Taper training by 30%-50%
  - Ingest 200-300 extra grams of CHO

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Vitamins & Minerals

- No clear ergogenic value of vitamin supplementation for athletes who consume a normal, nutrient dense diet.
- Some vitamins may help athletes tolerate training to a greater degree by reducing oxidative damage (Vitamin E, C) and/or help to maintain a healthy immune system during heavy training (Vitamin C).
- Some athletes susceptible to mineral deficiencies in response to training and/or prolonged exercise.
- Supplementation of minerals in deficient athletes has generally been found to improve exercise capacity.
- Some potential benefits reported from iron, sodium phosphate, sodium chloride, and zinc supplementation
- Use of a low-dose daily multivitamin and/or a vitamin enriched post-workout carbohydrate/protein supplement is advisable

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Water

- Most important nutritional ergogenic aid
- Performance can be impaired when ≥ 2% of body weight is lost through sweat.
- Fluid loss of > 4% of body weight during exercise may lead to heat illness, heat exhaustion, heat stroke, and death
- Athletes should ingest 0.5 to 2 L/h (e.g., 6-8 oz of cold water or a GES every 5 to 15-min) to maintain hydration
- Addition of 1 g/L of salt can help maintain hydration in hot & humid environments

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What are the ergogenic value of various nutritional supplements?

Exercise & Sports Nutrition Review

Apparently Effective

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Muscle Building Supplements	Weight Loss Supplements	Performance Enhancement
• Weight gain powders • Creatine • Protein/ EAA • *HMB*	• Low-calorie foods, MRPs, and RTDs • Some thermogenic supplements	• Water and sports drinks • Carbohydrate • Creatine • Sodium phosphate • Sodium bicarbonate • Caffeine • *β-alanine* • *Nitrates (e.g., Beet Root Juice)*

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Exercise & Sports Nutrition Review

Possibly Effective

Muscle Building Supplements	Weight Loss Supplements	Performance Enhancement
• BCAA	• High-fiber diets • Calcium • Green tea & caffeine • CLA	• Post-exercise carbohydrate & protein • EAA • BCAA • HMB • Glycerol

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Exercise & Sports Nutrition Review

Too Early to Tell

Muscle Building Supplements	Weight Loss Supplements	Performance Enhancement
• α-Ketoglutarate • α-Ketoisocaproate • Ecdysterones • Growth hormone releasing peptides and secretogues • Ornithine α-Ketoglutarate • Zinc/magnesium aspartate	• Gymnema sylvestre • Chitosan • Phosphatidl Choline • Betaine • Coleus Forskolin • DHEA • Psychotropic Nutrients/Herbs	• Medium chain triglycerides • Arginine / NO2 • GAKIC

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Exercise & Sports Nutrition Review

Apparently Ineffective

Muscle Building Supplements	Weight Loss Supplements	Performance Enhancement
• Glutamine	• Calcium Pyruvate	• Glutamine
• Smilax	• Chitosan	• Ribose
• Isoflavones	• Chromium (non-diabetics)	• Inosine
• Sulfo-polysaccharides (myostatin inhibitors)	• HCA	
• Boron	• L-Carnitine	
• Chromium	• Phosphates	
• Conjugated linoleic acids	• Herbal diuretics	
• Gamma oryzanol		
• Prohormones		
• Tribulus terrestris		
• Vanadyl sulfate (vanadium)		

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Performance Enhancement Nutrition Strategies

Strength / Power Athletes

Nutrition Strategies

Strength/Power Athletes

– Nutritional Goals
  - Provide CHO & PRO
  - Maintain Hydration
  - Increase power and recovery from high intensity exercise
  - Improve high intensity exercise performance
  - Increase muscle mass

Nutrition Strategies

Strength/Power Athletes

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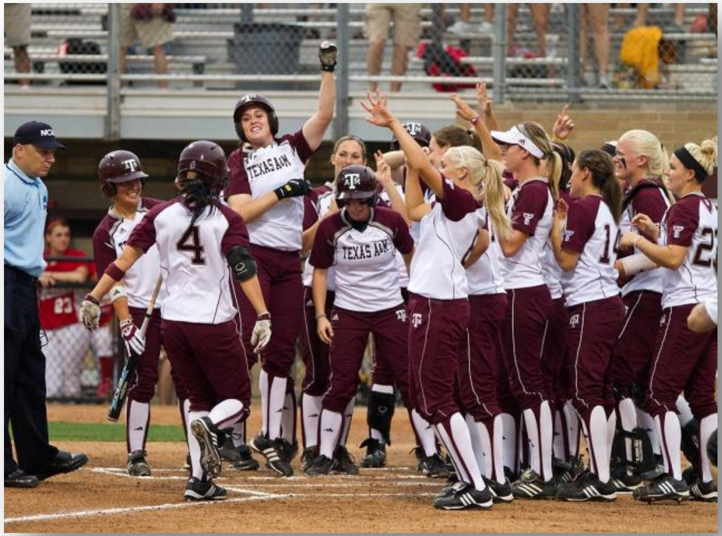

- Nutritional Strategies
  - Moderate to High CHO and PRO diet
  - Water/GES
  - Post-Exercise PRO/EAA
- Ergogenic Aids
  - Creatine
  - β-HMB
  - β-alanine
  - Sodium Bicarbonate

Nutrition Strategies

Strength/Power Athletes

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- Diet focused on goals (maintenance, weight gain, weight loss)
- **Carbohydrate** (40-55% of calories)
  - – 3 – 5 grams/kg/day typically sufficient
- **Protein** (15-30% of calories)
  - – 1.5 – 2.0 grams/kg/day general
  - – 2.0 – 2.25 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

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Essential Amino Acids

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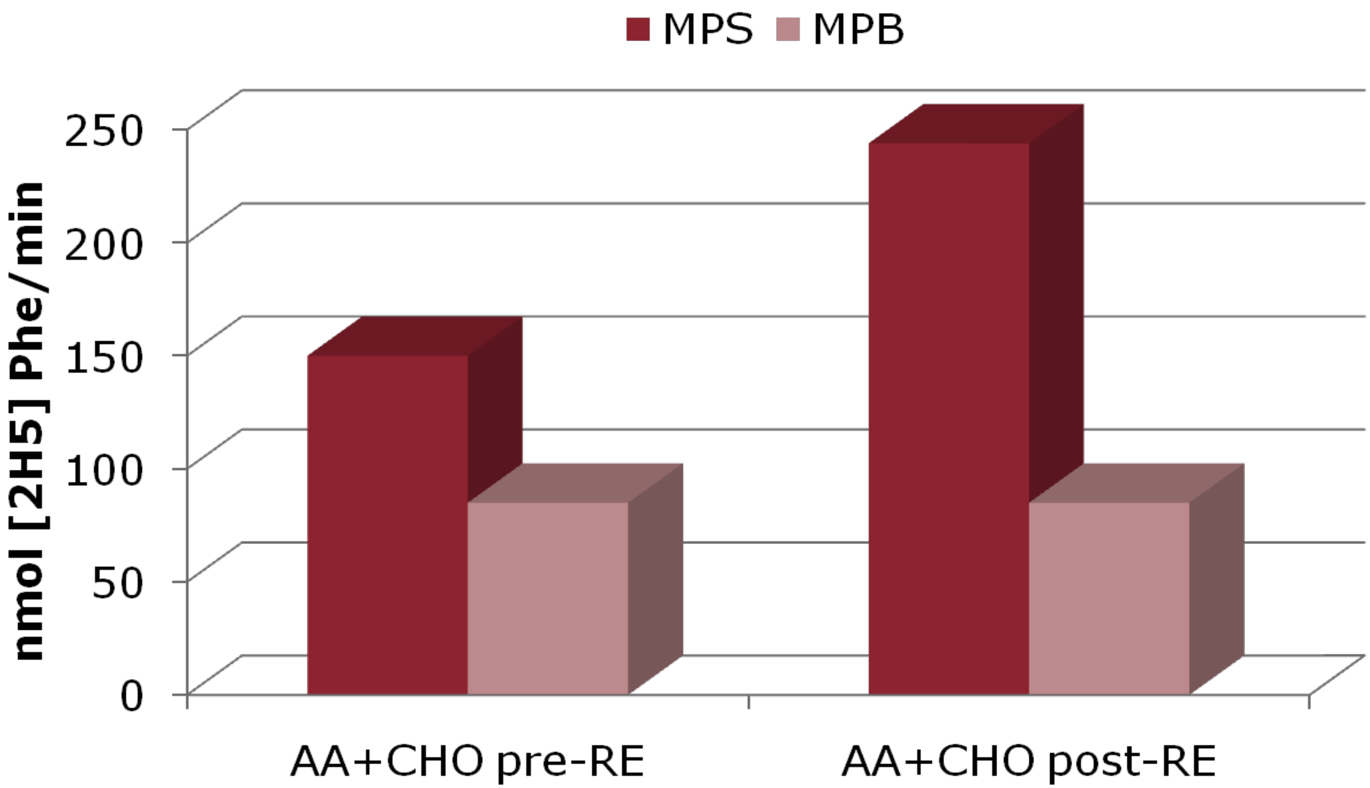
- EAA are amino acids the body is not able to synthesize and must be obtained in the diet.
- Some of these AA have ergogenic potential
- Timing EAA intake can influence muscle protein synthesis (MPS)

***Isoleucine**	**Phenylalanine**
***Leucine**	**Threonine**
Lysine	**Tryptophan**
Methionine	***Valine**

***BCAA**

Effect of Mixed AA & CHO on Protein Turnover

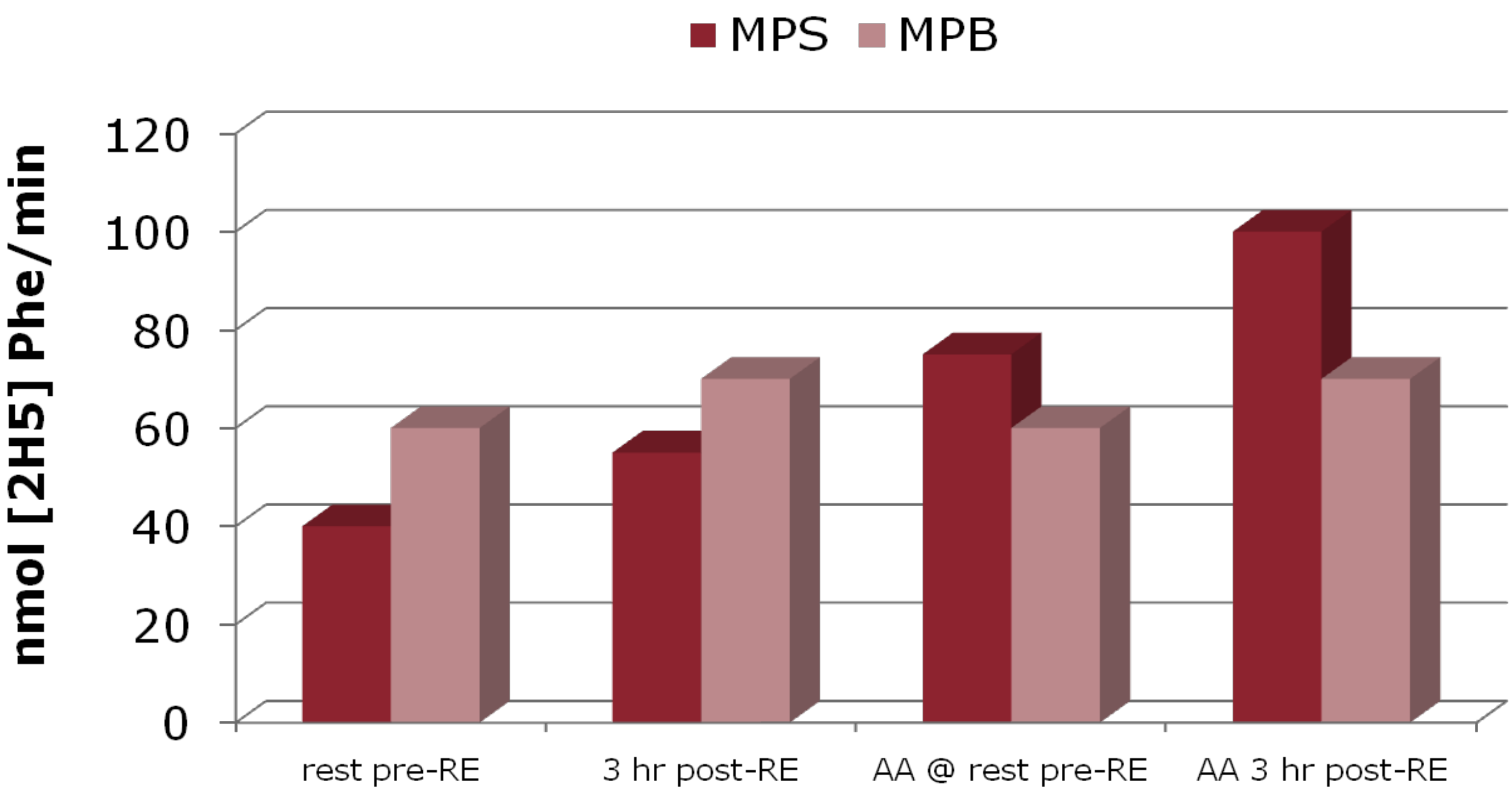
Rasmussen & Phillips. Ex Sport Sci Rev. 31(3): 127-31, 2003



40 grams infused mixed AA + 40 grams infused CHO

Effect of EAA on Protein Turnover

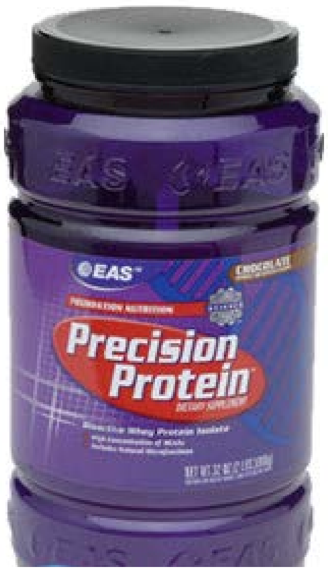
Rasmussen & Phillips. Ex Sport Sci Rev. 31(3): 127-31, 2003



6 grams oral EAA + 35 grams oral CHO

How much EAA is needed to enhance muscle protein synthesis?

