Nutritional Strategies to Prevent Overtraining

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

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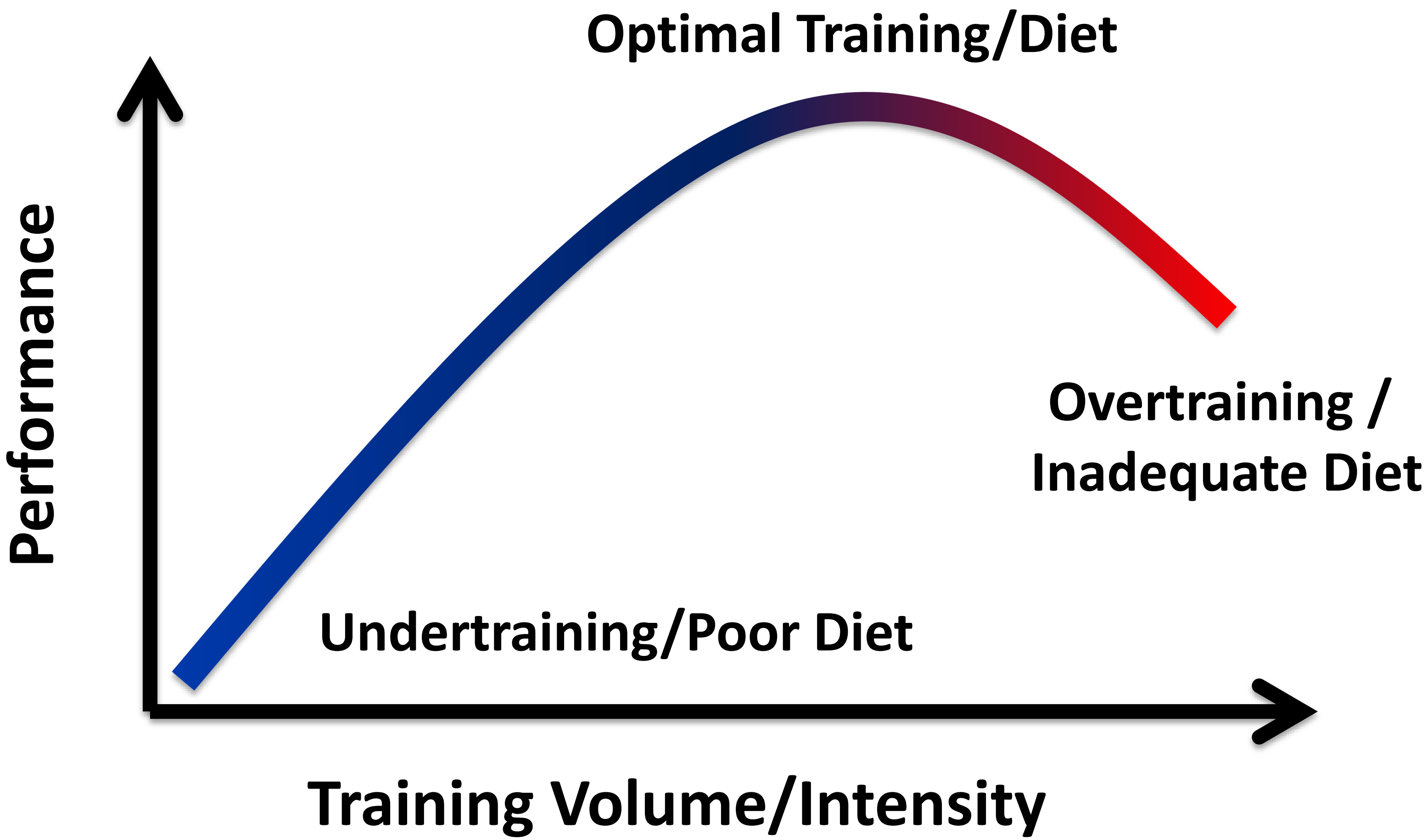
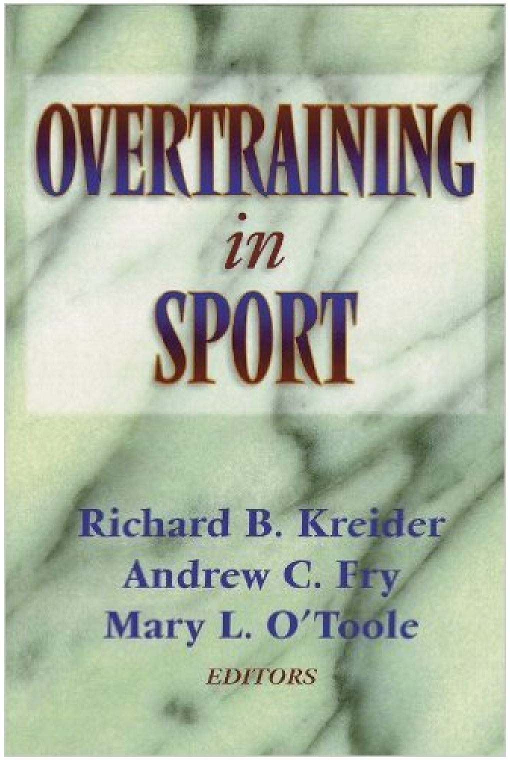
Training Stimulus



Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) Overtraining in Sport. Human Kinetics Publishers, Champaign, IL, 1998, 403 p.

Overreaching

An accumulation of training and/or non-training stress resulting in a short-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of overtraining in which restoration of performance capacity may take from several days to several weeks.



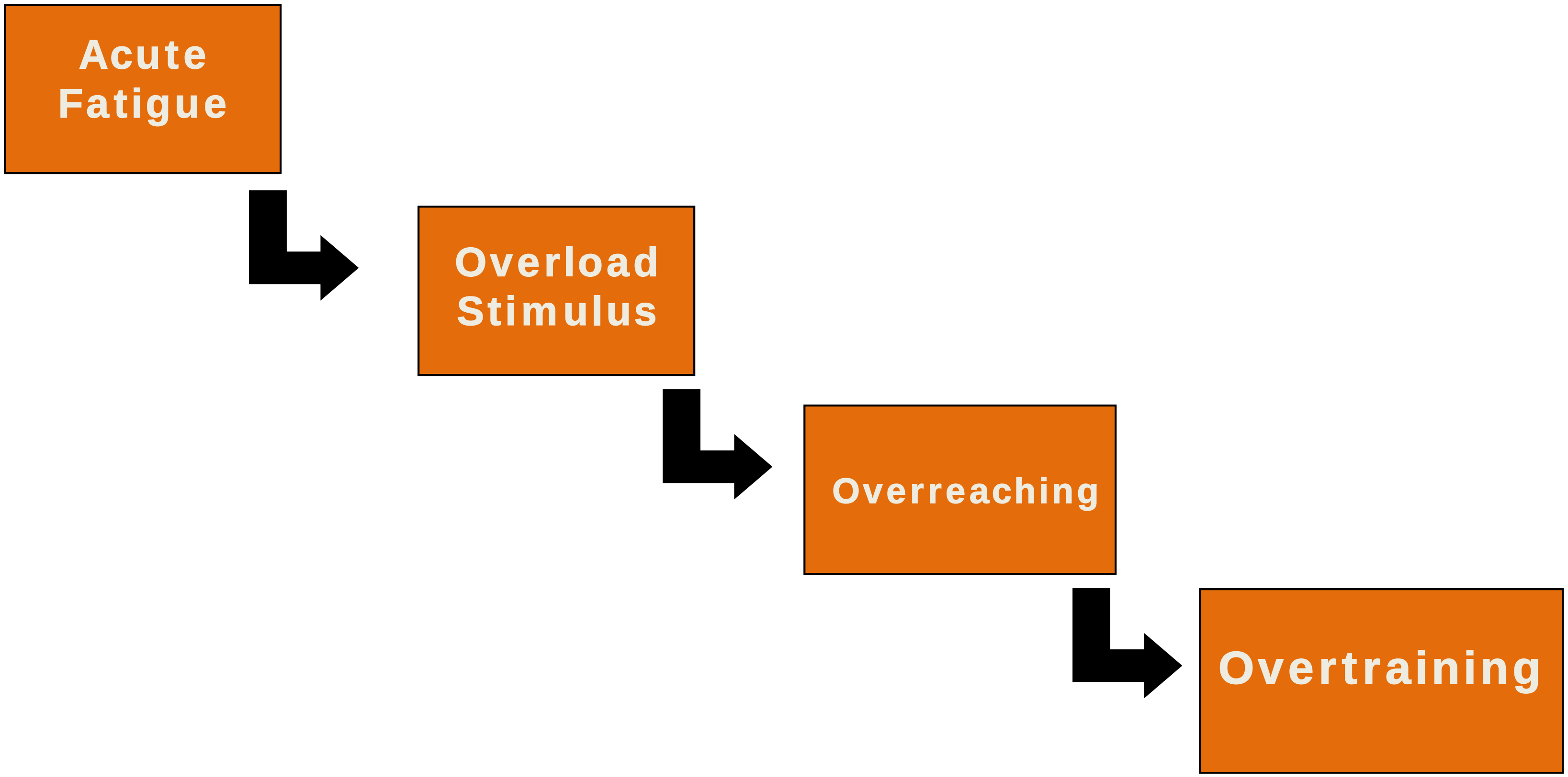
Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) **Overtraining in Sport**. Human Kinetics Publishers, Champaign, IL, 1998, 403 p.

Overtraining

An accumulation of training and/or non-training stress resulting in a long-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of overtraining in which restoration of performance capacity may take from several weeks to several months.

Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) **Overtraining in Sport**. Human Kinetics Publishers, Champaign, IL, 1998, 403 p.

Simplified Four Stage Process Leading To Overtraining



Markers of Overtraining

Physiological/Performance

- Increased frequency and depth of respiration
- Decreased body fat
- Increased oxygen consumption, ventilation, and HR at submaximal workloads
- Shift of the lactate curve towards the x axis
- Decreased evening post-workout weight
- Elevated basal metabolic rate
- Chronic fatigue
- Insomnia with and without night sweats
- Feels thirsty on a constant basis
- Anorexia nervosa and/or bulimia
- Loss of appetite
- Amenorrhea/oligomenorrhea
- Headaches
- Nausea
- Increased aches, pains, soreness
- Gastrointestinal disturbances

Fry et al. Sports Medicine. 2:32-65., 1991

Markers of Overtraining

Psychological

- Feelings of depression
- General apathy
- Decreased self-esteem/worsening feelings of self
- Emotional instability
- Difficulty in concentrating at work and training
- Sensitive to environmental and emotional stress
- Fear of competition
- Changes in personality
- Decreased ability to narrow concentration
- Increased internal and external distractibility
- Decreased capacity to deal with large amounts of information
- Gives up when the going gets tough

Fry et al. Sports Medicine. 2:32-65., 1991

Parasympathetic Markers

Endurance Overtraining

- Decreased performance
- Decreased body fat
- Decreased maximal oxygen uptake
- Altered blood pressure
- Increased muscle soreness
- Decreased muscle glycogen
- Altered resting heart rate
- Heart rate variability
- Increased submaximal exercise heart rate
- Decreased maximal lactate
- Increased creatine kinase

Kraemer, W.J. Physiological Adaptations to Anaerobic and Aerobic Endurance Training Programs. In T.R. Baechle and R.W. Earle. (Eds.). Essentials of Strength Training and Conditioning (2nd ed.) Champaign, IL: Human Kinetics. 2000.

