ChiroCredit.com Presents
Nutrition 134

Nutrition Supplements for Exercise and Sport
Part I

Exercise Statistics

• CDC researchers - 77,000 people -
• Only 20% of adults met federal guidelines for both aerobic and muscle-strengthening exercise
• >80% of adolescents do not do enough aerobic physical activity to meet the youth guidelines
• (2.5 hrs of moderate-intensity aerobic exercise/week or 1 hr 15 min of vigorous-intensity, or a combo - also muscle strengthening activities at least twice per week)

• 49.6% people exercise for at least 30 minutes three days per week
• 18.5% exercise one or two days per week
• 31.3% haven’t exercised within the last week
• 40.4% of obese Americans do not exercise 30 minutes any given day
• Average number of times a gym membership owner will go to the gym every week - 2
STUDY - 33% of adults and 25% of adolescents are completely inactive in any leisure-time aerobic activity
2010 - Less than 5% of adults participate in 30 minutes of physical activity each day
Physical Inactivity more common among women, blacks, hispanics, elderly, and the less affluent
Only 40% of Americans exercise enough to receive health benefits

Only 35% - 44% of adults 75 years or older are physically active - 28-34% of adults ages 65-74 are physically active
2010 - Children now spend more than seven and a half hours a day in front of a screen (e.g., TV, videogames, computer)
2011 - Nearly one-third of high school students play video or computer games for 3 or more hours on an average school day

2013 - Adults living in the following states are most likely to report exercising 3 or more days a week for at least 30 minutes:
Vermont (65%), Hawaii (62%), Montana (60%), Alaska (60%)
Least likely were Delaware (46%), West Virginia (47%) and Alabama (47%)
National average for regular exercise is 52%
Common Supplements Taken in Mainstream Population

- **U.S. Supplement sales** - $11.5 billion in 2012
- **NHANES Survey 2003 to 2006** - covered all types of supplements - 53% took at least one a day
- **2007 NHANES Survey** - Most common - multivitamin/mineral (39%)
- **18% of adults use supplements** (not including vitamins and minerals)
- **Most popular** - fish oil (37%), glucosamine (20%), Echinacea (20%), flaxseed oil (16%), ginseng (14%)

Survey of 2,000 people each year from 2007 - 2011
- Average supplement use was 66% and average regular use was 50%
- Multivitamins were the most commonly used supplement (71%), followed by fish oil (33%), calcium (32%), vitamin D (32%) vitamin C (32%)
- Sport supplements were used by 17% of the people (2011)

2013 survey of over 10,000 people
- Fish/marine oils (71.7%)
- Multivitamins (65.4%)
- Vitamin D (55.5%)
- CoQ10 (54.1%)
- Calcium (48.4%)
- B vitamins (44.2%)
- Vitamin C (41.2%)
- The use of calcium and multivitamins fell
Supplement Use in Sport and Exercise

- **Study** - Division I athletes - 89% use supplements (Froiland, 2004)
- **Study** - 88% use > 1 and 58% used >2 (Burns, 2004)
- **Study** - Canadian athletes (94%) use one or more at least once a month (Kristiansen, 2005) - *Child/adolescent athletes - from 22% to 71% - Elite athletes use the most*
- **Study** (2015) - 2,355 US adults - 46% took sports drinks, 32% protein bars, 27% energy drinks, 24% energy bars, and 12% energy shots

Most Common Sport Supplements from 2000 - 2008

- Vitamin/minerals (20-83)
- Sports drinks (56)
- Herbals (44-48)
- Energy drinks (42)
- Multivitamin only (42)
- Protein bars (38)
- Vitamin C (35)
- Iron (30)
- Meal replacement (22) and Protein (13-22)
- Creatine (16)

2015 Japanese Survey

- Surveys taken 1-5 months before the 2012 Olympic Games in London
- 552 Japanese athletes
- 82% used 1 or more supplements in the year prior
- 44% took at least 1 supplement daily
- Most common - amino acids (56%)
- Most common purpose - recovery from fatigue
- Information was from coaches, managers, and trainers
Exercise and Immunity

- Exercise causes stress - physical and psychological
- Neuroendocrine changes that occur with stress also occur with exercise - elevated epinephrine, cortisol, endogenous opiates, etc
- Acute physical stressors in animals and humans influence immune parameters

Exercise Causes

- Transient leukocytosis - Initial post exercise increase followed by decrease to pre exercise levels within 2-6 hours
- Largest increase is in neutrophils
- Increase in relative and absolute amounts of NK cells - 2-5x pre-exercise base levels
- NK Cell Cytotoxic activity increases