- As little at 3 grams of EAA's is enough to significantly increase protein synthesis (*Miller et al. 2003*)
- 6 grams of EAA's appears to be an optimal dose (*Borsheim et al. Am J Physiol. 283:E648-57, 2002*).
- 100 grams of CHO can increase protein synthesis by 35% while 6 grams of EAA's increases protein synthesis by 250% (*Biolo et al. 1997*, *Borsheim et al. 2003*)
- ***20 g of whey protein contains about 9 g of EAA's***



Amino Acids

Apparently Effective

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.***

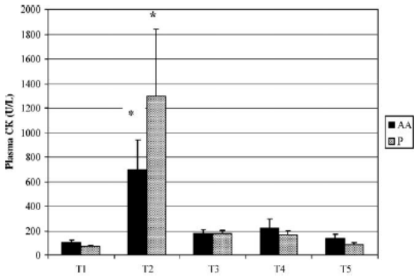


Fig. 1. Resting serum CK concentrations during 4 weeks of resistance training overreaching. Data presented are means ± SEM. *P < .05 from corresponding point T1.

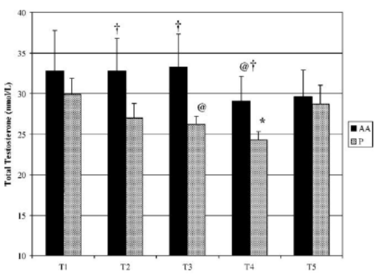


Fig. 2. Resting serum total testosterone concentrations during 4 weeks of resistance training overreaching. †P < .05 from corresponding value for P group. Data presented are means ± SEM. *P < .05 from corresponding point T1. @P = .08 from corresponding time point T1.

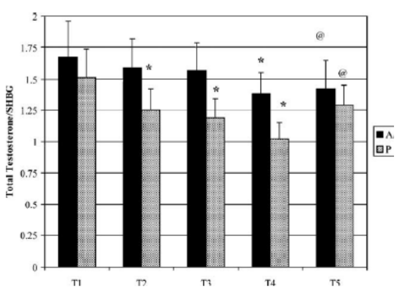


Fig. 4. Resting ratio of total testosterone to SHBG concentrations during weeks of resistance training overreaching. Data presented are means ± SEM. *P < .05 from corresponding point T1. @P = .07 from corresponding time point T1.

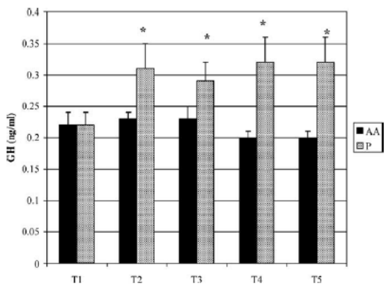
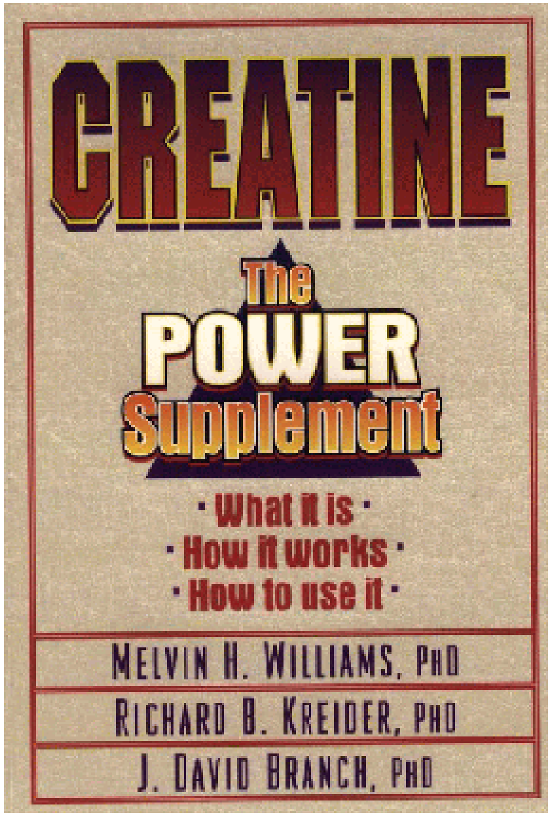


Fig. 5. Resting serum 22-kd GH concentrations during 4 weeks of resistance training overreaching. Data presented are means ± SEM. *P < .05 from corresponding point T1.

Creatine

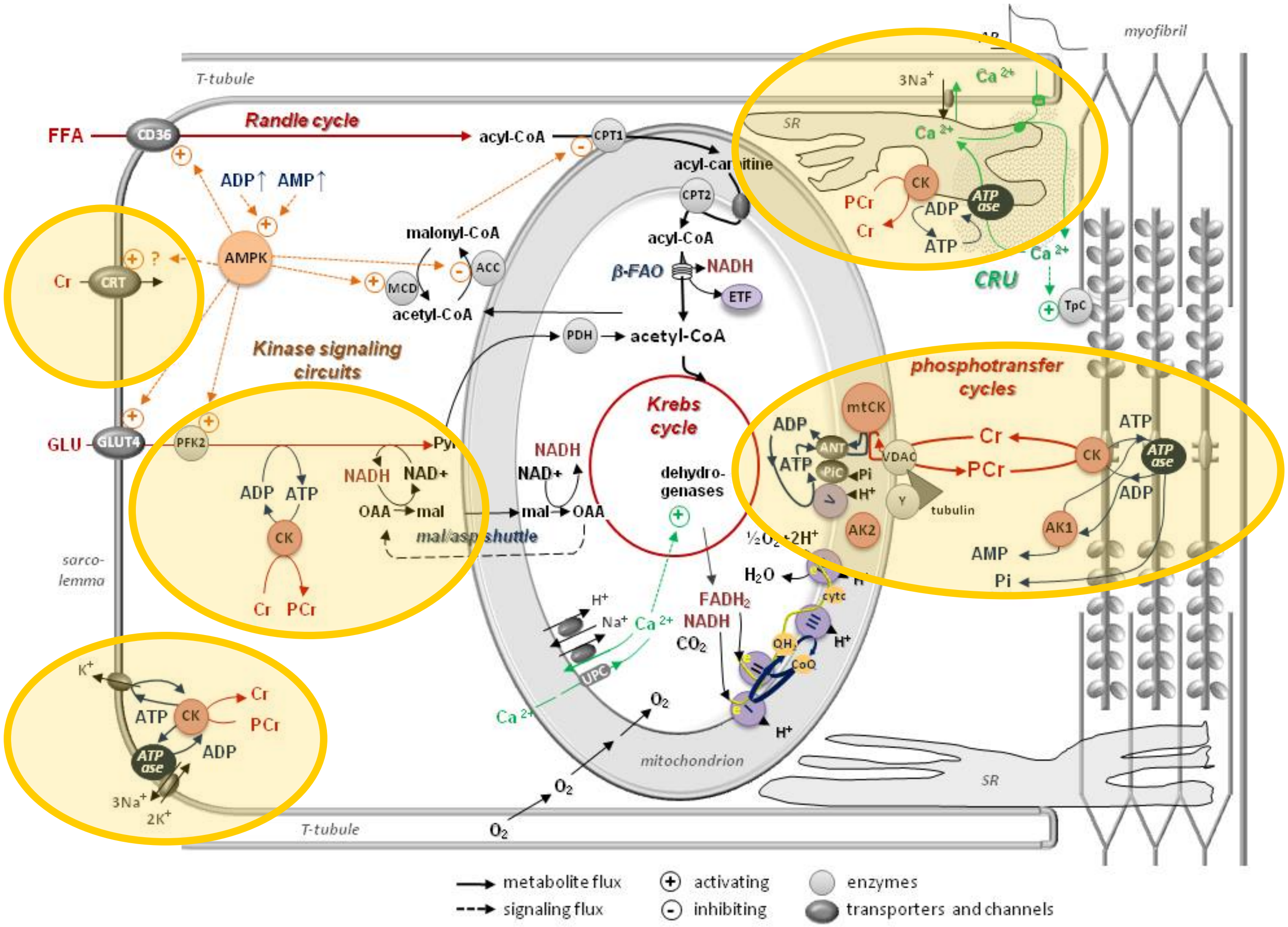
Apparently Effective



- Creatine is a naturally occurring non-essential amino acid discovered in 1832.
- Creatine supplementation studies began in early 1900s with interest rekindled by Ingwall and Hultman in 1970s.
- Athletes reported to be using creatine as an ergogenic aid since 1960's.
- Potential therapeutic role investigated since 1970's.
- Emphasis on ergogenic value in athletes since early 1990s as synthetic creatine became available.
- Current research on potential medical uses

Modeling CK transfer for systems bioenergetics

Modular organization of cardiac energy metabolism:
energy conversion, transfer and feedback regulation in cardiac intracellular energetic units



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

Creatine

Supplementation Protocols

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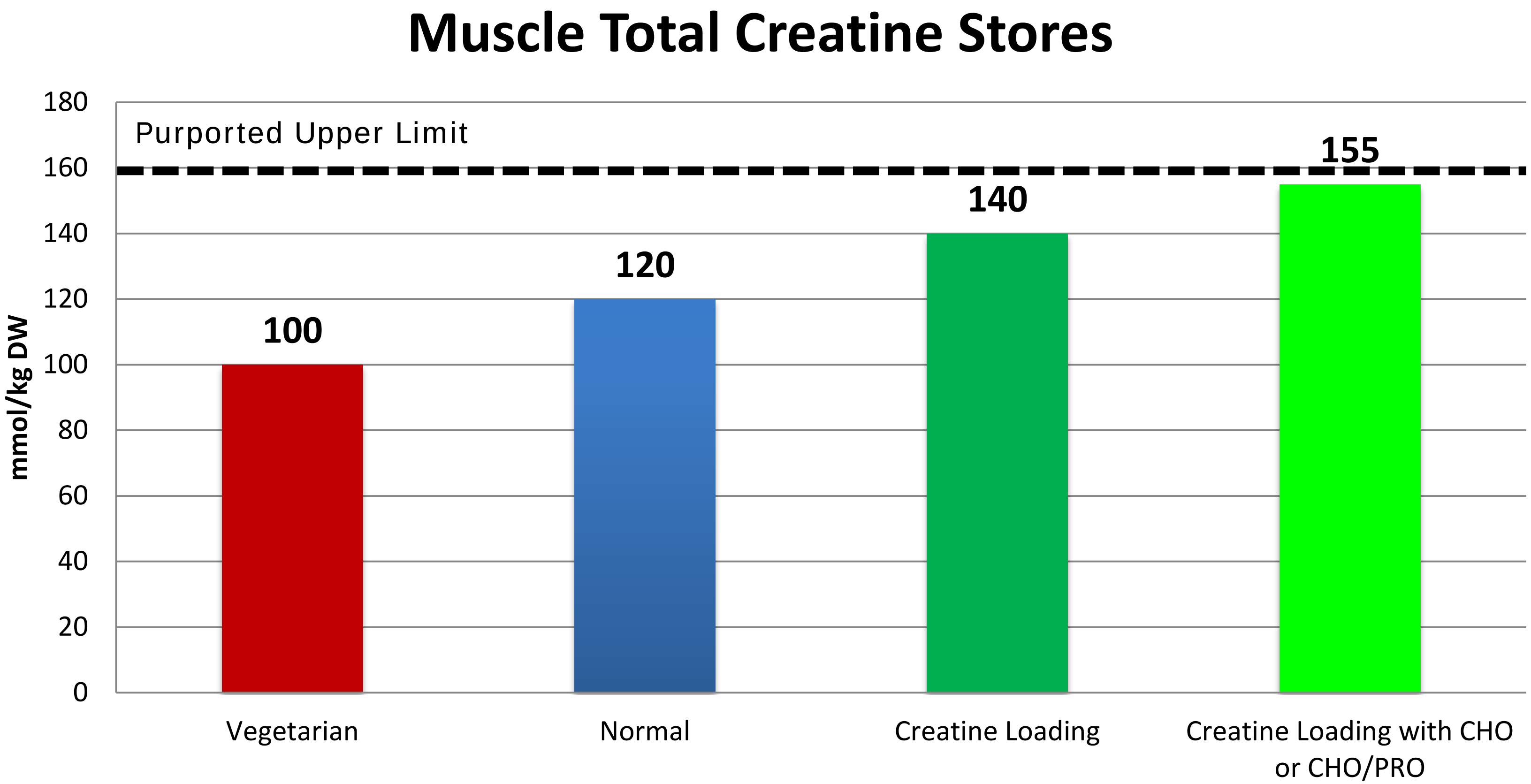
- High Dose Protocol
  - Ingest 15-25 g/d (0.3 g/kg/d) during training
- Loading/Maintenance Protocol
  - Ingest 0.3 g/kg/d (15-25 g/d) for 5-7 d
  - Ingest 0.03 g/kg/d (3-5 g/d) to maintain
- Low Dose Protocol
  - Ingest 0.03 g/kg/d (3-5 g/d)
- Cycling Protocol
  - Load/maintain during training and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

Creatine

Short-Term Supplementation

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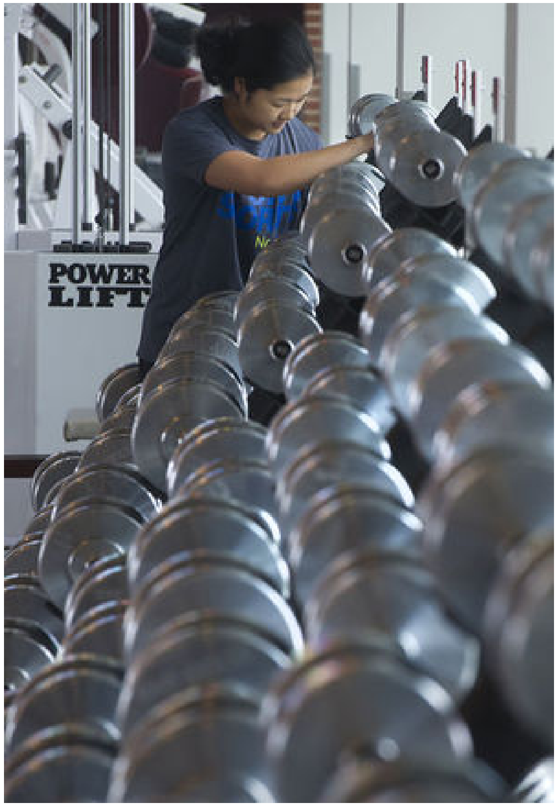
- Short-term creatine supplementation improves:
  - body mass by 1-2 kg in first week of loading;
  - maximal power/strength (5-15%);
  - work performed during sets of maximal effort muscle contractions (5-15%); and,
  - single-effort sprint performance (1-5%); and,
  - work performed during repetitive sprint performance (5-15%).