- Altered cortisol concentration
- Decreased total testosterone concentration
- Decreased ratio of total testosterone to cortisol
- Decreased ratio of free testosterone to cortisol
- Decreased ratio of total testosterone to sex hormone-binding globulin
- Decreased sympathetic tone (decreased nocturnal and resting catecholamines)
- Increased sympathetic stress response

Sympathetic Markers

Anaerobic Overtraining

- ***Psychological***
  - decreased desire and joy to train
- ***Hormonal***
  - Epinephrine and norepinephrine increases beyond normal exercise-induced levels (sympathetic overtraining system)
- ***Performance Decrements***
  - May be too late to be a good predictor to avoid overtraining

Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) Overtraining in Sport. Human Kinetics Publishers, Champaign, IL, 1998, 403 p.

Overtraining

Associated Factors

Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) **Overtraining in Sport**. Human Kinetics Publishers, Champaign, IL, 1998, 403 p.

- Sharp increases in training
- Training too often, too intensely, and/or too frequently
- Lack of rest/recovery days during training
- Training boredom/monotony
- Compulsive behavior toward training
- Poor performance / excessive competitiveness
- Inadequate and/or energy deficient diet
- Ignoring signs/symptoms

Overtraining Theories

Overtraining

Energy Deficit Theory

Increased Infections

Decreased Hunger

Suppressed Appetite

Decreased Energy Intake

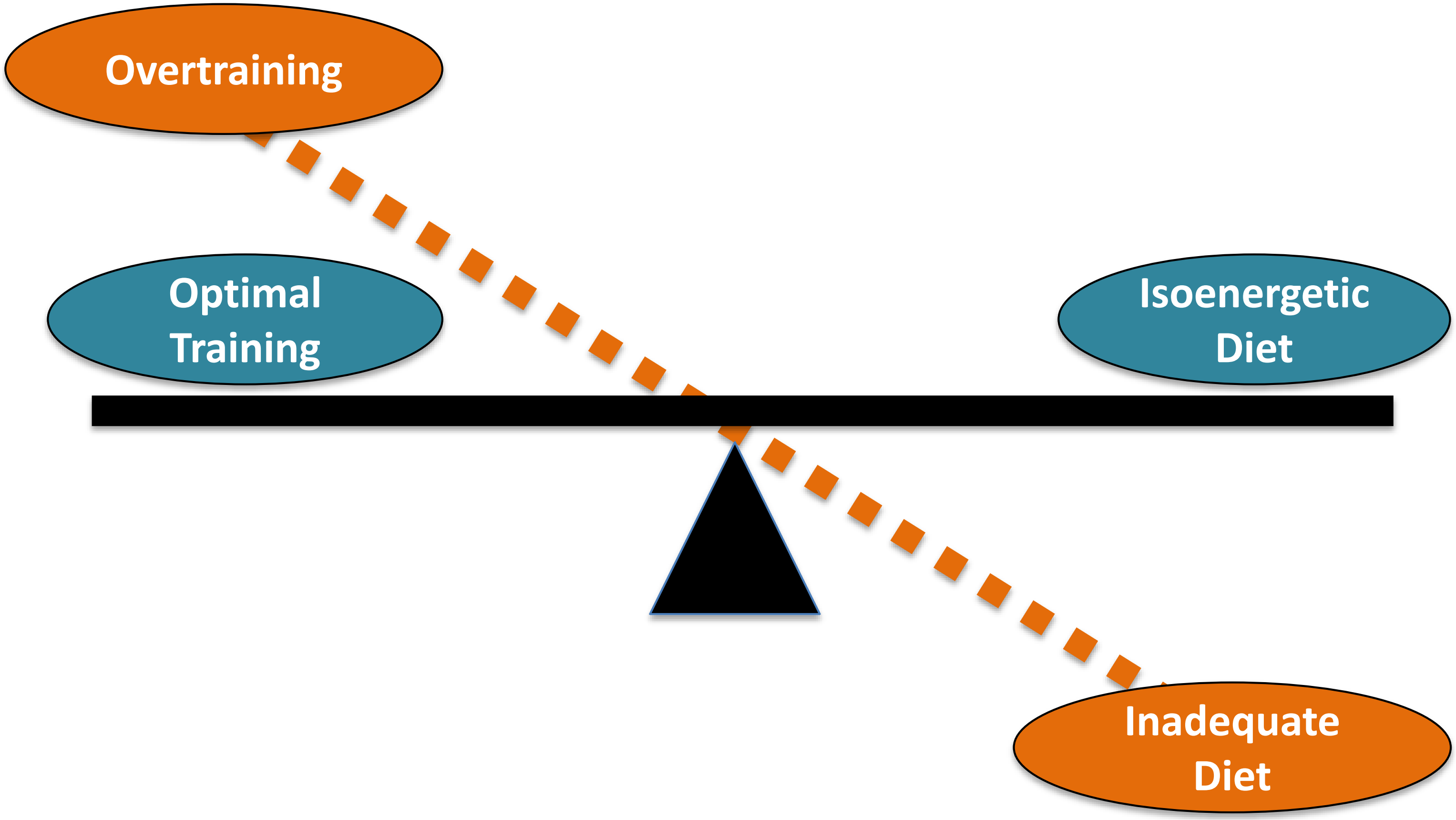
Weight Loss / Muscle Wasting

Fatigue / Poor Performance

Increased Risk to Injury

Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) Overtraining in Sport. Human Kinetics Publishers, Champaign, IL, 1998.

Relationship of Energy Intake



Overtraining

Role of Energy Intake

- Athletes often maintain negative energy balances during heavy training
- Chronic energy deficits suggested as a precursor to overtraining
- Overtrained athletes often experience decreased hunger and appetite suppression leading to weight loss and muscle wasting.
- Associated with female *and* male athlete triad.
- Need to ensure that athletes ingest an isoenergetic, nutrient dense diet with sufficient CHO to maintain glycogen stores

Overtraining

Factors Affecting Energy Intake

- Hunger and appetite
- Eating behaviors
- Food availability and time constraints
- Training phase
- Hormonal influences
- Psychological factors
- Social factors
- Environmental factors

Berning, J. *Energy intake, diet, and muscle wasting*. In Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) Overtraining in Sport. Human Kinetics Publishers, Champaign, IL, 1998.

Overtraining

Glycogen Depletion Theory

- Carbohydrate is the primary fuel for exercise
- Successive days of intense and prolonged training may deplete muscle glycogen levels
- Overreached and overtrained athletes may have lower glycogen levels
- Maintaining adequate glycogen levels is associated with positive training adaptations

Sherman, M. et al. *Carbohydrate metabolism during endurance exercise.* In Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) **Overtraining in Sport**. Human Kinetics Publishers, Champaign, IL, 1998.

Overtraining

Central Fatigue Theory

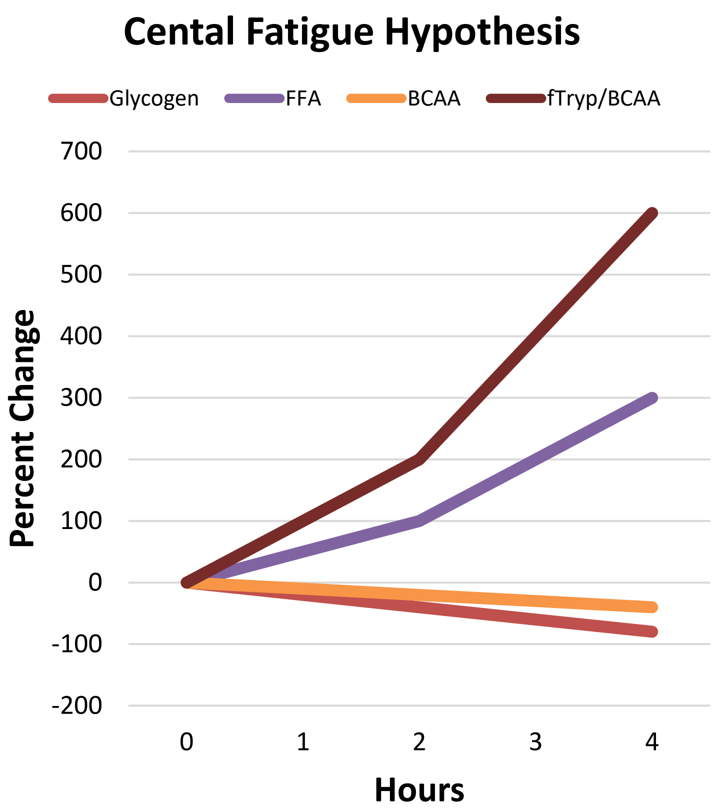
A subset of fatigue that is associated with alterations in CNS function that cannot be reasonably explained by peripheral markers of muscle fatigue.

Davis, J.M. Int. J. Sports Nutri. 5:S29-38, 1995

Overtraining

Central Fatigue Theory

- As FFA increase during exercise (> 1mmol/L), tryptophan which is bound to albumin is released into the blood
- Plasma BCAA levels decline due to increase oxidation as fuel
- Ratio of free tryptophan to BCAA increases promoting entry of tryptophan into the brain
- 5-HT (serotonin) levels increase in the brain and CNS



Kreider, R. *Central fatigue and overtraining.* In Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) Overtraining in Sport. Human Kinetics Publishers, Champaign, IL, 1998.

Overtraining

Central Fatigue Theory

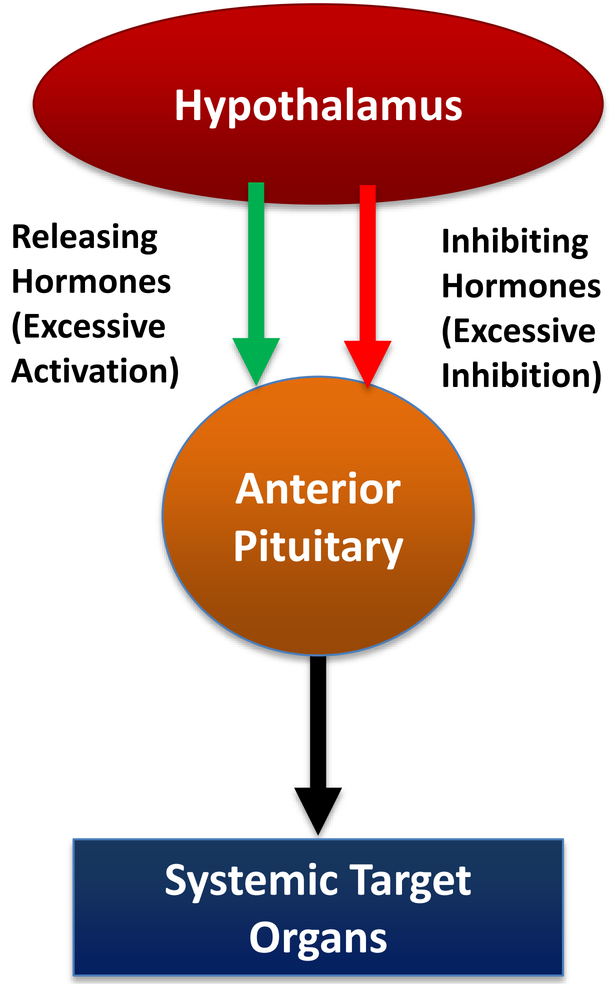
- 5-HT induces sleep, depresses motor neuron excitability and muscle power output, influences autonomic and endocrine function, suppresses appetite, affects psychological perception of fatigue, alters hormone regulation
- Chronic elevations in 5-HT have been reported in overtrained athletes and may explain some signs and symptoms of overtraining.

Kreider, R. *Central fatigue and overtraining.* In Kreider, R.B., A.C. Fry, and M.L. O'Toole (Eds.) **Overtraining in Sport**. Human Kinetics Publishers, Champaign, IL, 1998.