- Short intense exercise enhances several aspects of neutrophil and macrophage phagocytic activity
- STUDY - Neutrophil activation increased after short (<10min) vigorous ergometry exercise
- STUDY - Reduced growth of tumors in animals given long term exercise
Dark Side of Exercise

- Prolonged intense exercise = 
  Immunosuppression
- STUDY (2015) - Single bouts of prolonged exercise may impair T-cell, NK-cell, and neutrophil function
- STUDY - (1991) - Reduced lymphocyte proliferative responses (30%-40%) after cycling at intensities up to 75% max

Infectious Diseases and Exercise

- Greater incidence of infectious diseases particularly upper respiratory in marathon runners during intense training/overtraining
- Observations - symptoms of respiratory infection cluster around competitions
- Benefit with moderate exercise - Fewer respiratory infections - STUDY - (Nieman et al) - brisk walking - 45min - 5 days/week - 5.1 symptoms/day in exercise group - 10.8 in sedentary group

Conclusion

- Consensus of human and animal studies -
  *Intense exercise or overtraining depresses immune functions*
- Regular, moderate exercise enhances certain immune functions
Heat Removal

- Muscles release heat during exercise
- Blood is warmed with exercise and increases core temperature
- Stimulates hypothalamus to initiate the sweating mechanism
- Blood removes the heat by rushing to the skin so heat can be lost by sweating
- and thus evaporation
- 80% of all heat liberated is via evaporation
## Regulation of Fluids

- When fluid is lost via sweat
- Plasma volume decreases
- Plasma osmolality increases ([Cl] and [Na])
- Vascular pressure receptors and hypothalamic osmoreceptors sense these changes
- Increases Vasopressin (ADH) - from pituitary
- Increases Renin - released from the kidneys
- Both of these will increase water and sodium retention by the kidneys - retains water
- Provokes an increase in thirst

## Under normal situations

- Fluid intake will eventually exceed any fluid losses
- For athletes - difficult to get back to normal many do not ingest enough fluid to offset large losses during training
- Thirst mechanism is not reliable to maintain core balance
- If fluids are not replaced - dehydration will result and decrease performance
- Water replacement maintains core temperature

## Daily Fluid Loss

- Total volume of fluid loss depends on -
  - Environmental conditions
  - Size and surface area of the person
  - Metabolic rate of person
  - Volume of excreted fluids
Daily average losses without exercise (sedentary)
- 2-3 liters/day
- Athlete who trains 2 hours per day can easily lose an additional 2 liters
- Resulting in total losses of up to 5 liters/day for some athletes

Dehydration
- Many people are chronically dehydrated
- Without proper hydration - many chemical reactions within a cell may not occur
- Symptoms - elevated HR, muscle cramping, headache, fatigue, decreased appetite, dry mouth - can lead to tingling and numbness- ----> collapse

Fluid Intake - Adequate?
- 13 cross-sectional surveys in 13 countries (2015)
- 3,611 children (4-9 years) and 8,109 adolescents (10-18 years)
- Total fluid intake (water and beverages of all kinds) recorded over 7 consecutive days
- CONCLUSIONS: A high amount of children and adolescents are at risk of inadequate fluid intake
- Risk is especially high in males and adolescents
Data from the 2005-2006, 2007-2008 and 2009-2010 National Health and Nutrition Examination Survey (NHANES)

- 15,702 US adults
- Water and other beverages contributed 75-84% of dietary water - 17-25% came from foods
- Plain water (tap or bottled) contributed 30-37% of total dietary water
- Younger adults satisfied the DRIs for water
- Older people (83% of women and 95% of men) ≥71y failed to meet Institute of Medicine values - short in daily water from 603ml - 1218 ml

Institute of Medicine Guidelines for Daily Water Consumption

- From all beverages and food
- Women 2.7 liters (91 ounces)
- Men - 3.7 liters (125 ounces daily - about 1 gallon)
- No upper level for water

Voluntary Fluid Intake

- Voluntary fluid intake during physical activity usually replaces only 50% of the sweat loss
- Results in varying amounts of dehydration
- Often exceeds 3% of body weight
- Studies - World War II soldiers did not drink enough to replace all the water they lost by sweating - even when adequate supplies of drinking water was available
• It is not possible to adapt to dehydration
• Even small amounts of dehydration can be detrimental to an athlete’s performance
• Marathon runners typically lose about 3% - 5% of their body weight
• Body water loss equal to 1% of body weight diminishes ability to perform a set task
• STUDY - 4% dehydration can result in a 20-30% decrease in work performance

STUDIES
• STUDY - (Armstrong et al)
  - Dehydration of 2% of body weight can impair exercise performance during competitive runs as short as 1,500m - as well as 5,000m and 10,000m
• STUDY - (Below et al)
  - Cyclists - 50 minutes at 80% vo2max - then sprinted for 9-12 minutes
  - when dehydration was prevented (replacing 80% sweat loss) performance improved 6%
  - (with CHO drink - 12% improved)