Kreider & Jung, JENB, 2011

Creatine

Long-Term Supplementation

- Studies show long-term creatine supplementation enhances quality of training generally leading to 5-15% greater gains in strength and performance.
- Creatine supplementation during resistance-training typically promotes a 1-3 kg greater gain in FFM in 4 – 12 weeks
- Muscle biopsy studies show gains are due to greater protein content in muscle.



Kreider & Jung, JENB, 2011

Creatine

Use in Athletics

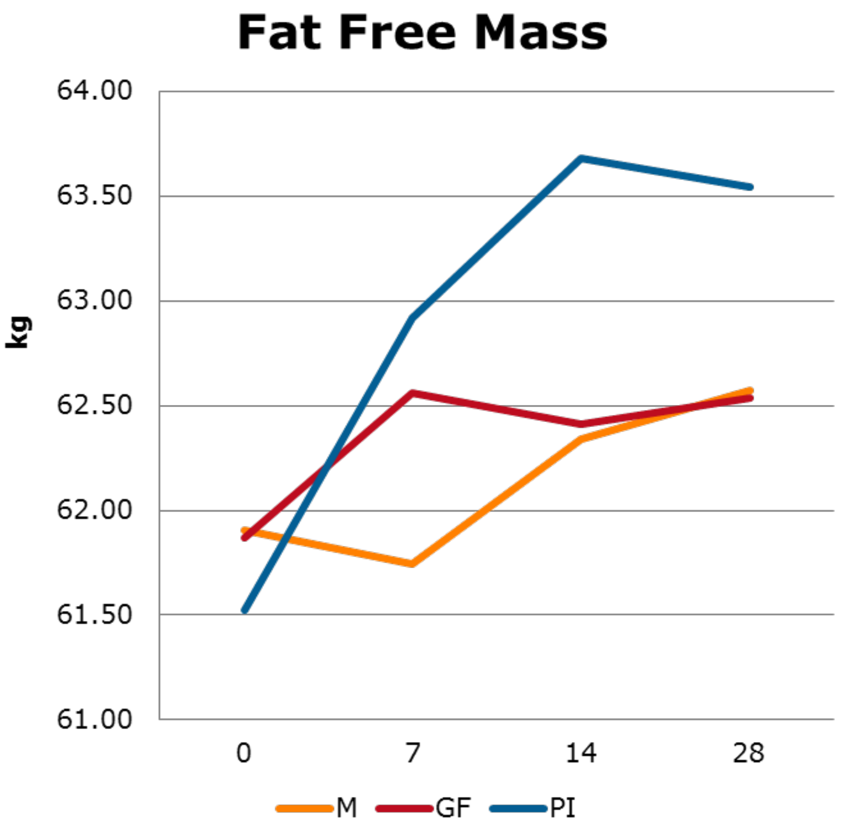
- **Increased PCr**
  - Track sprints: 100, 200 meters
  - Swim sprints: 50 meters
  - Pursuit cycling
- **Increased PCr Resynthesis**
  - Basketball
  - Field hockey
  - Football (American)
  - Ice hockey
  - Lacrosse
  - Volleyball
- **Reduced Muscle Acidosis**
  - Downhill skiing
  - Rowing
  - Swim events: 100, 200 meters
  - Track events: 400, 800 meters
- **Enhanced Training**
  - Most sports
- **Oxidative Metabolism**
  - Basketball
  - Soccer
  - Team handball
  - Tennis
  - Volleyball
  - Interval Training in Endurance Athletes
- **Increased Muscle Mass**
  - American, Australian football
  - Bodybuilding
  - Heavyweight wrestling
  - Power lifting
  - Rugby
  - Track/Field events
  - (Shot put; javelin; discus)
  - Weightlifting

Adapted from Williams, Kreider, and Branch, 1998.

Effects of ingesting Effects of Ingesting Supplements Designed to Promote Lean Tissue Accretion on Body Composition During Resistance-Training

Kreider et al. IJSN 6:234-46, 1996

- 28 resistance trained males
- In a DB-R-P manner, assigned to supplement diet with:
  - Maltodextrin (190 g/d)
  - Gainers Fuel 1000 (290 g/d)
  - Phosphagain (64 g/d CHO, 67 g/d PRO, 20 g/d CM)
- Greater gain in FFM and body mass in CM group
- Improved strength & muscle endurance in CM group



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

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

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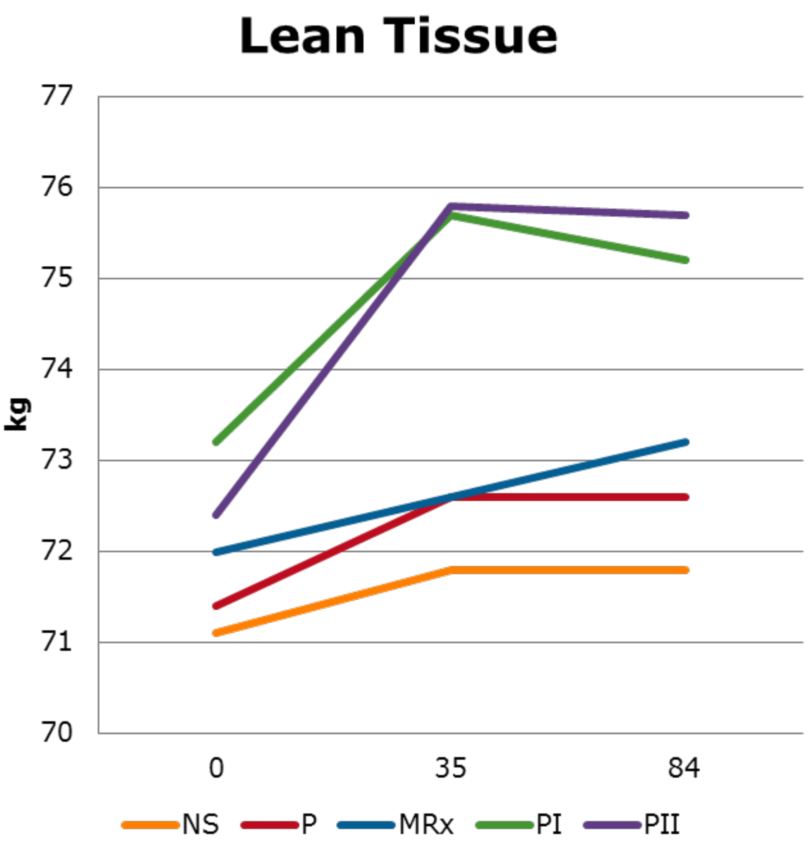
- 62 DI football players
- In a DB-R-P manner, assigned to supplement diet with:
  - Non-Supplemented Control
  - Maltodextrin Placebo
  - MetRx
  - Phosphagain I (20 g/d CM)
  - Phosphagain II (25 g/d CM)
- Greater gains in FFM & strength in CM groups



Effects of Creatine Supplementation on Body Composition, Strength, and Sprint Performance

Kreider et al. MSSE 30:73-82, 1998

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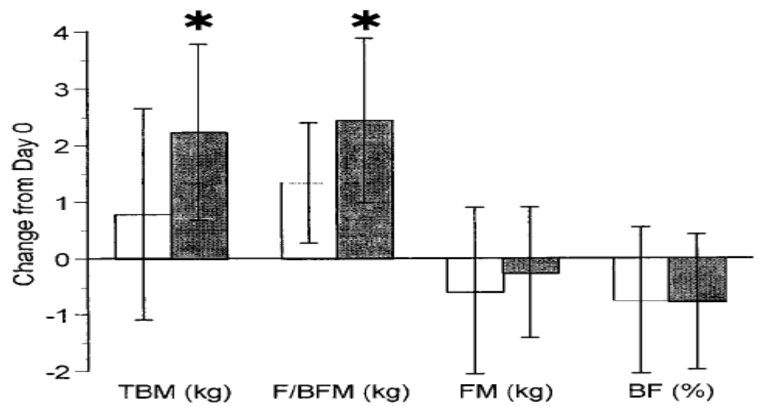
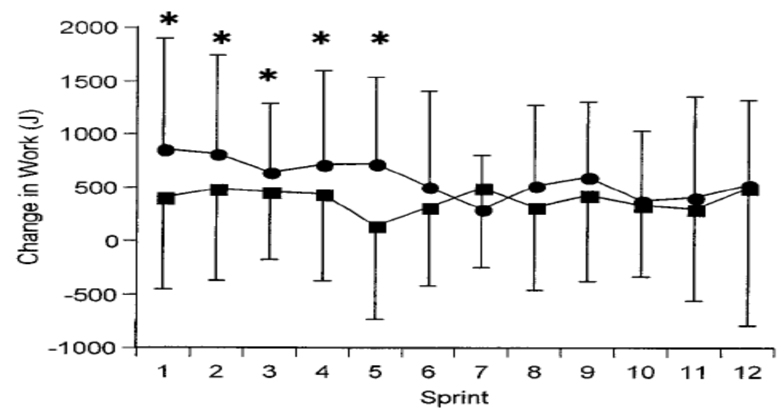
- 28 DI football players
- In a DB-R-P controlled manner, assigned to supplement diet with:
  - CHO containing placebo
  - CHO plus 15.75 g/d CM
- Greater gains in FFM, strength, and sprint performance
- Comprehensive safety analysis revealed no adverse effects during intense training





**Cited over 500 times*

Other Applications in Sport

Injury Prevention

Long-term Safety of Creatine Supplementation Among Athletes

21 Month Open Label Safety Study

- 100 NCAA division IA football players volunteered to participate
- Subjects elect to ingest creatine containing supplements or non-creatine supplements.
- Creatine supplementation:
  - 15.75 g/d for 5-d
  - Average of 5 g/d for 21 months
- Supplements administered following workouts/practices and documented
- Blood/urine samples collected at 0, 1.5, 2, 4, 6, 9, 12, 15, & 21 months.

Long-term Safety of Creatine Supplementation Among Athletes

Kreider et al. J Mol Cellular Biochem. 244:95–104, 2003

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- MANOVA revealed *no significant differences* (p=0.51) in a 55-item panel of blood and urine markers.
- RM ANOVA revealed *no clinically significant differences* among creatine users and controls in markers of renal function, muscle & liver enzymes, markers of catabolism, electrolytes, blood lipids, red cell status, lymphocytes, urine volume, clinical urinalysis, or urine specific gravity.
- No perception of greater incidence of side effects
- Some evidence of greater training tolerance

Long-term Safety of Creatine Supplementation Among Athletes

Greenwood et al. J Mol Cellular Biochem. 244:83–88, 2003

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- Creatine users (45-54% use rate) experienced:
  - Cramping (37/96, 39%)
  - Heat/dehydration (8/28, 36%)
  - Muscle tightness (18/42, 43%)
  - Muscle strains/pulls (25/51, 49%)
  - Non-contact joint injuries (44/132, 33%)
  - Contact injuries (39/104, 44%)
  - Illness (12/27, 44%)
  - Missed practices due to injury (19/41, 46%)
  - Players lost for season (3/8, 38%)
  - Total injuries/missed practices (205/529, 39%)

Cramping and Injury Incidence in Collegiate Football Players Are Reduced by Creatine Supplementation

Greenwood et al. J Athl Train. 38:216-219, 2003.

- 72 NCAA division IA football players volunteered to participate
- Subjects elected to ingest creatine containing supplements or non-creatine supplements.
- Creatine supplementation:
  - 0.3 g/kg/d for 5-d
  - 0.03 g/kg/d for ***~4 months***
- Environmental conditions ranged from 15 °C to 37 °C (mean = 27.3±11 °C) and 46.% to 91 RH (mean = 54.2±10%).
- Injuries treated by the athletic training staff were recorded and categorized as cramping, heat illness or dehydration, muscle tightness, muscle strains, noncontact joint injuries, contact injuries, and illness.
- The number of missed practices due to injury and illness was also recorded.

Cramping and Injury Incidence in Collegiate Football Players Are Reduced by Creatine Supplementation

Greenwood et al. J Athl Train. 38:216-219, 2003.