Overtraining

Hormone Dysregulation Theory

- Excessive exercise and/or inadequate energy intake down-regulates the hypothalamic-pituitary axis (HTPA)
- Leads to inadequate production of anterior and/or posterior pituitary hormones
- Altered hormonal status slows recovery from exercise
- Associated with overreaching, overtraining, and female (and male) athlete triad.

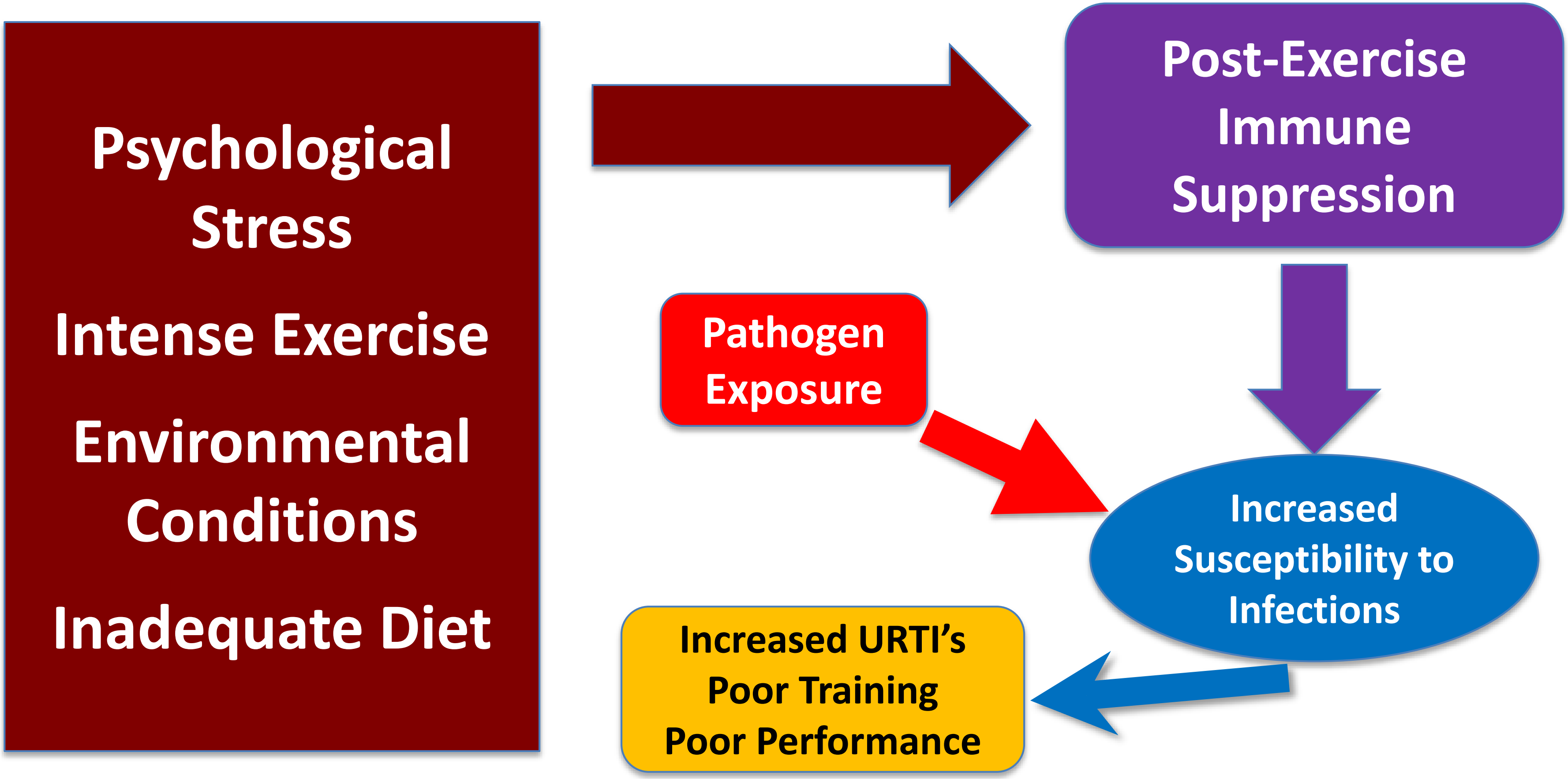


Hormonal Regulation Hypothesis

Gland	Hormone	Major Target Organs	Major Physiologic Effects
Anterior Pituitary	**Growth hormone**	Liver, adipose tissue	Promotes growth (indirectly), control of protein, lipid and carbohydrate metabolism
	Thyroid-stimulating hormone	Thyroid gland	Stimulates secretion of thyroid hormones
	Adrenocorticotropic hormone	Adrenal gland (cortex)	Stimulates secretion of glucocorticoids
	Prolactin	Mammary gland	Milk production
	Luteinizing hormone	Ovary and testis	Control of reproductive function
	Follicle-stimulating hormone	Ovary and testis	Control of reproductive function
Posterior Pituitary	**Antidiuretic hormone**	Kidney	Conservation of body water
	Oxytocin	Ovary and testis	Stimulates milk ejection and uterine contractions

Overtraining

Immunosuppression Theory



Markers of Overtraining

Immunological

- Increased susceptibility to and severity of illness, colds & allergies
- Flu-like illnesses
- Unconfirmed glandular fever
- Minor scratches heal slowly
- Swelling of the lymph glands
- One-day colds
- Decreased functional activity of neutrophils
- Decreased total lymphocyte counts
- Reduced response to mitogens
- Increased blood eosinophil count
- Decreased proportion of non-T, non-B lymphocytes
- Increased release of cytokines
- Significant variations in CD4:CD8 lymphocytes
- Bacterial infection
- Reactivation of herpes viral infection

Fry et al. Sports Medicine. 2:32-65, 1991.

Factors Affecting Immunosuppression

- Fasting/ inappropriate diet
- Low Glycogen stores
- Dehydration
- Sleep Deprivation
- Altitude (hypoxia)
- Jet Lag
- Psychological stress
- Extremes of heat/ cold
- Weather conditions
- Over-exertion

Overtraining

Recovery Theory

- Overtraining may be due to a lack of planned rest and recovery during intense training and/or stressful periods of training or competition.
- Need to plan for adequate sleep and recovery from intense training
- Need to plan tapering from training prior to competition

Strategies to Prevent Overtraining

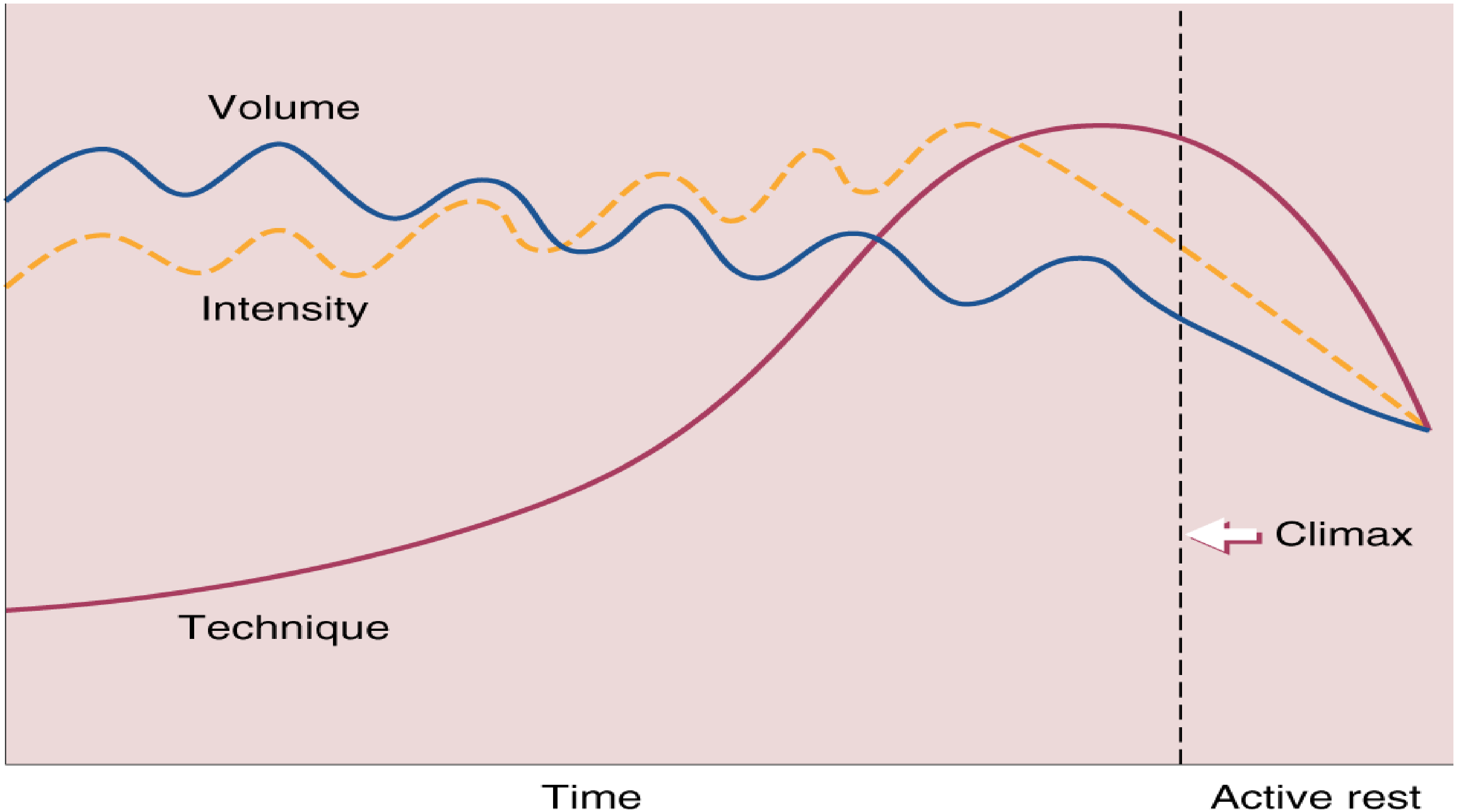
Preventing Overtraining

Proper Program Design

- Proper starting level
- Proper progression
- Periodized Training
- Training Variety
- Plan for adequate recovery

Modifications Model of Periodization

Advanced Athletes



Baechle T.R. and R.W. Earl. ***Essentials of Strength and Conditioning*** Association. 2nd Ed. 2000. Fig. 22.3

Period	Preparation →		First transition	Competition		
Phase/ Variable	**Hypertrophy / Endurance**	**Basic Strength**	**Strength / Power**	**Peaking**	**Maintenance**	**Second Transition (active rest)**
Intensity	**Low to moderate**	**High**	**High**	**Very High**	**Moderate**	
	50-75% 1RM	80-90% 1RM	87-95% 1RM† 75-90% 1RM†	$\geq$ 93% 1RM	~80-85% 1RM	**Recreational Activity (may not involve resistance exercise)**
Volume	High to moderate	Moderate	Low	Very Low	Moderate	
	3 – 6 Sets	3 – 5 Sets	3 – 5 Sets	1 – 3 Sets	~2 – 3 Sets	
	10 – 20 Repetitions	4 – 8 Repetitions	2 – 5 Repetitions	1 – 3 Repetitions	~6 – 8 Repetitions	

Adapted from Baechle T.R. and R.W. Earl. ***Essentials of Strength and Conditioning*** Association. 2nd Ed. 2000. Table 22.1

Preventing Overtraining

Recovery Plan

- Incorporate a recovery plan into program design / training schedules
- Ensure adequate sleep for athletes
- Increase recovery time after intense training bouts
- Reduce training volume and/or intensity during stressful periods and prior to competition
- Consider travel and time constraints