Urine Output
• Need enough water per day to urinate every 2-4 hours
• Normal urine should be pale and there should be enough of it
• If Dehydrated -
  • Small volume of urine
  • Dark urine
Water Fluid Guidelines for Exercise

• 24 hrs prior to exercise - drink in excess
• 2 hrs prior to exercise 16 - 24oz
• 15 minutes prior 8 - 16oz
• Immediately prior 3 - 6oz (100 - 200ml)
• Every 15-20 minutes during exercise 6 - 8oz
• After exercise - enough to restore lost weight
• 20oz of fluid for every pound of BW lost
• In warm environment - additional 8-16oz of fluid in the 30 minutes prior to exercise

Oxygenated Water

• Water that has had additional oxygen introduced into it under pressure resulting in higher oxygen concentrations
• However - a single breath of air contains more oxygen than a whole bottle of oxygenated water
• The amount of oxygen in a $3 bottle only lasts a few seconds in the body

3 Negative Studies

• STUDY - 12 subjects - 500 ml of either oxygenated or plain bottled water - No differences were detected between conditions for any variable at rest or in exercise
• Second part of the study - oxygenated water did not help with recovery
• STUDY - randomized, double blind crossover study - 11 subjects - no differences in VO2max or associated cardiorespiratory performance variables
• STUDY - 9 male recreational cyclists - oxygenated water water did not improve performance
- STUDY (2017) - randomized double blinded, crossover study
- 25 trained male runners
- Ingestion did not improve exercise performance
- Enhanced post-exercise recovery via increased lactate clearance

Electrolytes

- Sodium
- Chloride
- Potassium
- Primary way that most minerals are lost from the body is from urine
- Exception is sodium and chloride
- Sodium and Chloride are the key minerals that can be lost through sweat in substantial amounts

Electrolyte Need

- No need for K supplementation
- STUDY - (Costill et al) - low potassium diet - heavy exercise that induced high sweat volumes for short periods of time (4 days)
- No significant decrease in total body K
- Na and Cl may need to be supplemented
- 50-100meq Na would cover any losses
- 1/4 teaspoon of salt (50meq)
Sports Drink Recipe

- 1/4 cup sugar in dissolved hot water
- 1/4 teaspoon of salt
- 1/4 cup orange juice (others)
- Fill up to make 1 quart
- Same calories and salt as Gatorade - 50cal/8oz
Functions

• Increases delivery of water and electrolytes
• Increases delivery of CHO
• More concentrated the solution (more CHO) - more time it takes for gastric emptying
• Beverages at 6%-7% CHO empty from stomach at similar rates as water alone
• Carbonating the beverage has no effect on gastric emptying rates

Glucose and Sodium - major constituents
• Combinations of sucrose, glucose, fructose, maltodextrins (corn starch - polymers of dextrose - dextrorotary form of glucose) promote similar water flux rates
• Glucose polymers (repeating glucose units) offer no advantage over glucose
• [CHO] less than 8% (fewer than 19g CHO per 8oz) - appear to maximize fluid absorption

Positive Study

• (Coyle) - 1 hour of intense exercise
• CHO and fluid ingestion alone or in combination
• Large volume of fluid or 79g CHO individually ingested - each improved performance by 6%
• When large volume of fluid and CHO were combined - performance improved by 12%
2013 Positive Study

- 8 male tennis players
- Two, 3-match round-robin tournaments
- Sports drinks or placebos - before, during, and after each match
- Sports drinks maintained higher glycemia levels, higher stroke frequency and decreased rates of perceived exertion

Water vs. Sports Drink Intake

- Sports Drink - Need 5-10oz (150-300ml) with 4%-8% CHO every 15-20 minutes
- If exercise < 60 min - Water
- If exercise < 60 min (intense) - Sports drink
- If exercise > 60 min - Sports drink
- 0.5 - 0.7g of Na (1.2-1.8g of NaCl) per liter of solution

Why Take Sport Supplements?

- Do they effect performance
- Do they effect recovery
- Do they protect against muscle damage or free radicals
- Do they change any exercise parameters such as increasing strength or Vo2max
- Do they effect reversing a deficiency
• Exercise does not appear to increase an athlete's need for minerals (exceptions may be present).
• Exercise does increase sweat and urinary losses of most minerals.
• However, unsure if the body can adapt to the loss by increasing retention or absorption or perhaps minerals are redistributed during exercise or perhaps mineral concentrations are lowered due to expansion of plasma volume that occurs with exercise.