- Creatine users experienced significantly less:
  - Cramping
  - heat illness or dehydration
  - muscle tightness
  - muscle strains
  - total injuries
- There were no significant differences between groups regarding:
  - noncontact joint injuries
  - contact injuries
  - illness
  - missed practices due to injury
  - players lost for the season
- Incidence of cramping or injury in Division IA football players was ***significantly lower or proportional for creatine users compared with nonusers.***

First-Time Injuries, Illnesses, Missed Practices, and Players Lost for the Season Among Creatine-Supplemented and Nonsupplemented NCAA Division IA College Football Players*

	Creatine Users (n = 38)		Noncreatine Users (n = 34)	
Treated Injury	Injuries	No Injuries	Injuries	No Injuries
Cramping	10	28	18	16
Heat/dehydration	4	34	10	24
Muscle tightness	9	29	17	17
Muscle strains	11	27	19	15
Noncontact injuries	14	24	20	14
Contact injuries	38	38	34	34
Illness	10	28	12	22
Missed practices	17	21	20	14
Players lost for season	1	37	2	32
Total	114	266	152	188

*NCAA indicates National Collegiate Athletic Association.

Other Applications in Sport

Enhanced Recovery

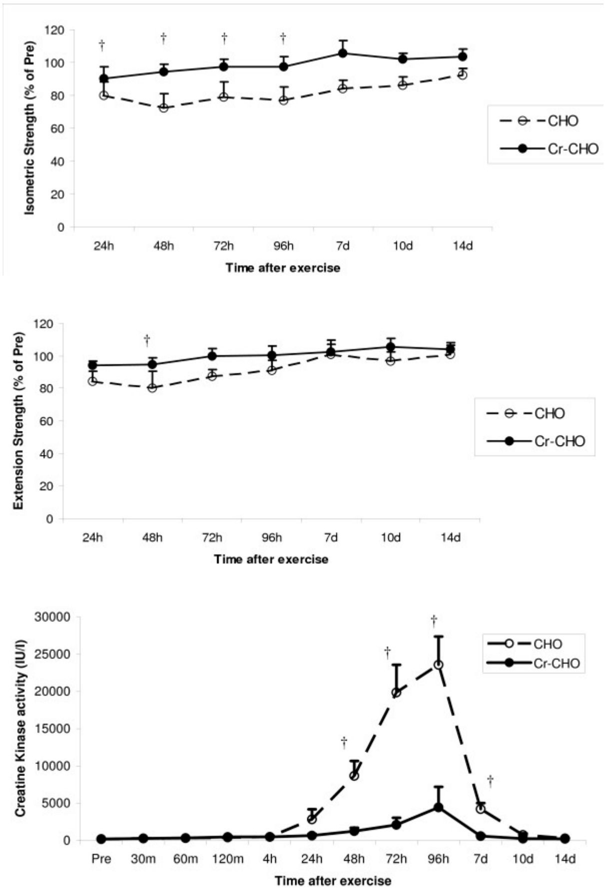
Creatine

Enhanced Recovery

Creatine supplementation enhances muscle force recovery after eccentrically-induced muscle damage in healthy individuals

Cooke et al. J Int Soc Sports Nutri. 6:13, 2008.

- 14 untrained males were randomly assigned to ingest 0.3 g/kg/d of CM with CHO for 5-d and 0.1 g/kg/d of CM with CHO for 14 days or a CHO placebo.
- After 5-d of supplementation, performed ***4 x 10 eccentric-only repetitions at 120% of their 1-RM*** max on the leg press, leg extension and leg flexion exercise machine.
- Plasma CK and LDH activity were assessed as relevant blood markers of muscle damage.
- The Cr-supplemented group had ***significantly greater isokinetic (10% higher) and isometric (21% higher) knee extension strength during recovery*** from exercise-induced muscle damage.
- ***Plasma CK activity was significantly lower (by an average of 84%) after 48 hrs, 72 hrs, 96 hrs, and 7 days recovery*** in the Cr group.
- ***Creatine improved the rate of recovery of knee extensor muscle function after injury***.



Creatine

Enhanced Recovery

The effects of creatine supplementation on muscular performance and body composition responses to short-term resistance training overreaching

Volek et al. Eur J Appl Physiol. 91(5-6):628-37, 2004.

- 17 men were randomly assigned to supplement with 0.3 g/kg per day of CM (n=9) or placebo (n=8) while performing ***resistance exercise (5 days/week for 4 weeks) followed by a 2-week taper phase***.
- 1RM squat and BP and explosive power in the BP were reduced during training in P but not CM.
- Explosive power in the BP, body mass, and LBM in the legs were augmented to a greater extent in CM by the end of the 6-week period.
- A tendency for greater 1-RM squat improvement (P=0.09) was also observed in CM.
- Changes were not related to changes in circulating hormone concentrations obtained in the resting, postabsorptive state.
- ***CM was effective for maintaining muscular performance during the initial phase of high-volume resistance training overreaching*** that otherwise results in small performance decrements.

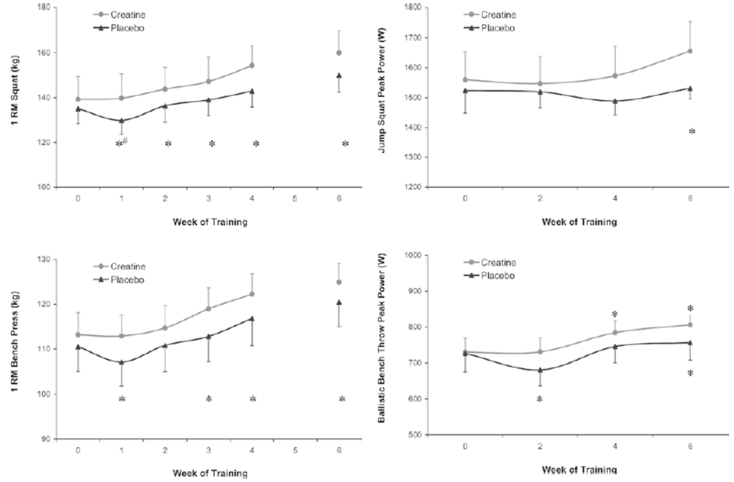


Table 5 Blood metabolite responses in subjects supplemented with creatine monohydrate (*CrM*) or placebo (*P*). Values are mean (SD). *CK* Creatine kinase, *TC* total cholesterol, *TG* triglycerides, *Hb* hemoglobin, *Hct* hematocrit

		Week 0	Week 1	Week 2	Week 3	Week 4	Main time effect	Group×time
Uric acid (mg/dl)	CrM	6.1 (1.3)	5.4 (1.5)**	5.3 (1.6)**	5.1 (1.4)**	5.0 (1.4)**	0.000	0.002
	P	6.1 (1.6)	7.2 (2.4)**	6.6 (1.7)	6.1 (1.7)	5.6 (1.8)		
Ammonia (μmol/l)	CrM	42.8 (19.1)	24.1 (21.3)*	23.8 (18.0)*	34.5 (17.4)	27.0 (19.0)	0.000	0.424
	P	38.2 (18.4)	20.5 (13.3)	17.1 (5.0)	35.5 (18.7)	37.2 (13.2)		
CK (IU/l)	CrM	91 (69)	836 (920)*	242 (124)	228 (146)	142 (74)	0.000	0.617
	P	72 (38)	1297 (1630)	177 (79)	162 (106)	88 (47)		
Glucose (mg/dl)	CrM	95.4 (10.5)	87.1 (7.2)*	92.8 (7.2)*	88.5 (6.3)*	90.4 (7.0)*	0.000	0.472
	P	97.9 (8.9)	90.0 (10.0)	92.8 (9.3)	89.0 (8.6)	88.2 (4.5)		
TC (mg/dl)	CrM	190 (38)	181 (38)	187 (45)	189 (41)	193 (30)	0.406	0.430
	P	189 (46)	181 (38)	191 (36)	180 (35)	180 (51)		
TG (mg/dl)	CrM	81 (31)	69 (32)	82 (40)	89 (42)	92 (44)	0.292	0.127
	P	126 (91)	99 (74)	126 (94)	102 (59)	90 (63)		
Hb (g/dl)	CrM	15.2 (1.0)	15.1 (1.2)*	14.9 (1.0)*	14.7 (0.9)*	14.9 (0.8)*	0.005	0.192
	P	15.7 (1.1)	14.6 (1.0)	15.0 (0.6)	14.8 (1.0)	14.8 (0.6)		
Hct (%)	CrM	44.9 (2.4)	42.2 (1.9)*	42.3 (1.9)*	43.1 (1.9)*	43.2 (1.5)*	0.000	0.957
	P	44.4 (2.0)	41.3 (2.4)	42.0 (1.6)	42.4 (2.0)	42.8 (1.3)		
Creatinine (mg/dl)	CrM	1.65 (0.09)	1.74 (0.09)**	1.76 (0.13)**, ***	1.77 (0.09)**, ***	1.79 (0.13)**, ***	0.005	0.000
	P	1.60 (0.07)	1.60 (0.07)	1.54 (0.04)	1.57 (0.03)	1.61 (0.06)		

*Significantly different ($P \leq 0.05$) from week 0 value for collapsed group means

**Significantly different ($P \leq 0.05$) from week 0 value for corresponding CrM or P group

***Significantly different ($P \leq 0.05$) from corresponding value for P group

Other Applications in Sport

Thermorgulation

Pitsiladis YP et al., Int J Sport Nutr Exerc Metab. 2004 Aug;14(4):443-60.

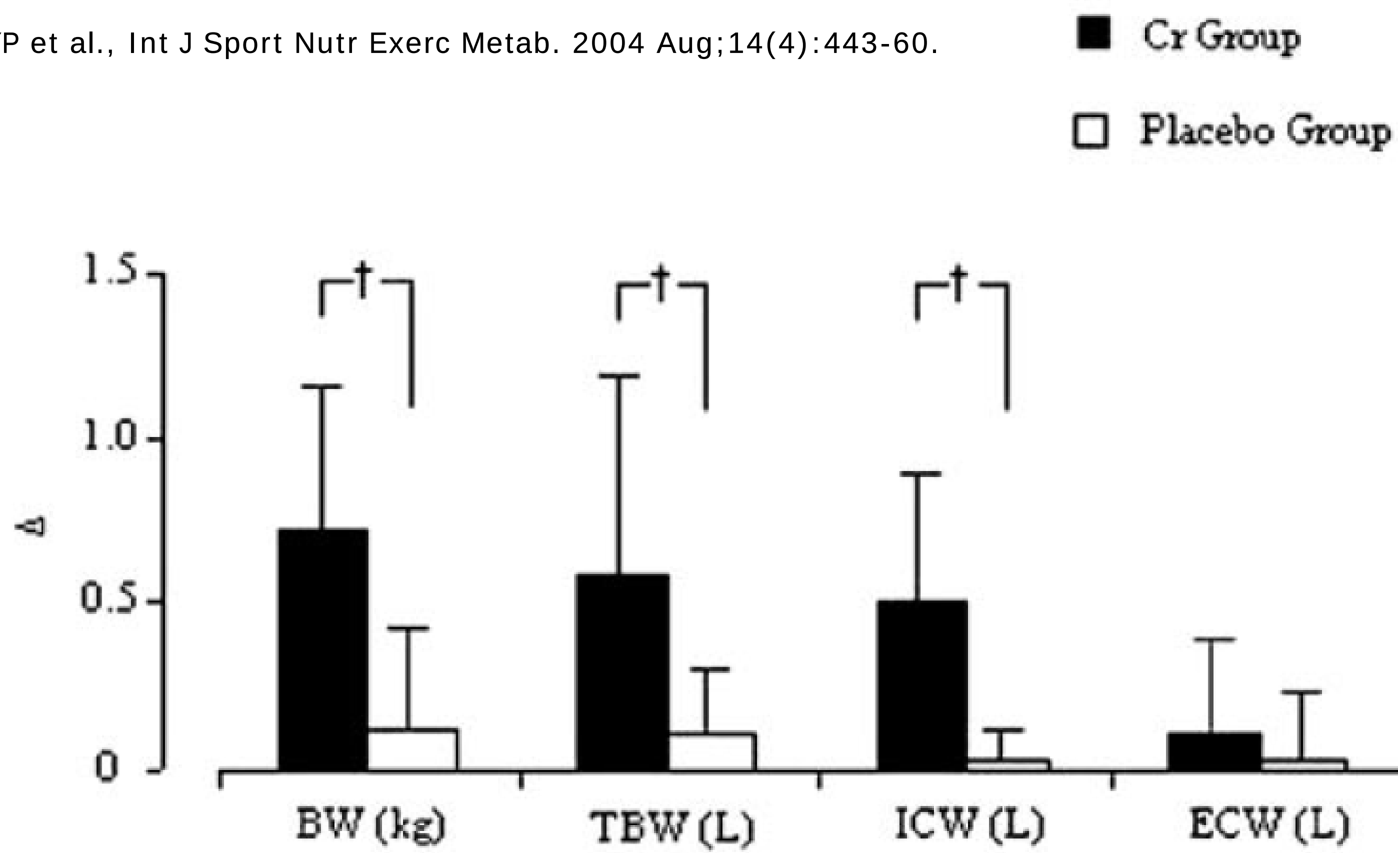
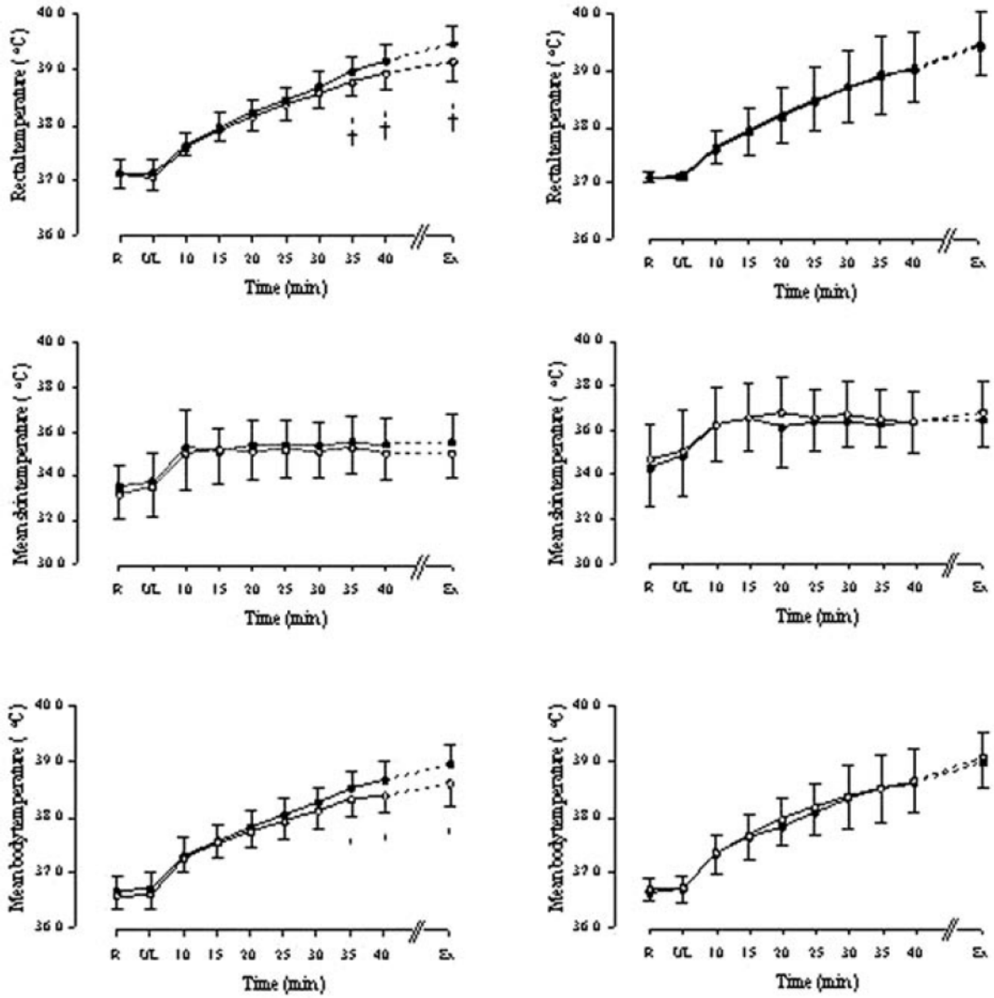