Preventing Overtraining

Recovery Nutrition

- Maintain an Energy Sufficient Diet
- Rehydration
- Glycogen Replenishment
- Promote Anabolism and Reduce Catabolism
- Manage Inflammation
  - Creatine
  - Tart cherries
  - Nitrates
- Support the Immune System
- Pre-sleep Nutrition

Nutritional Guidelines

Active Individuals and Athletes

- **Carbohydrate** (55%-65% of calories)
  - 3 – 5 g/kg/d – general fitness
  - 5 – 8 g/kg/d – moderate training
  - 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

Nutritional Guidelines

Strength / Power Athletes

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

- **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

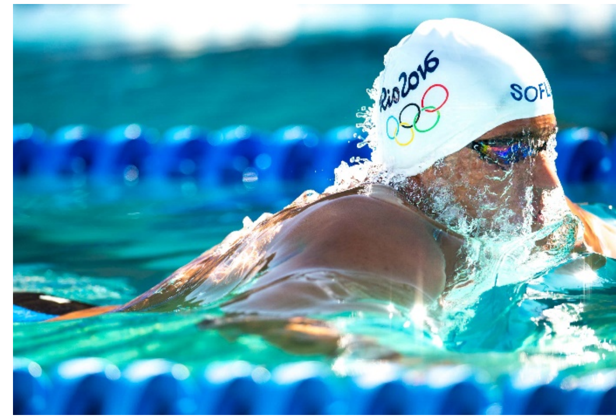
Kerksick et al., JISSN. In press, 2018

Nutritional Guidelines

Nutrient Timing

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

- 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

Preventing Overtraining

Rehydration

- GES ingestion during exercise helps maintain BG, prevent dehydration, delay central fatigue, and reduce immunosuppressive effects of intense exercise.
- Athletes should try to not lose more than 1 – 2% of their total body weight through sweat during an exercise bout or competition.
- Chronic dehydration compromises performance and increases susceptibility to dehydration and heat illness.
- Athletes should rehydration with ***2-3 cups*** of water or sports drink ***per 1 lbs. or 0.5 kg of body weight lost*** and make sure they are rehydrated after each workout.

Preventing Overtraining

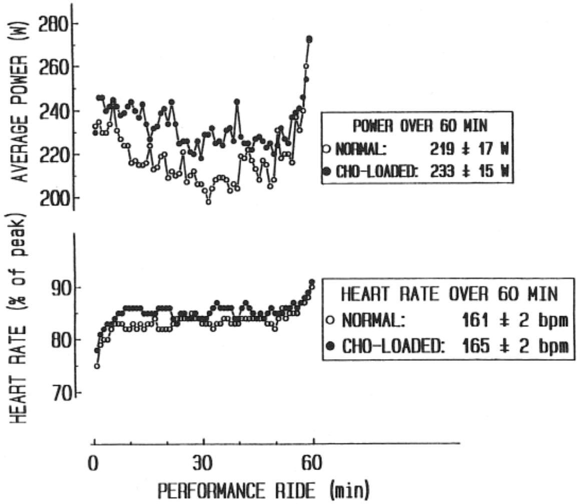
Replenish Glycogen

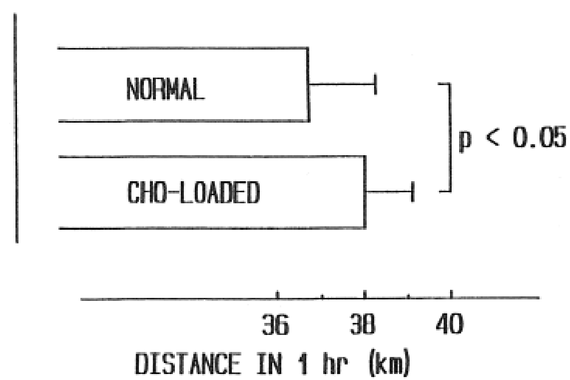
- Intramuscular and hepatic glycogen stores are best maximized by consumption of a high-CHO diet (5–8 g/kg/d during moderate training and 8–12 g/kg/d during heavy training).
- CHO feedings (> 8 g/kg/d or 1.2 g/kg/hour) during the first 4-hours following exercise that favor high-glycemic CHO (> 70) promote rapid restoration of glycogen stores.
- Athletes should emphasize CHO ingestion during the first 4 hrs after intense exercise.

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.





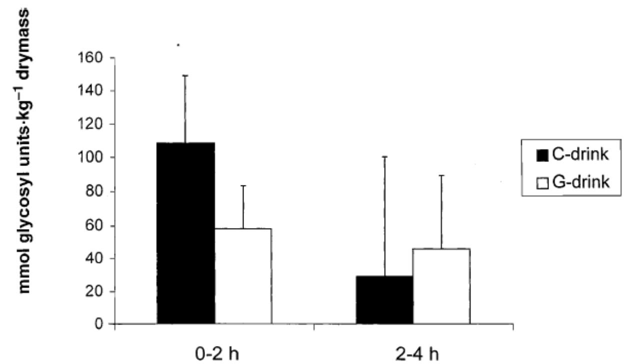
Muscle glycogen resynthesis rate in humans after supplementation of drinks containing carbohydrates with low and high molecular masses.

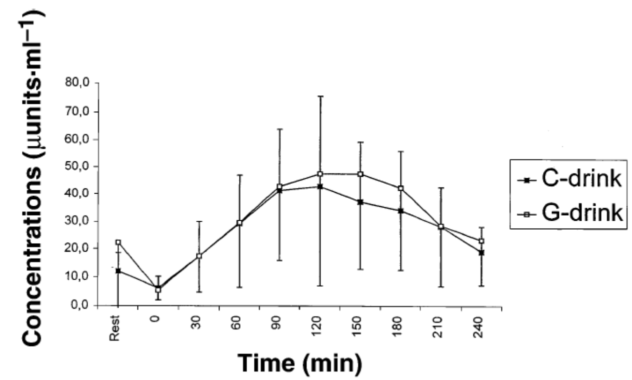
Piehl et al. Eur J Appl Physiol. 81(4):346-51, 2000

- 13 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 (+68%) during the initial 2 h with high MMM drink compared to the low MMM 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, indicating a more delayed replenishment rate with low MMM.
- 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)

*$P < 0.06$, # $P < 0.06$





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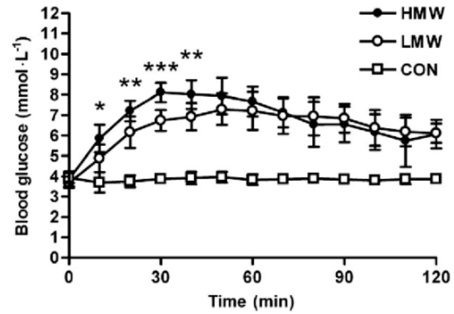
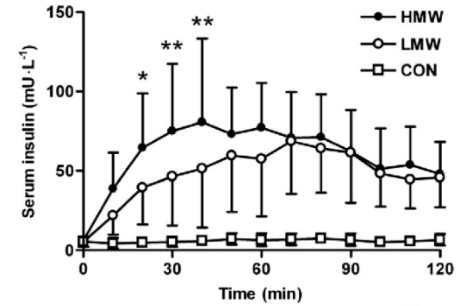
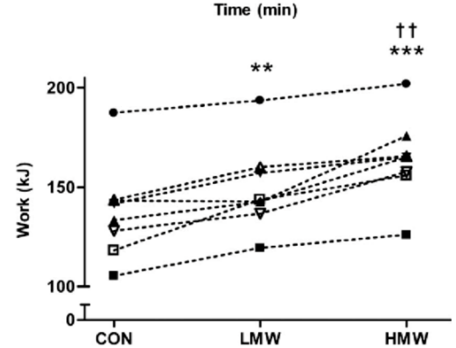
Post-exercise ingestion of a unique, high molecular weight glucose polymer solution improves performance during a subsequent bout of cycling exercise

Stephens et al. J Sports Sci. 26(2):149-54, 2008

- 8 healthy men cycled to exhaustion at 73.0% (s = 1.3) maximal oxygen uptake (90:15 min).
- Participants consumed a one-liter solution containing sugar-free flavored water (control), ***100 g of a low molecular weight glucose polymer (LMW) or 100 g of a very high molecular weight (HMW) glucose polymer, and rested on a bed for 2 h***.
- After recovery, a 15-min time-trial was performed on a cycle ergometer, during which work output was determined.
- Post-exercise ingestion of the very HMW glucose polymer solution resulted in ***faster and greater increases in blood glucose*** ($P < 0.001$) ***and serum insulin*** ($P < 0.01$) concentrations than the LMW glucose polymer solution, and ***greater work output during the 15-min time-trial*** (164.1 kJ, s = 21.1) than both the sugar-free flavored water (137.5 kJ, s = 24.2; $P < 0.05$) and the low molecular weight glucose polymer (149.4 kJ, s = 21.8; $P < 0.05$) solutions.
- ***Ingestion of HMW glucose polymers facilitated rapid re-synthesis of the muscle glycogen store during recovery following prolonged sub-maximal exercise***.



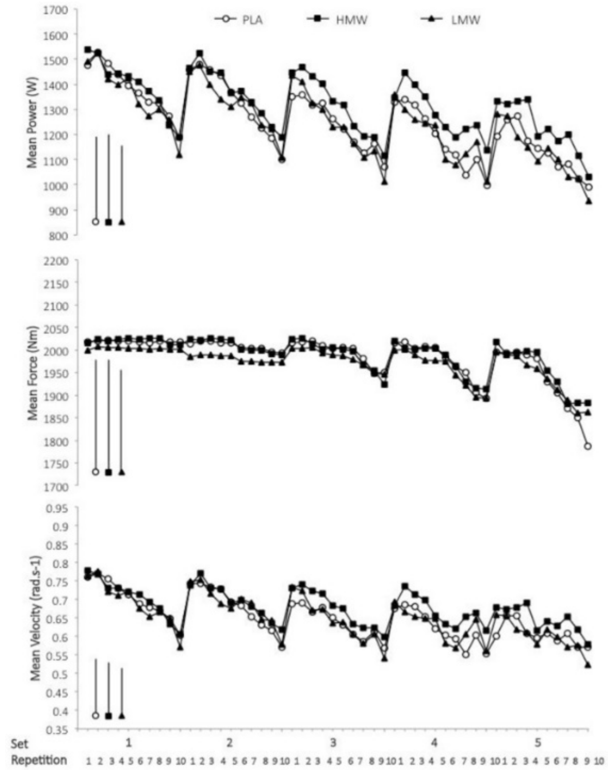




Ingestion of high molecular weight carbohydrate enhances subsequent repeated maximal power: a randomized controlled trial

Oliver et al. PLoS One. 16;11(9), 2016

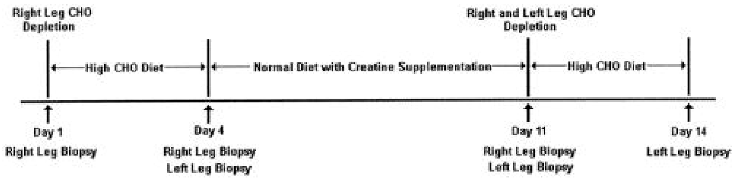
- 16 RT men participated in a DBPCRCO study comprising a ***muscle-glycogen depleting cycling exercise followed by ingestion of placebo (PLA), or 1.2 g/kg of LMW or HMW carbohydrate solution (10%).***
- Participants then performed ***5 sets x 10 maximal explosive repetitions of back squat @ 75% of 1RM***.
- 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***.

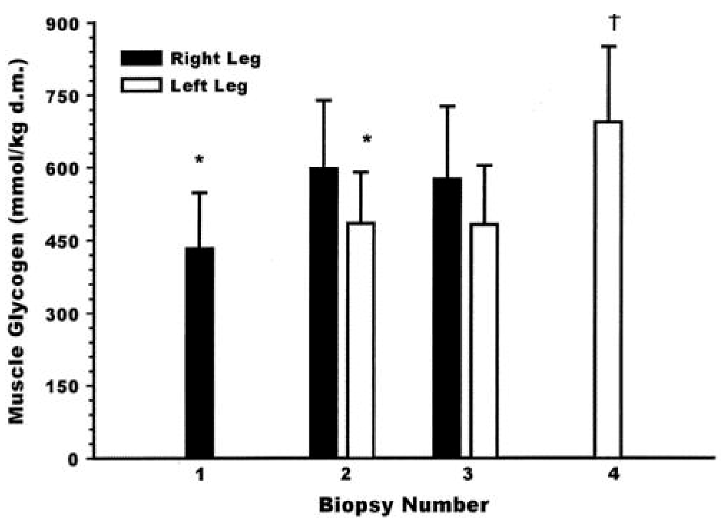


Muscle glycogen supercompensation is enhanced by prior creatine supplementation

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

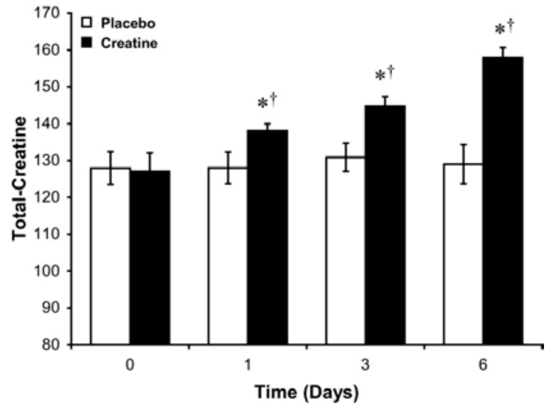
- 12 men performed glycogen loading protocols between a standard creatine load of 20 g/d for 5 d.
- The initial glycogen loading protocol increased muscle glycogen by 4% with no change in total muscle creatine.
- ***Creatine loading showed significant increases in total muscle creatine levels in both 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***.
- 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.

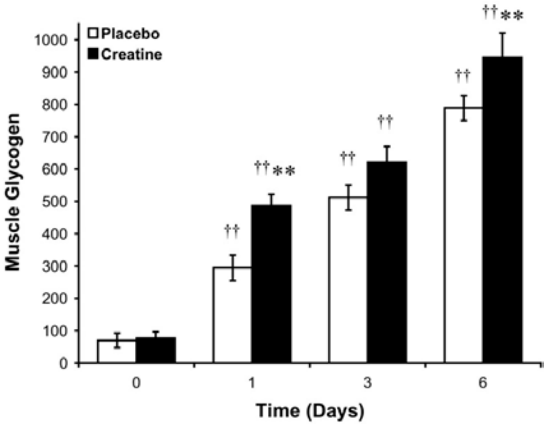




Creatine ingestion augments dietary carbohydrate mediated muscle glycogen supercompensation during the initial 24 h of recovery following prolonged exhaustive exercise in humans *Roberts et al Amino Acids. 48(8):1831-42, 2016*

- 14 healthy, male volunteers cycled to exhaustion at 70 % VO_{2peak}.
- Muscle biopsies were obtained at rest immediately post-exercise and after 1, 3 and 6 days of recovery, during which Cr or placebo supplements (20 g/d) were ingested along with a prescribed high CHO diet (37.5 kcal/kg/d, >80 % calories CHO).
- Oral-glucose tolerance tests (oral-GTT) were performed pre-exercise and after 1, 3 and 6 days of Cr and placebo supplementation.
- Exercise depleted muscle glycogen content to the same extent in both treatment groups.
- Creatine supplementation increased muscle total-Cr, free-Cr and phosphocreatine (PCr) content above placebo following 1, 3 and 6 days of supplementation (all $P < 0.05$).
- ***Creatine supplementation also increased muscle glycogen content noticeably above placebo after 1 day of supplementation (P < 0.05), which was sustained thereafter.***
- This study confirmed dietary ***Cr augments post-exercise muscle glycogen super-compensation, and demonstrates this occurred during the initial 24 h of post-exercise recovery (when muscle total-Cr had increased by <10 %)***



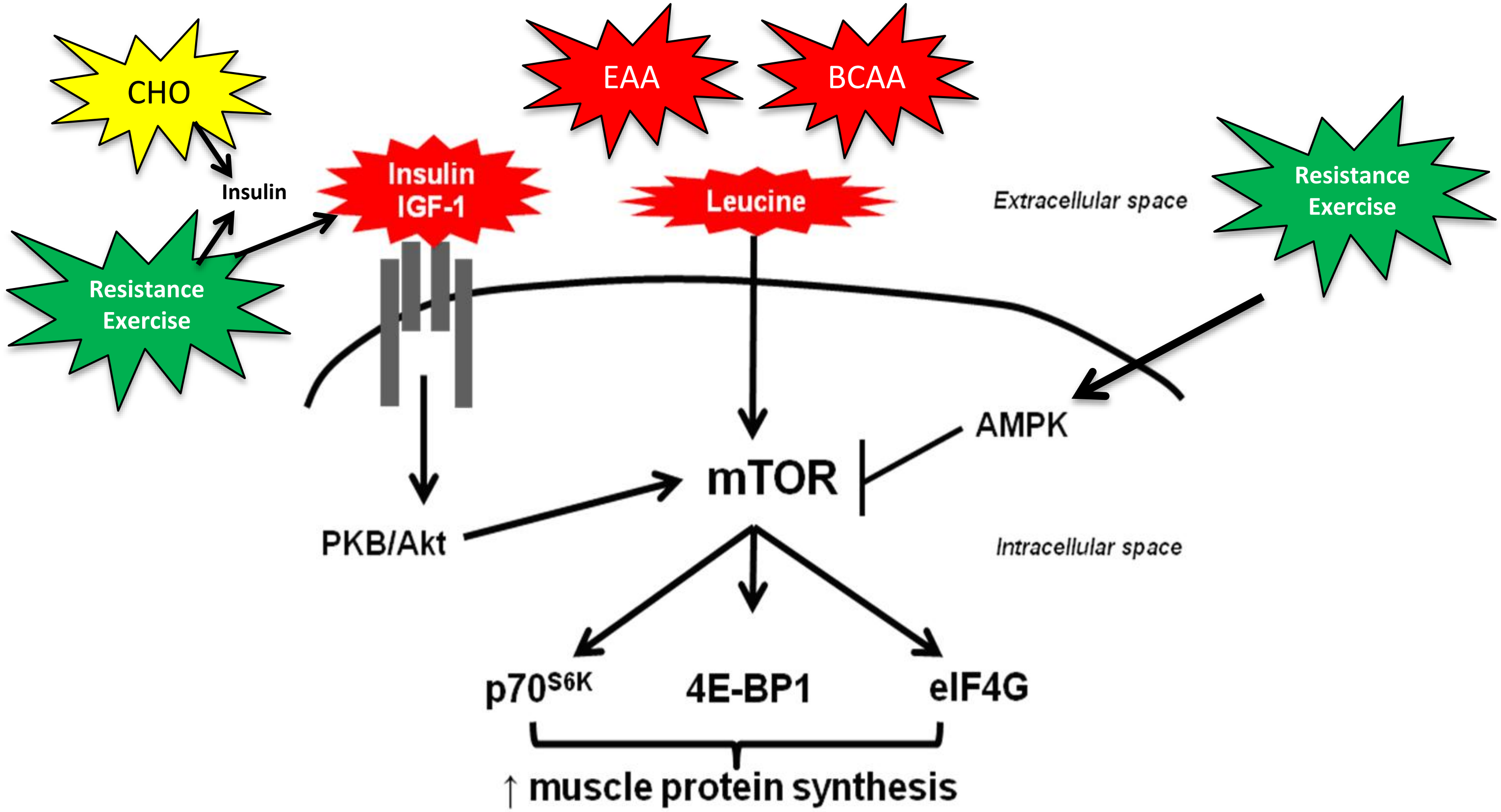


Preventing Overtraining

Promote Anabolism and Reduce Catabolism

- A single bout of resistance training modestly stimulates protein synthesis but also stimulates protein breakdown resulting an overall negative protein balance after exercise.
- Ingestion of protein or EAAs around an exercise bout substantially increases the levels of amino acids in the blood and muscle thereby maintaining a positive protein balance.
- Adding carbohydrate to protein or EAA may enhance glycogen replenishment and augment protein synthesis.

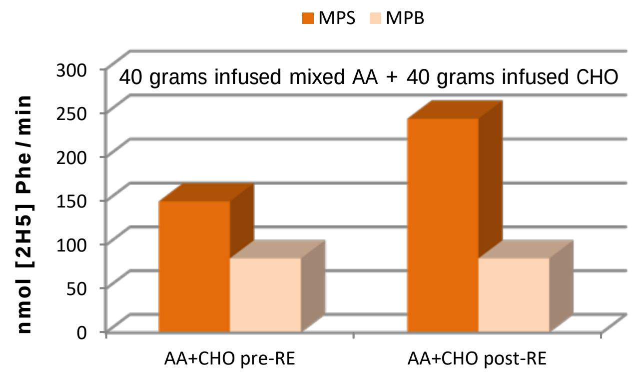
Essential Amino Acids



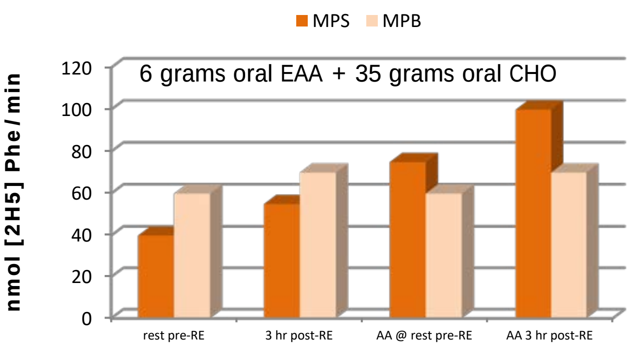
Preventing Overtraining

Carbohydrate/Protein Supplements

- 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***



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

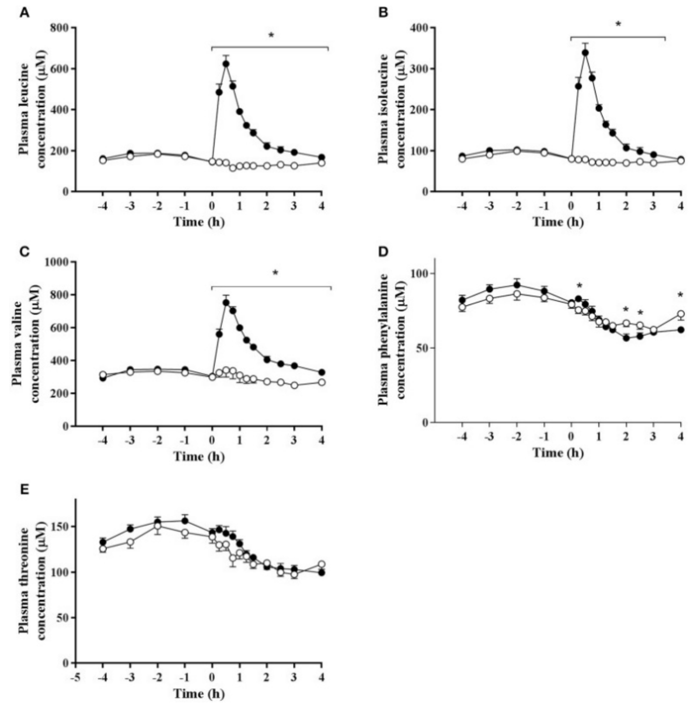


Rasmussen & Phillips. Ex Sport Sci Rev. 31(3): 127-31, 2003

Branched-chain amino acid ingestion stimulates muscle myofibrillar protein synthesis following resistance exercise in humans