Figure 1 — Changes in body weight (BW), total body water (TBW), intracellular water (ICW), and extracellular water (ECW; mean ± standard deviation). †Indicates a significant greater change in the Cr group compared to the placebo group.

Cr supplementation consisted of 22.8g/d Cr (equivalent to 5g Cr x 4 d) and 35g of glucose polymer made up in 500 mL of warm to hot water for 7d taken at equal intervals throughout the day.

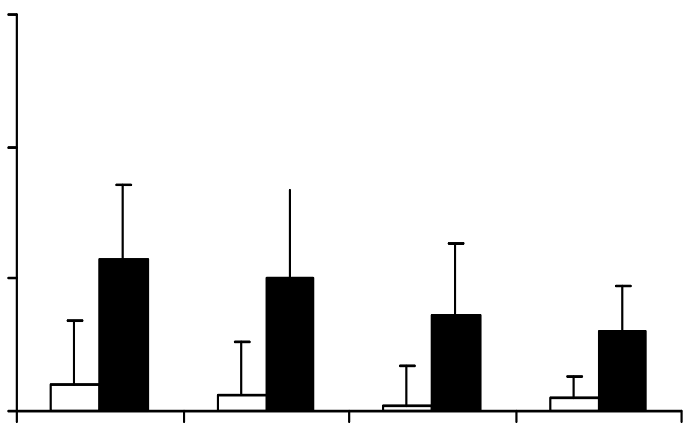
Pitsiladis YP et al., Int J Sport Nutr Exerc Metab. 2004 Aug;14(4):443-60. PI Group



International Journal of Sport Nutrition and Exercise Metabolism, 2007, 17, 70-91

Creatine and Glycerol Hyperhydration in Trained Subjects Before Exercise in the Heat

Chris Easton, Stephen Turner, and Yannis P. Pitsiladis



Other Applications in Sport

Rehabilitation

Oral creatine supplementation facilitates the rehabilitation of disuse atrophy and alters the expression of muscle myogenic factors in humans

Hespel et al. J Physiol. 536:625-33, 2001.

- 22 young healthy volunteers had their right leg casted to immobilize for 2 weeks.
- Subjects participated in a knee-extension rehabilitation program (3 sessions/wk x 10 wks).
- Half of the subjects received CM (from 20 g down to 5 g daily) while other ingested a maltodextrin placebo
- Before and after immobilization, and after 3 and 10 weeks of rehabilitation training, the cross-sectional area (CSA) of the quadriceps muscle was assessed by NMR imaging and isokinetic maximal knee-extension power (Wmax), and muscle biopsies from the vastus lateralis were examined to asses expression of the myogenic transcription factors MyoD, myogenin, Myf5, and MRF4, and muscle fibre diameters.

Oral creatine supplementation facilitates the rehabilitation of disuse atrophy and alters the expression of muscle myogenic factors in humans

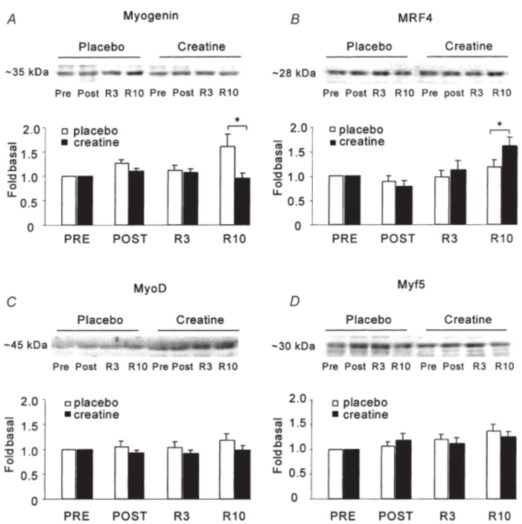
Hespel et al. J Physiol. 536:625-33, 2001.

- Immobilization decreased quadriceps muscle CSA (approximately 10 %) and Wmax (approximately 25 %) similarly in both groups.
- During rehabilitation, CSA and Wmax recovered at a faster rate in CR than in P.
- Immobilization did not change myogenic factor protein expression in either P or CR.
- After rehabilitation, myogenin protein expression was increased in P but not in CR ($P < 0.05$), while MRF4 protein expression was increased in CR but not in P ($P < 0.05$).
- The change in MRF4 expression was correlated with the change in mean muscle fibre diameter ($r = 0.73$, $P < 0.05$).
- ***Oral creatine supplementation stimulates muscle hypertrophy during rehabilitative strength training possibly due to a creatine-induced change in MRF4 and myogenin expression.***

Table 1. Effect of oral creatine supplementation on muscle cross-sectional area and muscle force and power during immobilization and rehabilitation

	Immobilization			Rehabilitation		
	Baseline	After	P value	3 weeks	10 weeks	P value
CSA quadriceps muscle (cm^2)						
Placebo	90.3 ± 4.6	81.8 ± 4.8*		89.3 ± 4.8	93.5 ± 6.0*	
Creatine	92.5 ± 4.9	82.3 ± 4.8*	0.30	94.6 ± 5.7	99.8 ± 6.0*	0.01
W_{max} (W)						
Placebo	160 ± 16	122 ± 13*		156 ± 17	165 ± 18	
Creatine	152 ± 17	113 ± 12*	0.61	160 ± 17	172 ± 17*	0.05
F_{max} (N m)						
Placebo	151 ± 12	117 ± 9*		155 ± 12	166 ± 13*	
Creatine	141 ± 10	112 ± 8*	0.70	154 ± 11*	168 ± 13*	0.42

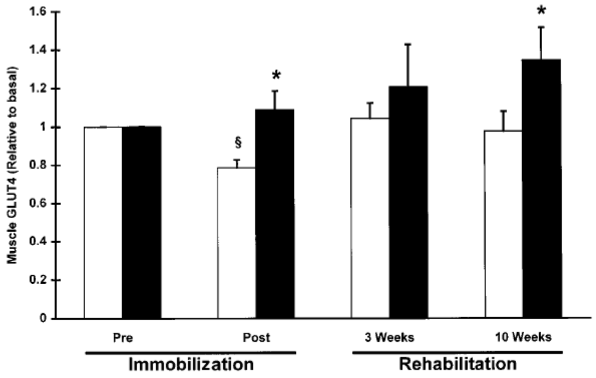
The cross-sectional area (CSA) of the right quadriceps muscle was measured by NMR imaging, and the dynamic power (W_{max}) and isometric torque (F_{max}) of the knee extensor muscles of the right leg were assessed on an isokinetic dynamometer. A cast was used to immobilize the right leg for a period of 2 weeks. Thereafter the subjects participated in a 10 week rehabilitation programme for the knee extensors of the same leg. The subjects ingested either supplementary creatine monohydrate (creatine group) or placebo (placebo group). Values are means ± S.E.M. of 10 observations in the creatine group and 9 observations in the placebo group. The P values refer to the treatment effect (creatine *versus* placebo) during immobilization and rehabilitation; * significant difference compared with the corresponding baseline value ($P < 0.05$). See Methods for further details.

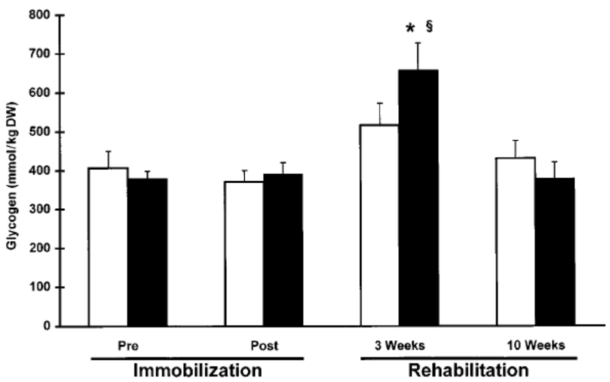


Effect of oral creatine supplementation on human muscle GLUT4 protein content after immobilization

Op't Eijnde et al. Diabetes. 50(1):18-23, 2001.

- Immobilization decreased GLUT4 in the placebo group (-20%, but not in the creatine group (+9% NS).
- Glycogen and total creatine were unchanged in both groups during the immobilization period.
- In the placebo group, during training, GLUT4 was normalized, and glycogen and total creatine were stable. Conversely, in the creatine group, GLUT4 increased by approximately 40% during rehabilitation.
- Muscle glycogen and total creatine levels were higher in the creatine group after 3 weeks of rehabilitation ($P < 0.05$), but not after 10 weeks of rehabilitation.
- ***Oral creatine supplementation offsets the decline in muscle GLUT4 protein content that occurs during immobilization and increases GLUT4 protein content during subsequent rehabilitation training in healthy subjects.***





Oral creatine supplementation enhances upper extremity work capacity in persons with cervical-level spinal cord injury

Jacobs et al. Arch Phys Med Rehabil. 83(1):19-23, 2002.

- In a randomized, double blind and crossover manner, 16 men with complete cervical-level SCI (C5-7) were randomly assigned to received either 20g/d of CM or placebo during treatment 1 with alternate supplement in treatment 2 after a 21-d washout.
- Incremental peak arm ergometry tests were performed immediately before and after each treatment phase.
- Results revealed that participants had higher VO_2, VCO_2, and VT at peak effort after creatine supplementation
- ***Creatine supplementation enhances the exercise capacity in persons with complete cervical-level SCI and may promote greater exercise training benefits.***

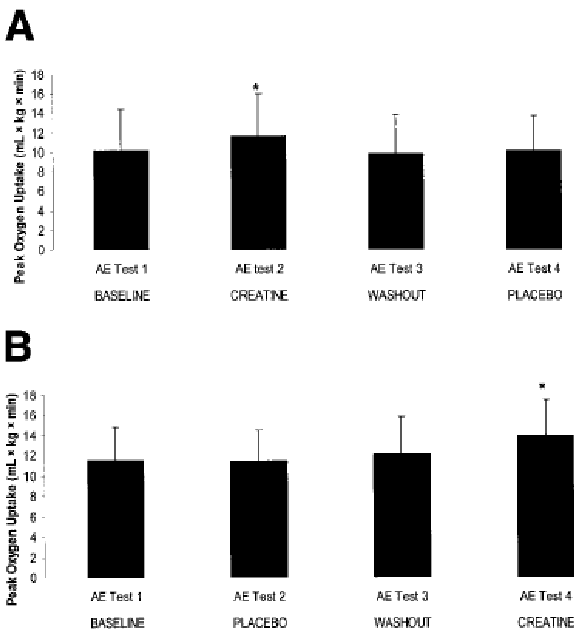


Fig 2. Peak oxygen uptake response to graded peak AE testing in subjects with cervical-level SCI (mean ± SD) receiving dietary supplementation of (A) creatine followed by placebo and (B) placebo followed by creatine. * $P < .001$; creatine versus baseline; creatine versus placebo.