Jackman et al. Front Physiol. 8:390, 2017

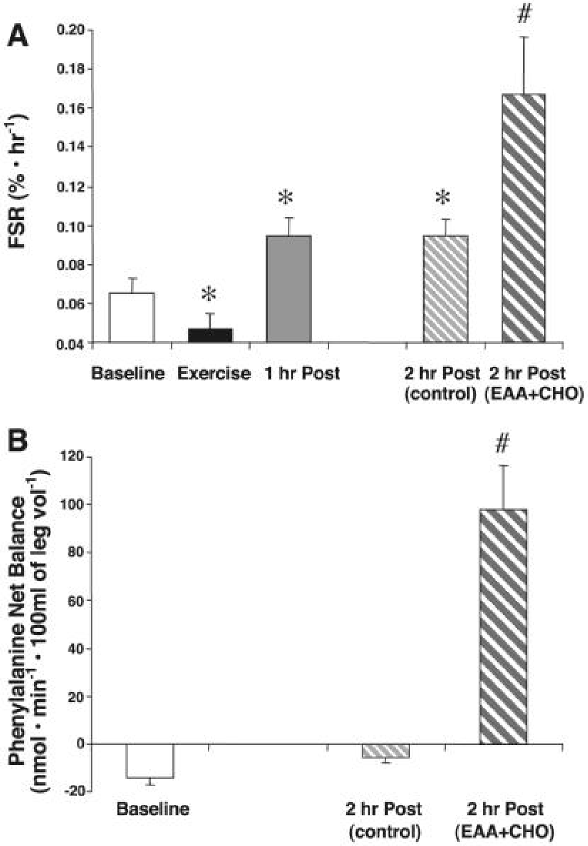
- 10 young RT men completed two trials, ingesting either ***5.6 g BCAA*** or a ***placebo*** (PLA) drink ***immediately after resistance exercise***.
- Myofibrillar-MPS was measured during exercise recovery with a primed, constant infusion of L-[ring13C6] phenylalanine and collection of ***muscle biopsies pre and 4 h-post drink ingestion***.
- The percentage increase from baseline in plasma leucine (300 +/- 96%), isoleucine (300 +/- 88%), and valine (144 +/- 59%) concentrations ***peaked 0.5 h-post drink in BCAA***.
- ***A greater phosphorylation status of S6K1Thr389*** and PRAS40 was observed ***in BCAA*** than PLA at 1 h-post drink ingestion.
- ***Myofibrillar-MPS was 22% higher in BCAA (0.110 +/- 0.009%/h) than PLA (0.090 +/- 0.006%/h).***
- Phenylalanine Ra was ~6% lower in BCAA (18.00 +/- 4.31 mumol.kgBM-1) than PLA (21.75 +/- 4.89 mumol.kgBM-1; P = 0.028) after drink ingestion.
- ***Ingesting BCAAs alone increases the post-exercise stimulation of myofibrillar-MPS and phosphorylation status mTORC1 signaling.***



Leucine-enriched essential amino acid and carbohydrate ingestion following resistance exercise enhances mTOR signaling and protein synthesis in human muscle

Dreyer et al. Am J Physiol Endocrinol Metab. 2008 Feb;294(2):E392-400

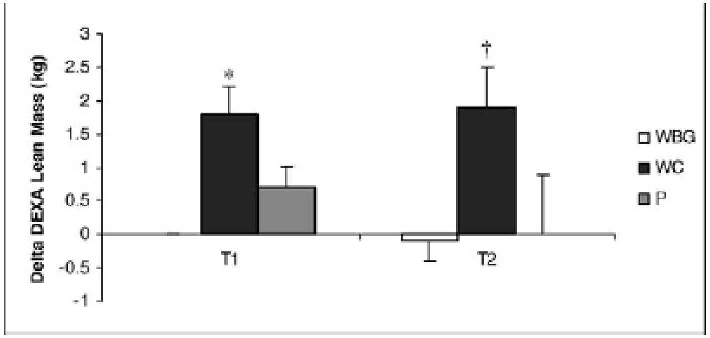
- 16 male subjects were randomized to ingest a ***control or EAA+CHO*** supplement solution 1 h after resistance exercise.
- ***Postexercise FSR was elevated above baseline in both groups at 1 h but was further elevated in the EAA+CHO group at 2 h postexercise***.
- Increased FSR was associated with enhanced phosphorylation of mTOR and S6K1 ($P < 0.05$).
- Akt phosphorylation was elevated at 1 h and returned to baseline by 2 h in the control group, but it remained elevated in the EAA+CHO group.
- 4E-BP1 phosphorylation returned to baseline during recovery in control but became elevated when EAA+CHO was ingested.
- eEF2 phosphorylation decreased at 1 and 2 h postexercise to a similar extent in both groups ($P < 0.05$).
- ***Results suggest that enhanced activation of the mTOR signaling pathway is playing a role in the greater synthesis of muscle proteins when resistance exercise is followed by EAA+CHO ingestion***.

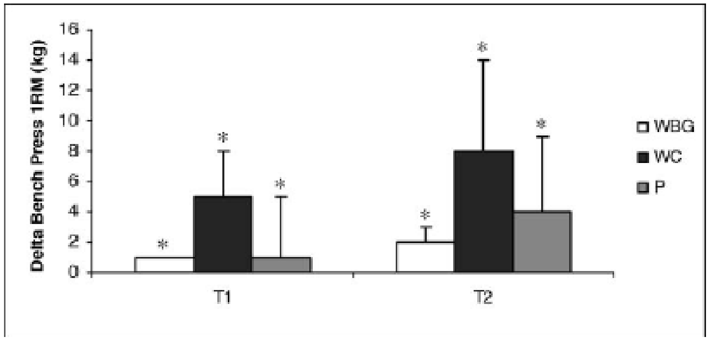


Effects of protein and amino acid supplementation on resistance training adaptations

Kerksick et al. JSCR. 20(3):643-653, 2006

- 36 resistance trained males participated in a 4 d/week resistance training program for 10-weeks
- In a DB-PC-R manner, assigned to supplement diet with:
  - 48 g/d CHO Placebo
  - 40 g/d Whey + 8 g/d Casein
  - 40 g/d Whey + 3 g/d BCAA + 5 g/d glutamine
- Greater change in FFM in WC group
- Similar gains strength, muscular endurance, and anaerobic sprint capacity
- ***Combining fast and slow digesting protein may provide greater benefits than fast digesting proteins and amino acids.***



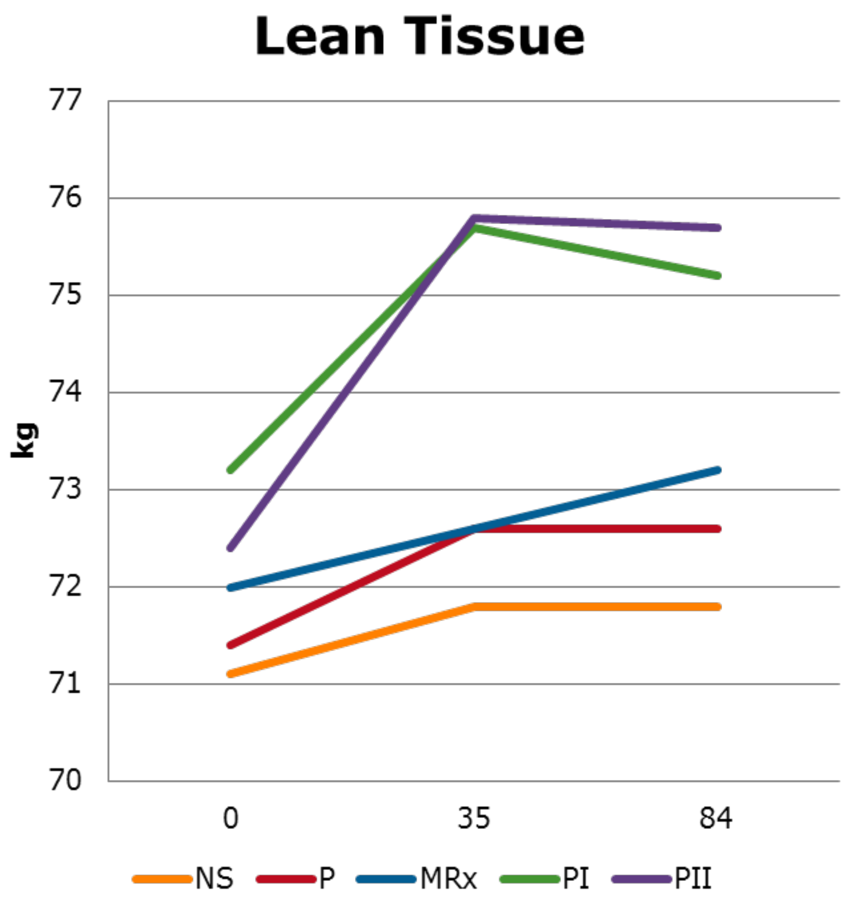


Kerksick et al. ***JSCR.*** *20(3):643-653, 2006.*

Effects of nutritional supplementation during off-season college football training on body composition and 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



Preventing Overtraining

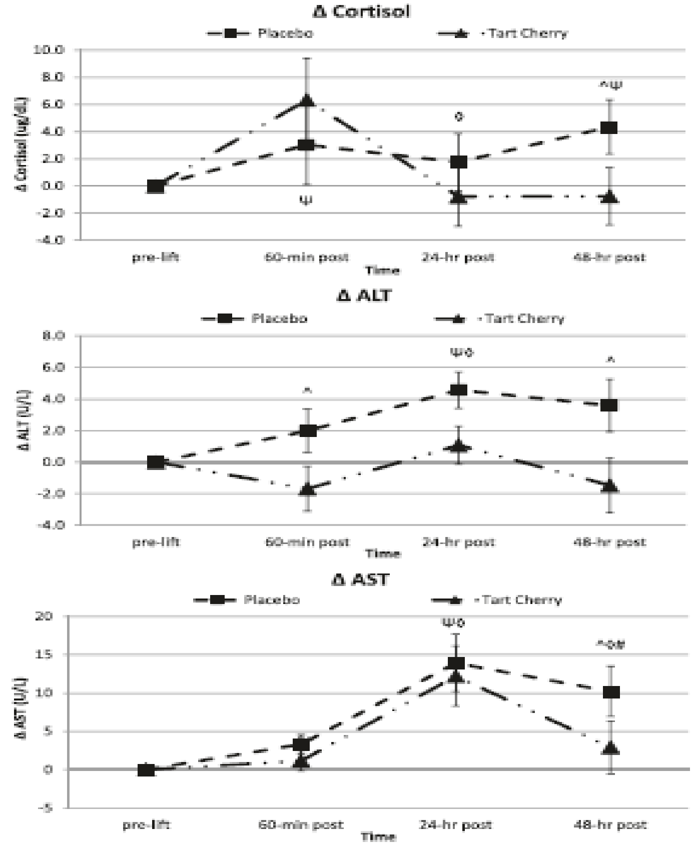
Manage Inflammation

- Endurance athletes experience significant amounts of free radical formation and peroxidation.
- Athletes engaged in intense training and/or training may benefit from diets rich in antioxidant foods (e.g., grapes, blueberries, red berries, green vegetables, nuts).
- Athletes may also benefit from antioxidant supplementation (e.g., vitamin A, β-carotene, vitamin C, vitamin E, selenium, L-carnitine, lutein, zeaxanthin, lycopene, quercetin, resveratrol, glutathione, N-acetyl-cysteine, alpha lipoic acid, creatine, etc.) as a means of minimizing exercise-induced oxidation and muscle damage particularly when training at altitude.

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

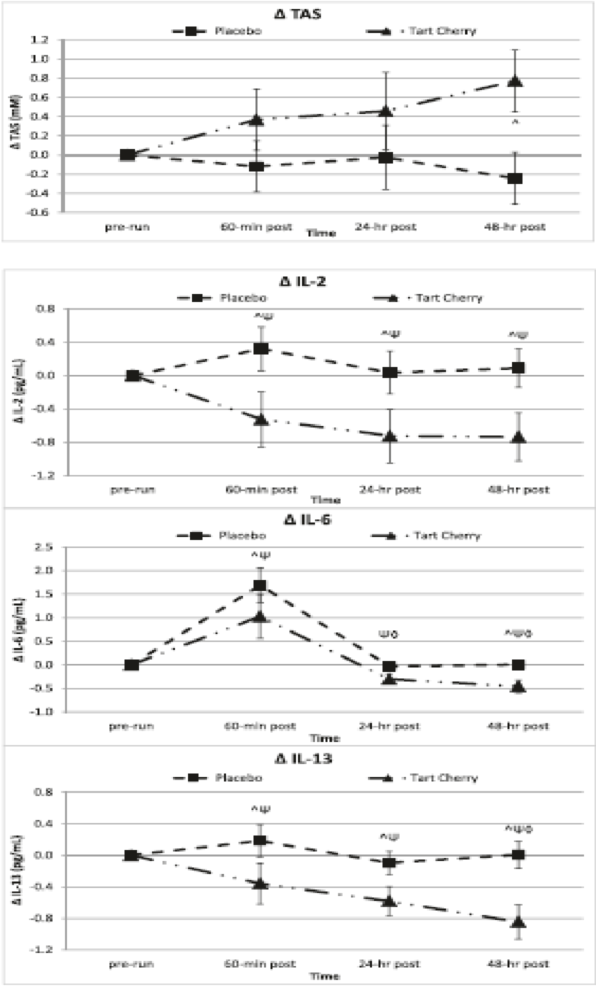
- 23 resistance-trained men were randomly assigned to ingest, in a double blind manner, capsules containing 480 mg/d of a PL or powdered tart cherries (TC) for 10-d prior to and for 48-h post-exercise.
- Subjects performed 10 sets of 10 reps at 70% of a 1-RM back squat exercise after 10-d of supplementation.
- 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

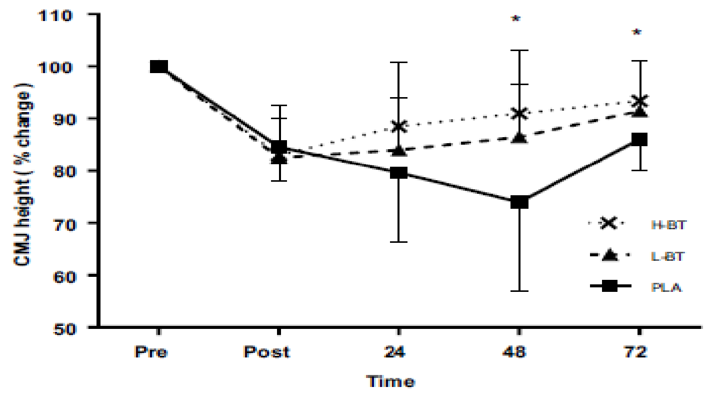
- 27 endurance-trained athletes ingested, in a double-blind manner, capsules containing 480 mg of PL or powdered TC for 10-d prior to performing a half marathon and for 48-hr post-run.
- Fasting blood samples and quadriceps muscle soreness ratings were taken pre-run, 60-min, 24 and 48-h post-run.
- *TC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

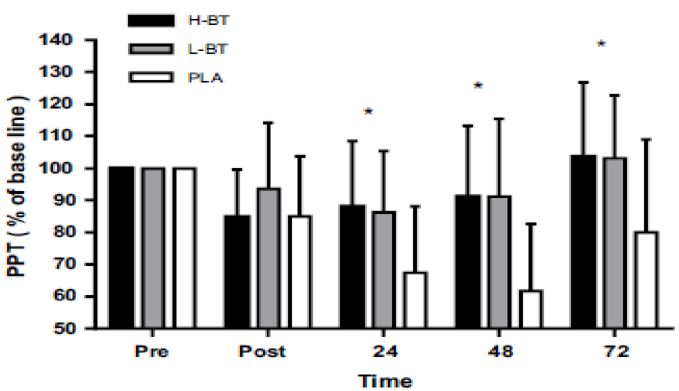


The effects of beetroot juice supplementation on indices of muscle damage following eccentric exercise

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.

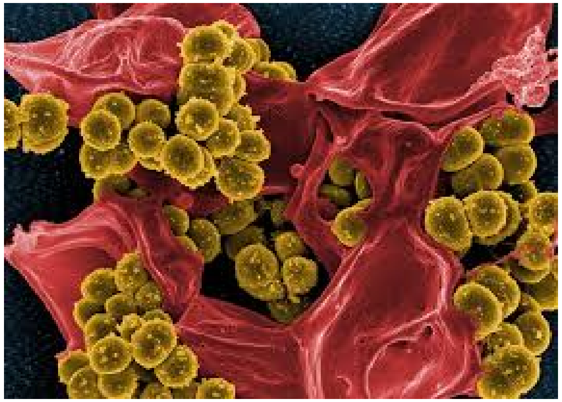




Preventing Overtraining

Immune Support Nutrients

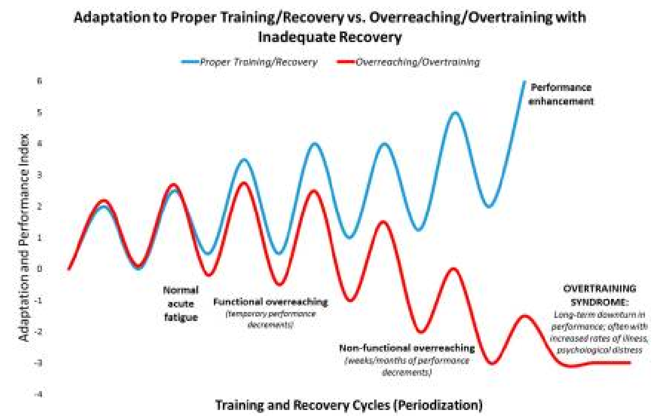
- High intensity exercise can promote immunosuppression and increase risk to upper respiratory tract infections (UTRI).
- Immunosuppression in athletes is further compromised by psychological stress, foreign travel, disturbed sleep, environmental extremes, exposure to large crowds or an increase exposure to pathogens due to elevated breathing during exercise or competition.
- Consuming a ***GES*** during exercise as well as ***vitamin C, glutamine, echinacea, quercetin, and zinc*** supplementation have been reported to enhance immune function.
- Additionally, ***beta-glucan*** and probiotics have also been suggested to help athletes maintain a healthy immune system during training.

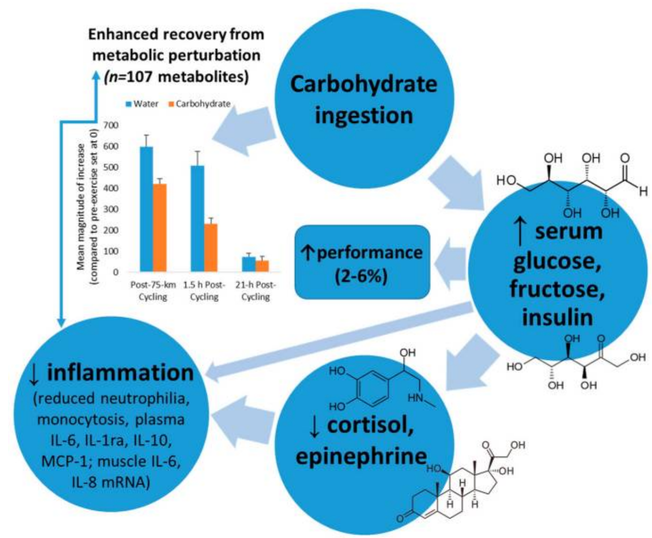


Potential impact of nutrition on immune system recovery from heavy exertion: a metabolomics perspective

Nieman et al. Nutrients. 9(5): 2017

- The most effective nutritional countermeasures, especially when considered from a metabolomics perspective, include acute and chronic increases in dietary ***carbohydrate*** and ***polyphenols***.
- Carbohydrate supplementation reduces post-exercise stress hormone levels, inflammation, and fatty acid mobilization and oxidation.
- Ingestion of fruits high in carbohydrates, polyphenols, and metabolites effectively supports performance, with added benefits including enhancement of oxidative and anti-viral capacity through fruit metabolites, and increased plasma levels of gut-derived phenolics.
- Future targeted lipidomics-based studies will help discover whether ***n-3-polyunsaturated fatty acid (n-3-PUFA)*** supplementation enhances inflammation resolution in athletes post-exercise.

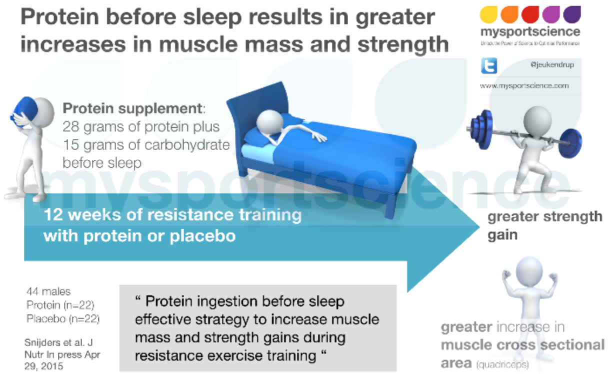




Preventing Overtraining

Pre-Sleep Nutrition

- Casein has a more prolonged release of amino acids compared to whey protein.
- Therefore, it is viewed as a more anticatabolic protein that whey which is more anabolic.
- For this reason, some have contended that ingestion of casein protein before sleeping at night may be an effective strategy to maintain availability of amino acids during the nighttime fast thereby preventing excessive muscle protein breakdown.
- Theoretically, this may lead to greater training adaptations over time. There is some support for this theory.



Pre-sleep protein ingestion to improve the skeletal muscle adaptive response to exercise training

Trommelen and van Loon. Nutrients. 8:763, 2016

- ***Overnight muscle protein synthesis rates are restricted by the level of amino acid availability***.
- Protein ingested prior to sleep is effectively digested and absorbed, and thereby stimulates muscle protein synthesis rates during overnight recovery.
- Recent studies investigating the impact of pre-sleep protein ***ingestion suggest that at least 40 g of protein is required to display a robust increase in muscle protein synthesis rates throughout overnight sleep***.
- ***Prior exercise allows more of the pre-sleep protein-derived amino acids to be utilized for de novo muscle protein synthesis during sleep***.
- ***Pre-sleep protein ingestion represents an effective dietary strategy to improve overnight muscle protein synthesis***, thereby improving the skeletal muscle adaptive response to exercise training.