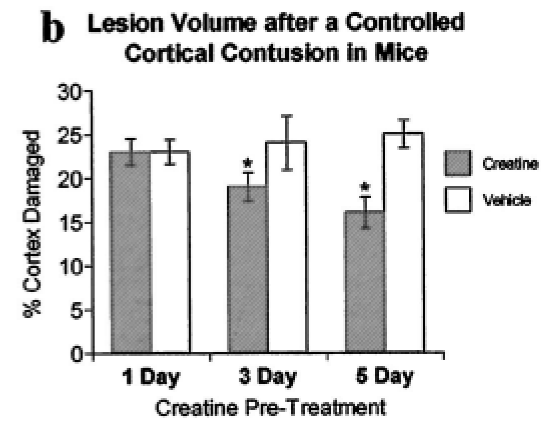
Other Applications in Sport

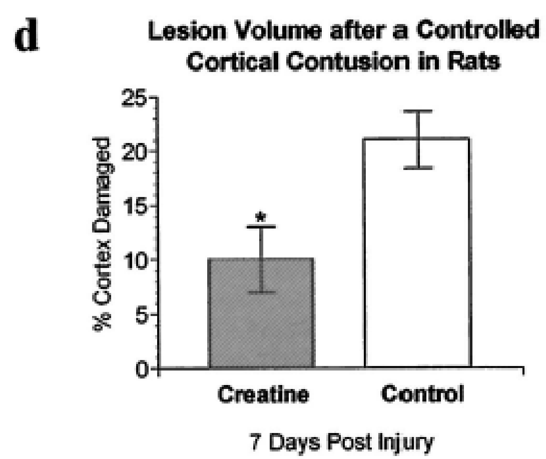
Concussion / Spinal Cord Neuroprotection

Dietary supplement creatine protects against traumatic brain injury

Sullivan et al. Ann Neurol. 48(5):723-9, 2000

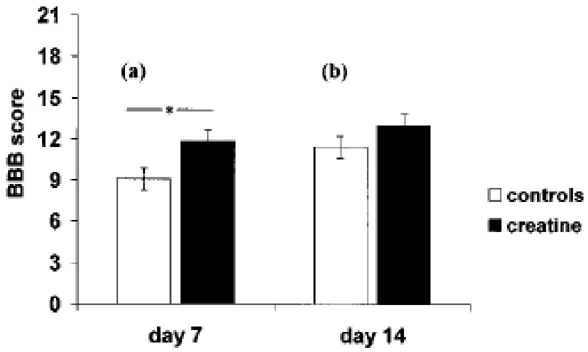
- Adult ICR mice (40) and adult Sprague-Dawley rats (24) underwent ***controlled cortical contusions*** that results in severe behavioral deficits, loss of cortical tissue, blood-brain barrier disruption and loss of hippocampal neurons mimicking human closed-head injury.
- Animals received daily injections of CM or olive oil for 1, 3, and 5-days before injury.
- ***CM ameliorated the extent of cortical damage by as much as 36% in mice and 50% in rats.***
- Protection seems to be related to creatine-induced maintenance of mitochondrial bioenergetics.
- Mitochondrial membrane potential was significantly increased, intramitochondrial levels of reactive oxygen species and calcium were significantly decreased, and adenosine triphosphate levels were maintained.
- Induction of mitochondrial permeability transition was significantly inhibited in animals fed creatine.
- Creatine may provide clues to the mechanisms responsible for neuronal loss after traumatic brain injury and ***may be useful as a neuroprotective agent against acute and delayed neurodegenerative processes.***

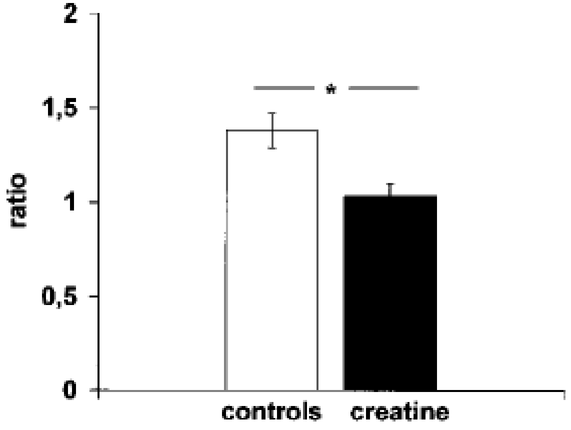




Protective effects of oral creatine supplementation on spinal cord injury in rats *Hausmann et al. Spinal Cord. 40(9):382-8, 2002*

- 20 adult rats were fed for 4 weeks with or without creatine (5 g CM / 100 g dry food) before undergoing a ***moderate spinal cord contusion***.
- Following an initial complete hindlimb paralysis, rats of both groups substantially recovered within 1 week.
- CM fed animals scored 2.8 points better than the controls in the BBB open field locomotor score (11.9 and 9.1 points respectively after 1 week; P=0.035, and 13 points compared to 11.4 after 2 weeks).
- The histological examination 2 weeks after SCI revealed that in all rats a cavity had developed which was comparable in size between the groups.
- In creatine fed rats, a significantly smaller amount of scar tissue surrounding the cavity was found.
- Creatine treatment reducd the spread of secondary injury.
- ***Our results favor a pretreatment of patients with creatine for neuroprotection in cases of elective intramedullary spinal surgery.***
- Further studies are needed to evaluate the benefit of immediate creatine administration in case of acute spinal cord or brain injury.

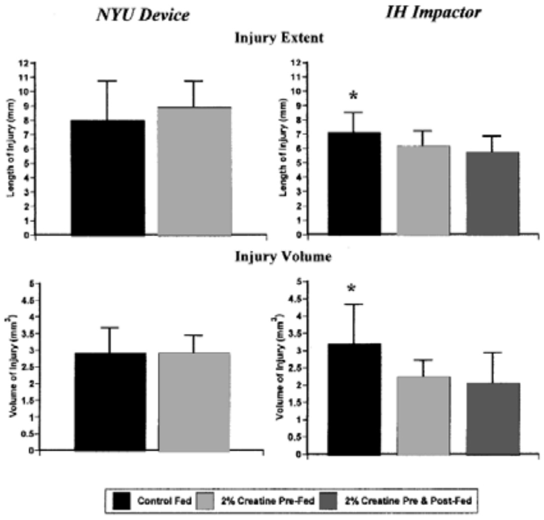


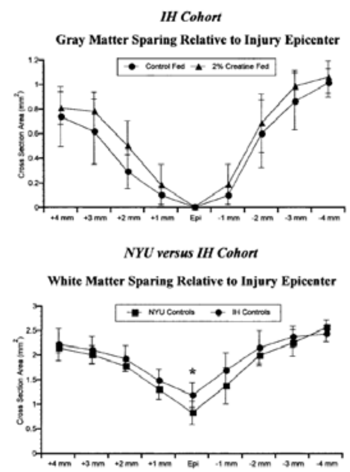


Creatine diet supplement for spinal cord injury: influences on functional recovery and tissue sparing in rats

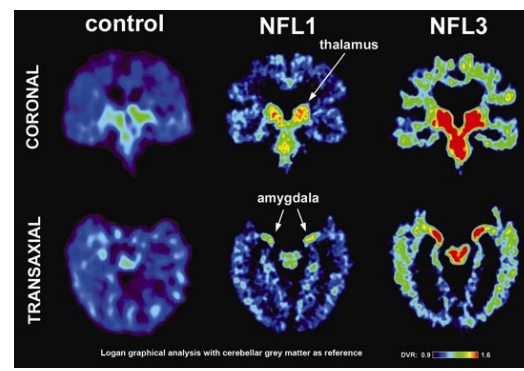
Rabchevsky et al. J Neurotrama. 20(7):659-69, 2003

- ***Spinal cord injury (SCI) instruments (NYU and Infinite Horizon [IH] methods)*** were used to assess the efficacy of creatine-supplemented diets on hind limb functional recovery and tissue sparing in adult rats.
- Rats were fed control versus 2% creatine-supplemented chow for 4-5 weeks prior to SCI (pre-fed), after which most resumed a control diet while some remained on a 2% creatine diet (pre & post-fed).
- Following long-term behavioral analysis (BBB), the amount of spared spinal cord tissue among the dietary regimen groups was assessed using stereology.
- Relative to the control fed groups injured with either method, none of the creatine fed animals showed improvements in hind limb function or white matter tissue sparing.
- Although creatine did not attenuate gray matter loss in the NYU cohort, it ***significantly spared gray matter in the IH cohort with pre-fed and pre & post-fed regimens.***
- Such selective sparing of injured spinal cord gray matter with a dietary supplement yields a promising strategy to promote neuroprotection after SCI.





Given concerns over the impact of concussions on brain function among athletes involved in contact sports and TBI in the military, a strong case could be made that creatine supplementation should be used as a prophylactic means of reducing the potential negative effects of neurological injury in sports / combat with potential for head trauma and/or spinal cord injury.



ISSN Position Stand

Creatine

jissn journal of the international society of sports nutrition™

- Creatine monohydrate is the most effective ergogenic nutritional supplement currently available to athletes in terms of increasing high-intensity exercise capacity and lean body mass during training.
- Creatine monohydrate supplementation is not only safe, but possibly beneficial in regard to preventing injury and/or management of select medical conditions when taken within recommended guidelines.
- There is no scientific evidence that the short- or long-term use of creatine monohydrate has any detrimental effects on otherwise healthy individuals.
- If proper precautions and supervision are provided, supplementation in young athletes is acceptable and may provide a nutritional alternative to potentially dangerous anabolic drugs.
- 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.
- The addition of carbohydrate or carbohydrate and protein to a creatine supplement appears to increase muscular retention of creatine, although the effect on performance measures may not be greater than using creatine monohydrate alone.
- The quickest method of increasing muscle creatine stores appears to be to consume ~0.3 grams/kg/day of creatine monohydrate for at least 3 days followed by 3–5 g/d thereafter to maintain elevated stores. Ingesting smaller amounts of creatine monohydrate (e.g., 2–3 g/d) will increase muscle creatine stores over a 3–4 week period, however, the performance effects of this method of supplementation are less supported.
- Creatine products are readily available as a dietary supplement and are regulated by the U.S. Food and Drug Administration (FDA).
- Creatine monohydrate has been reported to have a number of potentially beneficial uses in several clinical populations, and further research is warranted in these areas.

Buford et al. JISSN. 4.6, 2007

β-HMB

Apparently Effective

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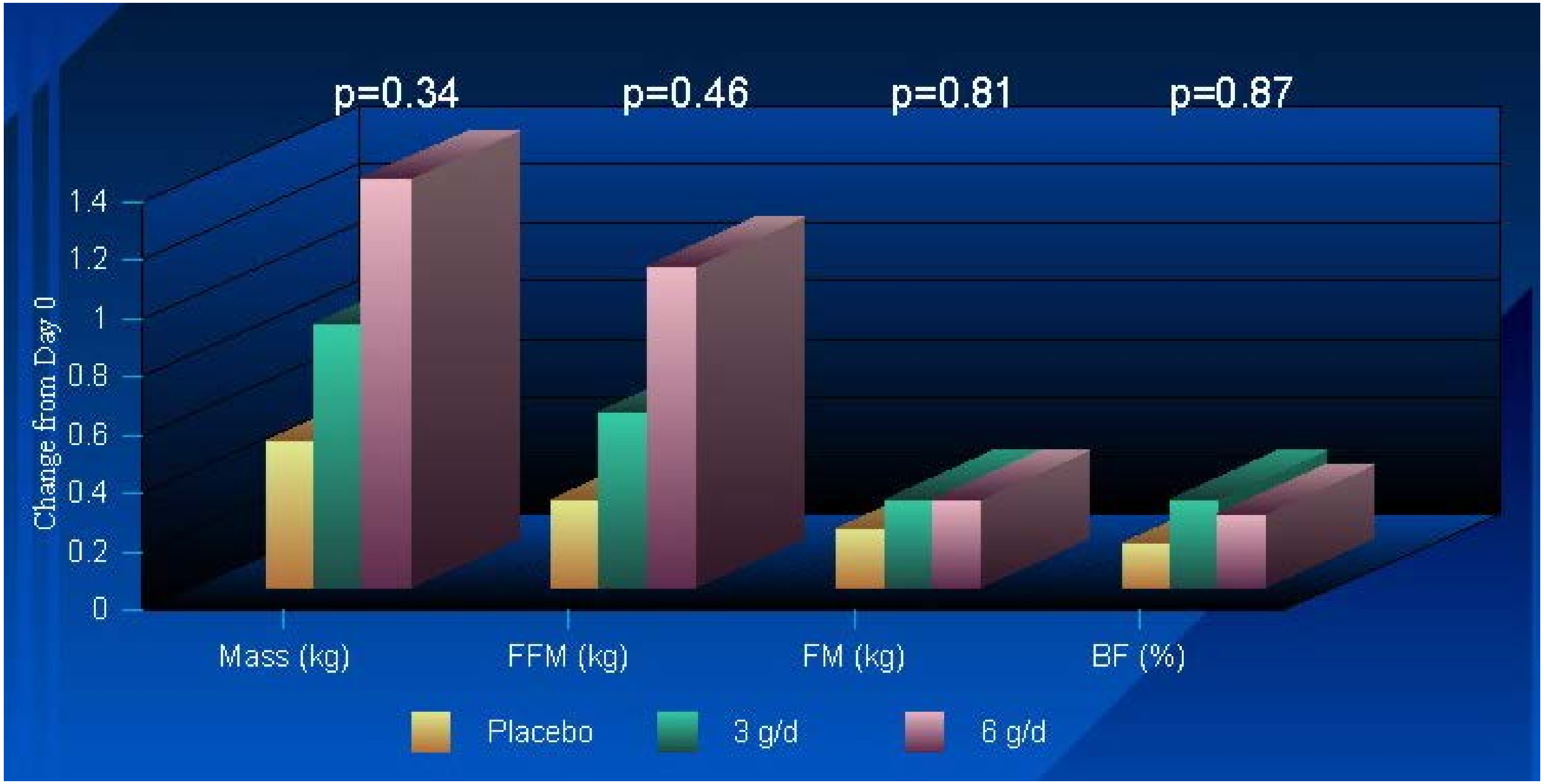
- Leucine, α-ketoisocaproate (KIC) and β-HMB have been reported to inhibit protein degradation
- Ingestion of 1.5 to 3 g/d of HMB reported to increase FFM and strength in untrained subjects initiating training
- Gains in muscle mass typically 0.5 – 1 kg greater than controls during 3 – 6 weeks of training
- 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

β-HMB

Apparently Effective

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



β-HMB

Apparently Effective

The effects of 12 weeks of beta-hydroxy-beta-methylbutyrate free acid supplementation on muscle mass, strength, and power in resistance-trained individuals: a randomized, double-blind, placebo-controlled study

Wilson et al. Eur J Appl Physiol. 114(6):1217-27, 2014

- A three-phase DBPCR intervention study was conducted.
- Phase 1 was an 8-week-periodized resistance-training program;
- Phase 2 was a 2-week overreaching cycle; and Phase 3 was a 2-week taper.
- Muscle mass, strength, and power were examined at weeks 0, 4, 8, and 12 to assess the chronic effects of HMB-FA; and assessment of these, as well as cortisol, testosterone, and creatine kinase (CK) was performed at weeks 9 and 10 of the overreaching cycle.
- ***HMB-FA enhances hypertrophy, strength, and power following chronic resistance training, and prevents decrements in performance following the overreaching.***

Table 1 Effect of beta-hydroxy-beta-methylbutyrate free acid (HMB-FA) supplementation on muscle strength and power in participants performing a 12-week resistance-training regimen

	Week of study				*p* value[a]
	0	4	8	12	
Total strength[b] (kg)					
Placebo	426.7 ± 14.5	444.6 ± 14.5	457.8 ± 14.5	452.0 ± 14.5	
HMB-FA	426.7 ± 14.5	458.7 ± 14.5	477.6 ± 14.5	503.8 ± 14.5	0.0001
Squat (kg)					
Placebo	143.8 ± 5.2	150.4 ± 5.2	155.4 ± 5.2	151.1 ± 5.2	
HMB-FA	143.7 ± 5.2	154.9 ± 5.2	162.4 ± 5.2[#]	179.9 ± 5.2[#]	0.0001
Bench press (kg)					
Placebo	112.9 ± 6.6	116.4 ± 6.6	118.5 ± 6.6	116.7 ± 6.6	
HMB-FA	112.4 ± 6.6	120.8 ± 6.6	123.7 ± 6.6	125.2 ± 6.6[#]	0.02
Deadlift (kg)					
Placebo	170.4 ± 9.2	178.2 ± 9.2	184.3 ± 9.2	184.5 ± 9.2	
HMB-FA	170.3 ± 9.2	182.7 ± 9.2	191.2 ± 9.2	198.4 ± 9.2[#]	0.009
Wingate peak power (W)					
Placebo	879.1 ± 38.3	927.0 ± 38.3	987.2 ± 38.3	982.5 ± 38.3	
HMB-FA	879.7 ± 38.3	936.0 ± 38.3	980.7 ± 38.3	1,038.6 ± 38.3[#]	0.01
Vertical jump power (W)					
Placebo	5,224 ± 73	5,636 ± 73	5,839 ± 73	5,854 ± 73	
HMB-FA	5,219 ± 73	5,835 ± 73[#]	6,039 ± 73[#]	6,211 ± 73[#]	0.001

Table 2 Effect of beta-hydroxy-beta-methylbutyrate free acid (HMB-FA) supplementation on muscle strength and power during the overreaching phase, weeks 8, 9, and 10, of a 12-week resistance-training regimen

	Week of study			*p* value[a]
	8	9	10	
Total strength[b] (kg)				
Placebo	467.8 ± 11.9	443.6 ± 11.9	447.6 ± 11.9	
HMB-FA	469.4 ± 11.9	464.5 ± 11.9[#]	467.3 ± 11.9[#]	0.01
Squat (kg)				
Placebo	159.2 ± 4.8	152.6 ± 4.8	150.6 ± 4.8	
HMB-FA	159.3 ± 4.8	158.3 ± 4.8[#]	162.6 ± 4.8[#]	0.0001
Bench press (kg)				
Placebo	121.4 ± 4.7	113.5 ± 4.7	115.6 ± 4.7	
HMB-FA	121.4 ± 4.7	120.3 ± 4.7[#]	120.1 ± 4.7[#]	0.05
Deadlift (kg)				
Placebo	187.2 ± 6.9	177.3 ± 6.9	181.4 ± 6.9	
HMB-FA	188.8 ± 6.9	185.9 ± 6.9	184.7 ± 6.9	0.26
Wingate peak power (W)				
Placebo	983.9 ± 38.8	917.5 ± 38.8	939.5 ± 38.8	
HMB-FA	977.6 ± 38.8	965.4 ± 38.8[#]	972.7 ± 38.8[#]	0.04
Vertical jump power (W)				
Placebo	5,949 ± 57.5	5,723 ± 57.5	5,656 ± 57.5	
HMB-FA	5,949 ± 57.5	5,867 ± 57.5[#]	5,870 ± 57.5[#]	0.0001

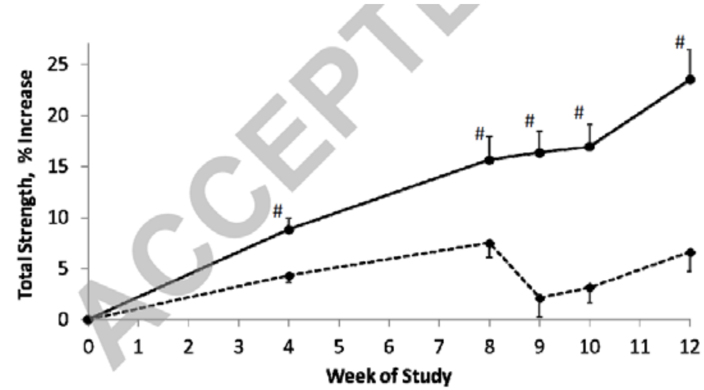
β-HMB

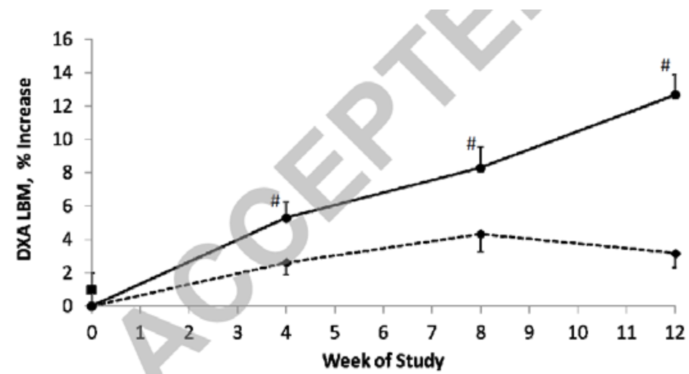
Apparently Effective

Interaction of Beta-Hydroxy-Beta-Methylbutyrate Free Acid (HMB-FA) and Adenosine Triphosphate (ATP) on Muscle Mass, Strength, and Power in Resistance Trained Individuals

Lowery et al. J Strength Cond Res. In press, 2015

- Investigated the effects of 12 weeks of HMB-FA (3g) and ATP (400mg) administration on lean mass (LBM), strength, and power in trained individuals.
- A three-phase DBPCR intervention
- Phases consisted of an 8-week periodized resistance-training program (Phase 1), followed by a 2-week overreaching cycle (Phase 2), and a 2-week taper (Phase 3).
- Participants taking HMB-FA experienced a 12.7% increase in LBM, a 23.5% increase in strength gains, a 21.5% increase in VJ, and a 23.7% increase in Wingate power.
- During the overreaching cycle, strength and power declined in the placebo group (4.3 to 5.7%) while supplementation with HMB-FA/ATP resulted in continued strength gains (1.3%).
- ***HMB-FA and ATP blunted the typical response to overreaching, resulting in a further increase in strength during that period.***





ISSN Position Stand

β-HMB

- HMB can be used to enhance recovery by attenuating exercise induced skeletal muscle damage in trained and untrained populations.
- An athlete will benefit from consuming HMB in close proximity to their workout.
- HMB appears to be most effective when consumed for 2 weeks prior to an exercise bout.
- 38t $mg \cdot kg \cdot BM^{-1}$ 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.
- 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
- HMB has been demonstrated to increase LBM and functionality in elderly, sedentary populations.
- HMB in conjunction with a structured exercise program may result in greater declines in fat mass (FM).
- HMB's mechanisms of action include an inhibition and increase of proteolysis and protein synthesis, respectively.
- Chronic consumption of HMB is safe in both young and old populations.

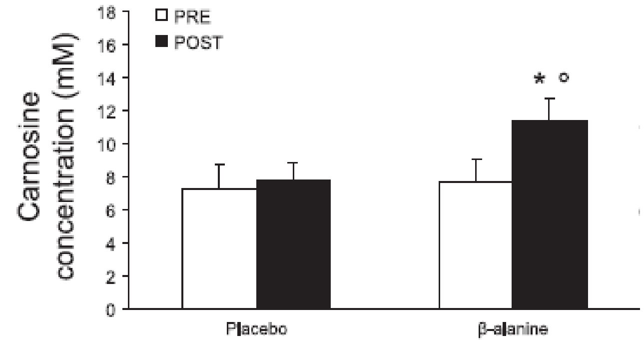
Wilson et al. JISSN. 10:6, 2013

Beta-Alanine

Apparently Effective

EXERCISE & SPORT NUTRITION LABORATORY
TEXAS A&M UNIVERSITY

- Muscle carnosine has been reported to serve as a physiological buffer, possess antioxidant properties, influence enzyme regulation, and affect sarcoplasmic reticulum calcium regulation.
- Beta-alanine (β-ALA) is a non-essential amino acid. β-ALA supplementation (e.g., 2–6 grams/day) has been shown to increase carnosine concentrations in skeletal muscle by 20–80% (*Culbertson et al, Nutrients, 2010*).



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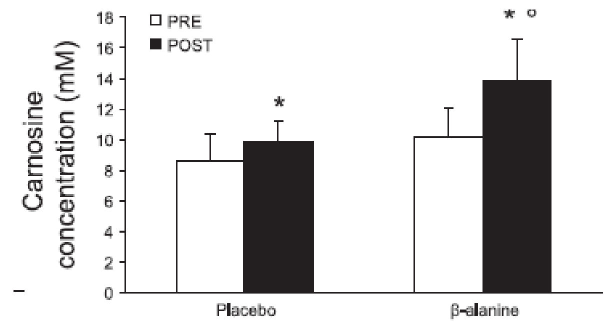

Gastrocnemius

Dareve et al. JAP, 2007

Beta-Alanine

Apparently Effective

- Stout et al. (*JISSN, 2008*) reported that 28-d of β-ALA supplementation (3-6 g/d) delayed the onset of neuromuscular fatigue.
- Hoffman et al. (*IJSNEM, 2008*) reported that creatine / β-ALA supplementation (10/3 g/d) increased FFM in college football players participating in a 10-wk resistance training program.
- Kendrick et al. (*AA, 2008*) reported that 3.6 g/d of β-ALA for 4-wks increased training adaptations

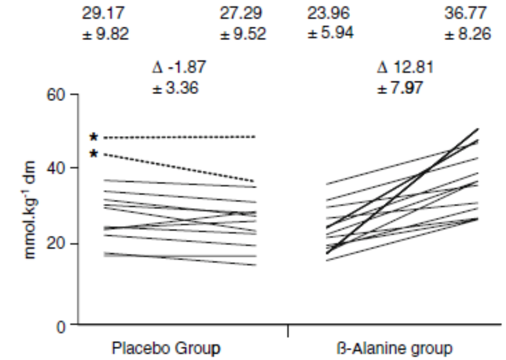

Fig. 2 Changes in M-[Carn] in each individual following training, with or without *β*-alanine supplementation. Values marked by *asterisks* are discussed in the text

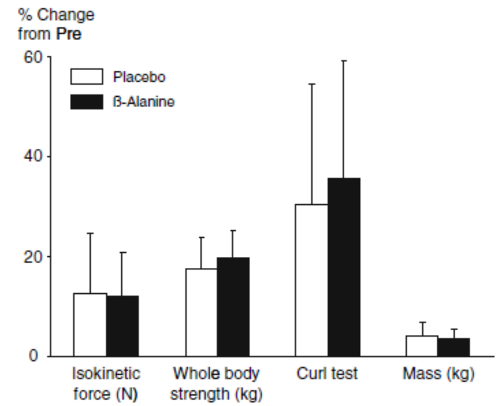

Fig. 1 The percentage change in exercise performance measures and mass. All values were significantly increased pre to post but there was no significant difference between treatment groups

ISSN Position Stand

Beta Alanine

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- Four weeks of beta-alanine supplementation (4–6 g daily) significantly augments muscle carnosine concentrations, thereby acting as an intracellular pH buffer;
- Beta-alanine supplementation currently appears to be safe in healthy populations at recommended doses;
- The only reported side effect is paraesthesia (tingling), but studies indicate this can be attenuated by using divided lower doses (1.6 g) or using a sustained-release formula;
- 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;
- Beta-alanine attenuates neuromuscular fatigue, particularly in older subjects, and preliminary evidence indicates that beta-alanine may improve tactical performance;
- 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);
- 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

Sodium Bicarbonate

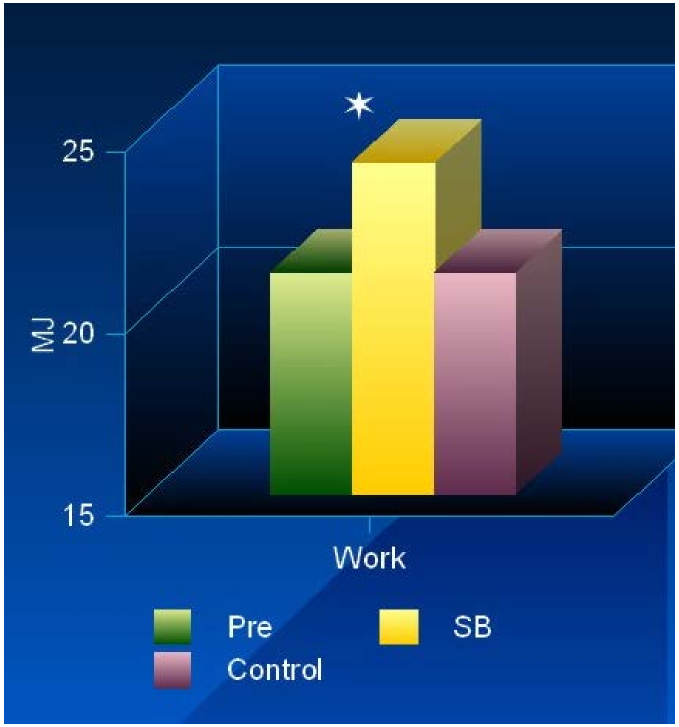
Apparently Effective

- 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



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Performance Enhancement Nutrition Strategies

Endurance Athletes

Nutrition Strategies

Endurance Athletes

- Goals
  - Provide necessary dietary carbohydrate
  - Maintain hydration and blood glucose levels during exercise
  - Spare muscle glycogen utilization during exercise
  - Promote glycogen resynthesis
  - Increase endurance capacity
  - Increase anaerobic threshold
  - Maintain muscle mass

Nutrition Strategies
Endurance Athletes

- Nutritional Strategies
  - High CHO diet
  - CHO Loading
  - Post-Exercise CHO/PRO
- Ergogenic Aids
  - Water/GES during exercise
  - Caffeine
  - Sodium Phosphate
  - Nitrates (Beet Root Juice)
  - Creatine

Glucose Electrolyte Solutions

Apparently Effective

- 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

Apparently Effective

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.