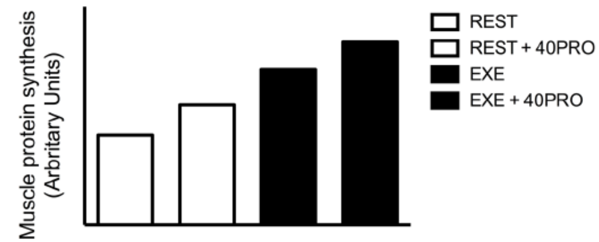


Table 1

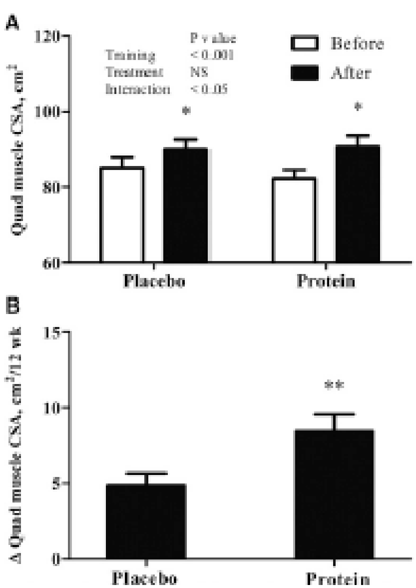
Quantity of protein sources to provide 40 g pre-sleep protein.

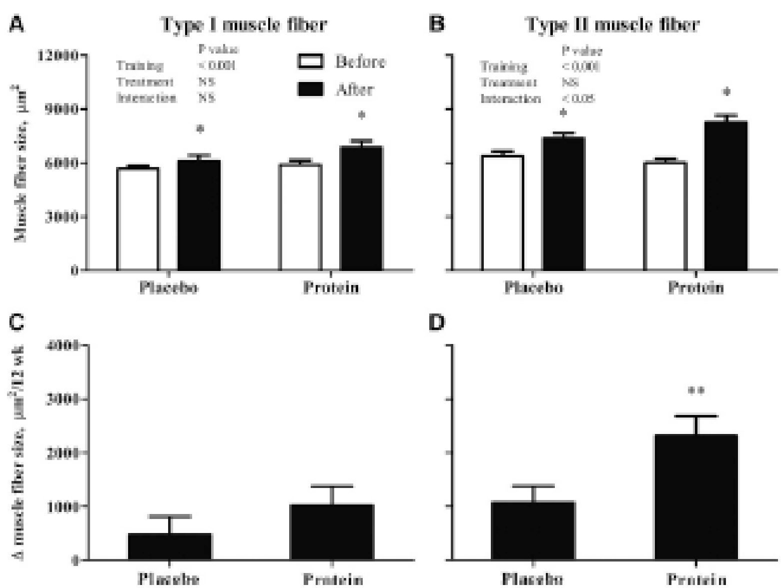
Food Item	Quantity
Cooked eggs	7 eggs
Low fat milk	5 cups (1025 mL)
Low fat yogurt	5 cups (1176 mL)
Chicken breast	2 breasts (176 g)
Steak	2 steaks (168 g)
Protein concentrate in water	3 scoops (60 g)
Protein concentrate in low-fat milk	2 scoops in 300 mL

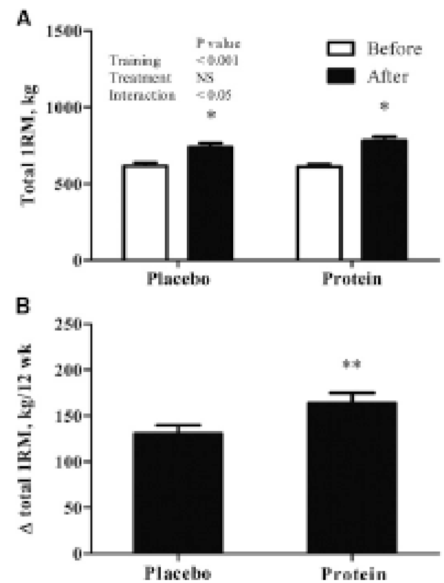
Protein ingestion before sleep increases muscle mass and strength gains during prolonged resistance-type exercise training in healthy young men

Snidjers et al. J Nutr. 2015 Jun;145(6):1178-84

- 44 young men were randomly assigned to a progressive, 12-wk resistance exercise training program.
- One group consumed a protein supplement containing ***27.5 g of protein, 15 g of carbohydrate, and 0.1 g of fat every night before sleep***.
- ***Protein ingestion before sleep represents an effective dietary strategy to augment muscle mass and strength gains during resistance exercise training in young men***.







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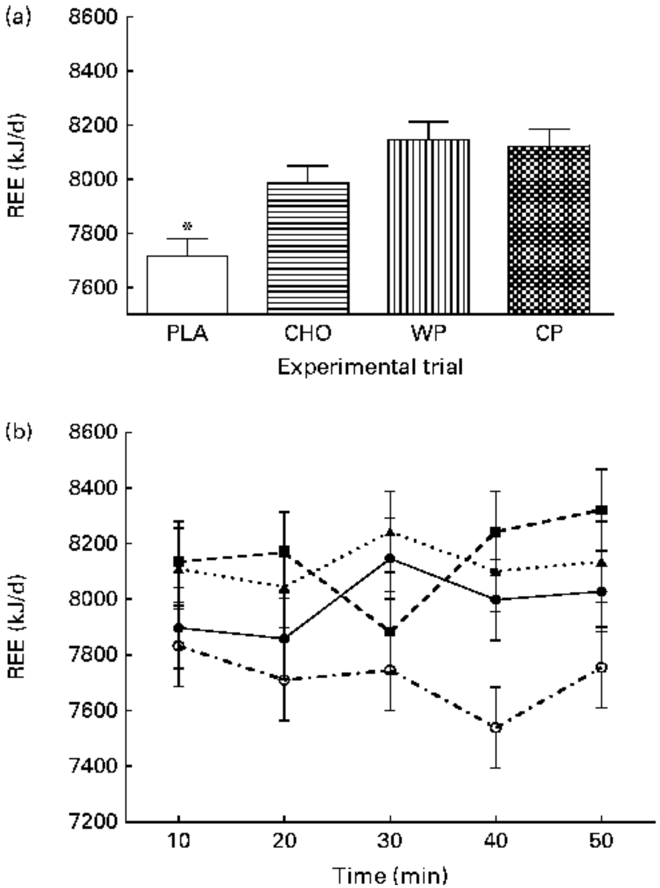
Night-time consumption of protein or carbohydrate results in increased morning resting energy expenditure in active college-aged men

Madzima et al. Br J Nutri. 111:71-77, 2014

- 11 men participated in a randomized, double-blind, cross-over study.
- A single dose ***of WP (30 g), CP (30 g), CHO (33 g) or PLA was consumed 30 min before sleep***, and each trial was separated by 48-72 h.
- The next morning (05.00-08.00 hours), measurements of satiety, hunger and desire to eat and REE were taken.
- There were no significant differences in appetite measures among the groups.
- ***The predicted REE was significantly greater after consumption of the WP (8,151 (sem 67) kJ/d), CP (8,126 (sem 67) kJ/d) and CHO (7,988 (sem 67) kJ/d) than after that of the PLA (7716 (sem 67) kJ/d).***
- No significant differences between the WP and CP groups in any metabolic measurements.
- ***Night-time consumption of WP, CP or CHO, in the hours close to sleep, elicits favorable effects on the next-morning metabolism when compared with that of a PLA in active young men***



Preventing Overtraining

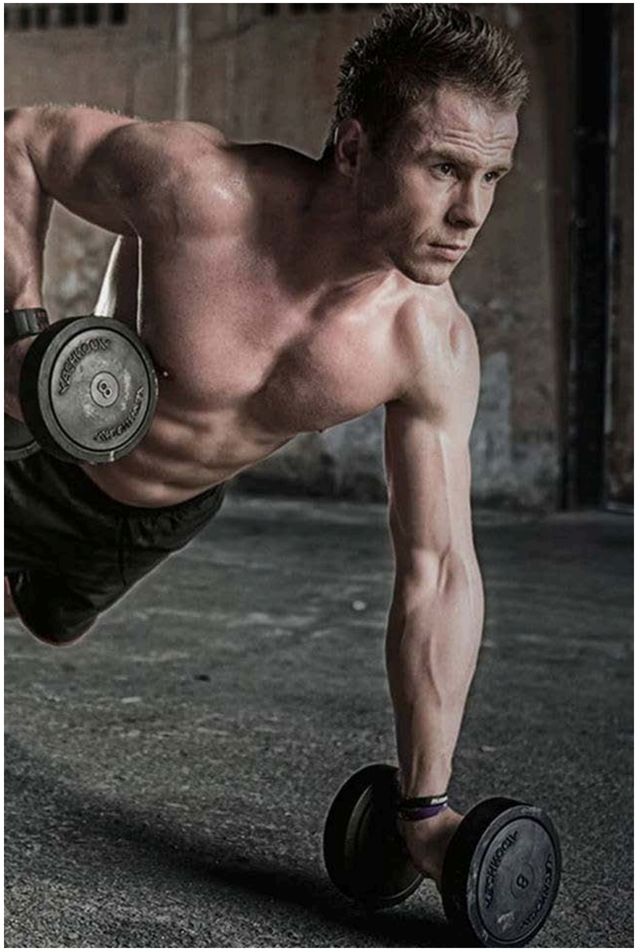
Monitor Athletes

- Frequent performance monitoring
- Monitor changes in FFM during training
- Conduct readiness to train and/or perform, mood state, and symptoms of illness each day.
- Recovery-Stress Questionnaire
  - ***General Stress Subscale*** (General Stress, Emotional Stress, Social Stress, Conflicts/Pressure, Fatigue, Lack of Energy and Physical Complaints).
  - ***General Recovery Activity Subscale*** (Success, Social Recovery, Physical Recovery,General Well-being and Sleep Quality).
  - ***Sport-specific Stress Subscale*** (Disturbed Breaks, Burnout/Emotional Exhaustion and Fitness/ Injury).
  - ***Sport-specific Recovery Activity Subscale*** (Fitness/Being in Shape, Personal Accomplishments, Self-efficacy and Self-regulation).
- Athlete Burnout Questionnaire (ABQ)
- Profile of Mood States (POMS) – 6 item version
- Stellenbosch Mood Scale

Markers of Overtraining

Biochemical

- Negative nitrogen balance
- Hypothalamic dysfunction
- Flat glucose tolerance curves
- Depressed muscle glycogen concentration
- Decreased bone mineral content
- Delayed menarche
- Decreased hemoglobin
- Decreased serum iron, ferritin and TIBC
- Mineral depletion (Zn, Co, Al, Mn, Se, Cu, etc.)
- Increased urea concentrations
- Elevated cortisol levels
- Elevated ketosteroids in urine
- Low free testosterone
- Increased serum sex hormone binding globulin
- Decreased ratio of free testosterone to cortisol of more than 30%
- Increased uric acid production
- Decreased immune status and/or function



Fry et al. Sports Medicine. 2:32-65., 1991

Preventing Overtraining

Summary

- Overtraining and/or under recovery remains a significant problem among highly trained athletes, particularly endurance athletes.
- Understanding and monitoring signs and symptoms of overtraining, incorporating sound training principles, and planning rest into the training program can help mitigate overtraining.
- Recovery nutrition plays an important role in enhancing recovery, keeping athletes healthy during training, and rehabilitation from injury.

Preventing Overtraining

Summary – Nutritional Interventions

- Consumption of a daily multivitamin (with iron for women);
- Supplementing the diet with nutrients in which athletes may be susceptible to developing deficiencies;
- Rehydration;
- Glycogen replenishment
- Promoting an anabolism and reducing catabolism;
- Managing inflammation;
- Providing nutrients to support the immune system;
- Incorporating a pre-sleep nutritional intervention

Nutritional Strategies to Prevent Overtraining

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

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