ISSN Position Stand

Caffeine

- Caffeine is effective for enhancing sport performance in trained athletes when consumed in low-to-moderate dosages (~3-6 mg/kg) and overall does not result in further enhancement in performance when consumed in higher dosages (≥ 9 mg/kg).
- Caffeine exerts a greater ergogenic effect when consumed in an anhydrous state as compared to coffee.
- 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.

Goldstein et al. JISSN. 7:5, 2010

ISSN Position Stand

Caffeine

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- 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.
- The literature is equivocal when considering the effects of caffeine supplementation on strength-power performance, and additional research in this area is warranted.
- The scientific literature does not support caffeine-induced diuresis during exercise, or any harmful change in fluid balance that would negatively affect performance.

Goldstein et al. JISSN. 7:5, 2010

Sodium Phosphate

Apparently Effective

- 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.

Sodium Phosphate

Apparently Effective

Study	Findings
Cade et al., MSSE, 1984	Trained runners; 9% ↑ in VO_2max; ↓ submaximal lactate levels
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; 11% ↑ in VO_2max; 20% ↑ in time to exhaustion
Kreider et al., IJSN, 1992	Trained cyclists & triathletes; 9% ↑ in VO_2max; 10% ↑ in VANT; 17% ↑ in power during 40 km race; 13% ↑ in EJ and 24% ↑ MFS

Nitrates

Apparently Effective

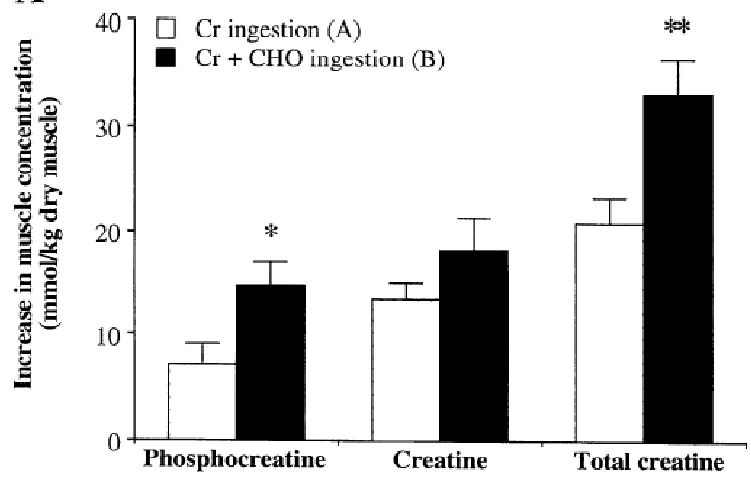
- Nitrate ingestion has been shown to reduce the oxygen cost of exercise and improve exercise tolerance.
- Larsen et al. (*Acta physiologica. 2007;191:59–66*) reported a reduction in maximal oxygen consumption; yet a trend for improvement in time-to-exhaustion accompanying the ingestion of sodium nitrate 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.

Creatine

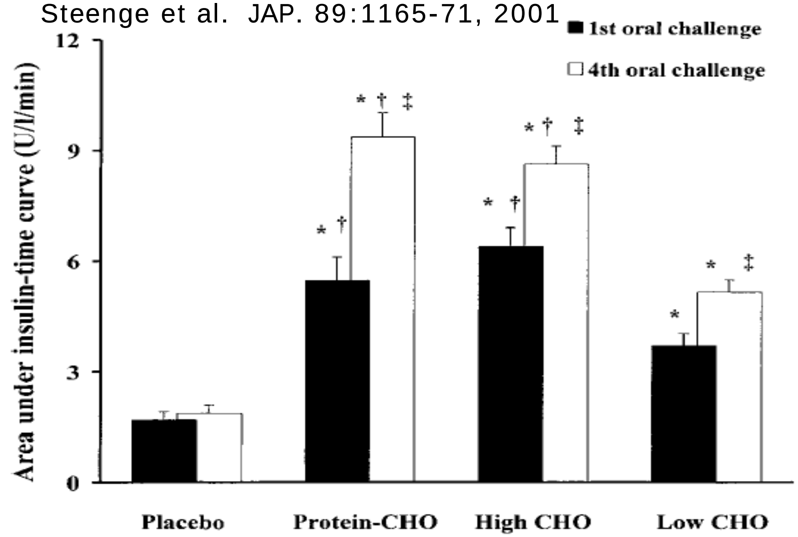
Glycogen Synthesis

- *Green et al (1996a; 1996b)* demonstrated that co-ingesting creatine (5 g) with large amounts of glucose (e.g., 95 g) enhanced creatine and carbohydrate storage in muscle.
- *Steenge et al. (2000)* found ingesting creatine (5 g) with 47–97 g of carbohydrate and 50 g of protein also enhanced creatine retention.
- The researchers suggested that creatine transport was mediated in part by glucose and insulin.

Green et al. Am J Physiol. 271:E821-6, 1996



Steenge et al. JAP. 89:1165-71, 2001



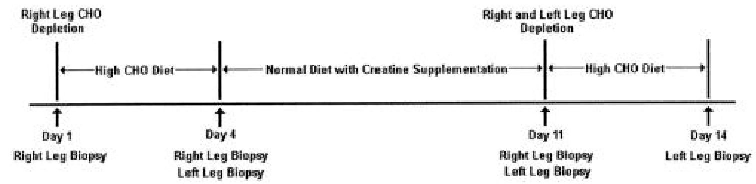
Creatine

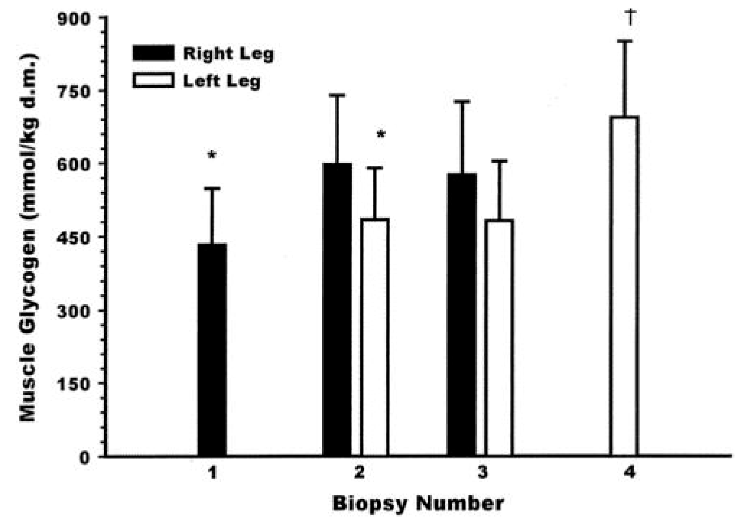
Glycogen Synthesis

Muscle glycogen supercompensation is enhanced by prior creatine supplementation

Nelson et al. Med Sci Sports Exerc. 33(7):1,096-1,100, 2001.

- 12 men performed two standard glycogen loading protocols interspersed with a standard creatine load of 20 g/d for 5 d.
- The initial glycogen loading protocol increased muscle glycogen by 4% with no change in total muscle creatine.
- Creatine loading showed significant increases in total muscle creatine levels in both the left leg (+ 41.1±31.1 mmol/kg DM) and the right leg (+36.6±19.8 mmol/kg DM with no change in either leg's muscle glycogen content.
- After the final glycogen loading, a significant 53% increase in muscle glycogen (+241±150 mmol/kg DM) was detected.
- The postcreatine load total glycogen content (694±156 mmol/kg DM) was significantly greater than the precreatine load total glycogen content (597±142 mmol/kg DM).
- Results reveal that a ***muscle's glycogen loading capacity is influenced by its initial levels of creatine*** and the accompanying alterations in cell volume.





Creatine

Reduces Catabolism

The effect of creatine supplementation upon inflammatory and muscle soreness markers after a 30km race

Santos et al. Life Sci. 75(16):1917-24, 2004.

- 34 experienced marathon runners were supplemented for 5 days prior to the 30km race with 4 x 5g of creatine and 15g/d of maltodextrin while the control group received the same amount of maltodextrin.
- Pre-race and 24-hour post blood samples were collected
- Athletes from the control group presented an increase in plasma CK (4.4-fold), LDH (43%), PGE2 6.6-fold) and TNF-alpha (2.34-fold) concentrations
- ***Creatine attenuated the changes observed for CK (by 19%), PGE2 and TNF-alpha (by 60.9% and 33.7%, respectively) and abolished the increase in LDH*** plasma concentration observed after running 30km.
- The athletes did not present any side effects such as cramping, dehydration or diarrhea, neither during the period of supplementation, nor during the 30km race.

Table 2

Creatine kinase (CK), lactate dehydrogenase (LDH), prostaglandin E_2 (PGE_2), tumour necrosis factor-alpha (TNFα) and creatinine plasma concentrations measured immediately before and 24h after a 30km running, in the plasma obtained from athletes subjected to a placebo (Con, n = 16) or a creatine supplementation protocol (CR, n = 18)

	Con Before	Con After	Cr Before	Cr After
CK (U/l)	48.26 ± 27.28	213.19 ± 113.60*	32.17 ± 16.42	170.95 ± 61.82*
LDH (U/l)	208.9 ± 17.6	298.7 ± 23.6*	198.7 ± 13.5	185.3 ± 21.5#
PGE2 (pg/ml)	42.76 ± 4.95	329.35 ± 17.96*	47.12 ± 8.76	110.42 ± 12.38*#
TNFα (pg/ml)	91.18 ± 7.55	213.76 ± 15.05*	97.77 ± 9.24	141.6 ± 3.32*#
Creatinine (mg/dl)	0.22 ± 0.03	0.34 ± 0.09	0.31 ± 0.05	0.41 ± 0.07

The results are expressed as mean ± SEM of 23 samples.

*$p < 0.05$ for comparison with the values obtained before the exercise bout.

#$p < 0.05$ for comparison with the values obtained for the control group. The observed power was 1,00 for LDH, PGE_2 and TNFα.

The effect of creatine supplementation upon inflammatory and muscle soreness markers after a 30km race

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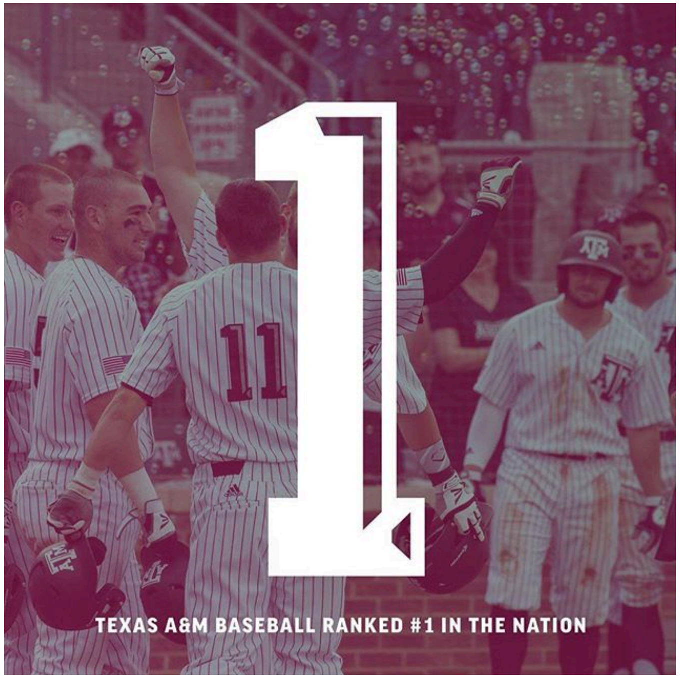
- The athletes did not present any side effects such as cramping, dehydration or diarrhea, neither during the period of supplementation, nor during the 30km race.

Performance Enhancement Program

Summary

- Stress high CHO, nutrient dense, isoenergetic diet
- Daily multi-vitamin (with iron for women)
- Taper & CHO load before competition
- Pre-practice snack with compliant energy bars/drinks/shake
- Water and GES during exercise
- Post-practice snack with compliant energy bars/drinks/shake
- Evening snacks or compliant energy bar/shake
- Sport specific use of effective and non-banned ergogenic aids



Performance Enhancement Program

Summary

- Strength/Power/Sprint Athletes
  - Moderate to High CHO/PRO diet
  - Water/GES
  - Post-Exercise PRO
  - Creatine
  - β-alanine
  - Sodium Bicarbonate
- Endurance Athletes
  - High CHO diet/CHO loading
  - Water/GES
  - Caffeine
  - Sodium Phosphate
  - Nitrates (Beet Root Juice)
  - Creatine

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Nutritional Strategies to Optimize Performance

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Serve as scientific consultant to Nutrabolt Inc. (Bryan, TX)

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