Boron
• Claims - Br increases testosterone levels - thereby increasing growth and strength.
• Based on Nielsen study where Br caused a doubling of serum testosterone levels in postmenopausal women - problem - subjects were deprived Br for 4 months - Males did not have increase serum testosterone.
• Study - bodybuilders given Br supplements - Serum Br levels increased - no significant increases in serum testosterone, lean body mass or strength.
Calcium - Copper - Vanadium

- Calcium - not studied for ergogenic potential - Inadequate calcium in female athletes - Leads to greater risk of stress fractures
- Copper - part of superoxide dismutase - which increases with training - Most athletes consume enough - Supplements not necessary
- Vanadium - No evidence of anabolic effects - might act like insulin or help to increase the effects of insulin - possible serious side effects

Chromium

- Active component of the glucose tolerance factor - potentiates the actions of Insulin in CHO - lipid - protein metabolism
- Enhances insulin signaling and insulin-mediated glucose uptake and transport
- May help bind insulin to receptors
- Insulin regulates and enhances protein synthesis by increasing uptake of amino acids

Theory

- Many Americans are deficient - up to 50%?
- Exercise may affect Cr status - 24 hour Cr losses were 2x higher on the day of exercise - than on a rest day
- Benefit?
- Cr may increase insulin action and may increase lean body mass and decrease fat
- Conflicting Studies
Negative Studies

- **STUDY -** (Clancy et al)
  - Football players - spring training
  - Weight lifting - 4 days/wk - Running - 2 days/wk
  - 200mcg Cr picolinate or placebo for 9 weeks
  - No changes in strength or body composition
- **STUDY -** (Hallmark et al)
  - Weight lifted 3x/week for 12 weeks
  - Placebo or 200mcg Cr picolinate
  - No significant strength or body composition changes

Iron

- Many women athletes are deficient
- Incidence of GI bleeding in runners - 8%-85%
- Women runners are often in negative iron balance due to low meat and high fiber diet
- However -
  - Incidence of IDA is no greater in female athletes than in the adult and adolescent female population (5%-6%)
Deficiency and Supplementation

- IDA has significant impact upon exercise and performance
- Iron depletion without anemia also has a negative impact on exercise
- Most studies have not found exercise improvements in non-anemic iron deficient women
- Also - exercise performance after iron supplements in athletes with normal iron status - no benefits

Magnesium

- Involved in energy production - effects glucose mobilization/utilization in the periphery and CNS
- Exercise may lower Mg status
- 2 STUDIES - Mg blood levels are lower than baseline after 30 minutes of swimming, after a 120km hike, a marathon race, 12min of cycling at 80% max and after a treadmill 2 hour run at 65% vo2 max

2 Positive Animal Studies

- Study - (Chen, HY 2014) - Rats - saline or Mg sulfate - Mg enhanced glucose availability in the peripheral and central systems - Increased muscle lactate clearance in the muscle during exercise
- Study - (Cheng, SM 2010) - Gerbils - MgSulfate Improved duration time of forced swimming - also raised glucose levels and attenuated lactate levels
Positive Human Studies

- In general - 
  - Mg has been shown to increase physical capacity of endurance athletes

- Strength STUDY - (Brilla and Haley)
  - 2 groups - Mg oxide or placebo
  - Mg group had twice the strength in leg extension exercise compared to placebos

Phosphate

- High energy - athletes phosphate load
- BENEFITS -
  - Increased aerobic capacity
  - Increased peak power output
  - Increased anaerobic threshold
  - Improved myocardial and cardiovascular responses to exercise

- 3-5g/day of oral phosphate salts (capsules) - taken for 3 to 6 days - or immediately before sport event
  - STUDY - 8 cyclists - 3 days - 3.6g NaP
  - VO2 max significantly higher in phosphate group
  - STUDY - 1g NaP (qid) - 3 days
  - Increased VO2 max
  - Decreased blood lactate levels
2015 Positive Study

- 17 trained male cyclists - randomized to 6 days of sodium phosphate or placebo
- cycling sprints
- Sodium phosphate group had significantly improved work and mean power output
- Placebo group - no differences in total work or power output

Precautions

- Safe for most people up to 4 grams/day when used occasionally or short-term
- >4grams - serious kidney damage in some people
- Side effects - nausea, bloating and stomach pain
- Irregular heartbeat, fainting, seizures

Zinc

- Excreted in the urine, feces, and sweat
- Increased excretion of zinc with exercise
- Athletes are often deficient
- STUDY - (Haralambe) - 23% men and 43% women athletes had below normal range
- STUDY - >40% of elite women marathon runners consume less than 10mg/day (RDI 7-10 based on age)(Deuster et al)
Positive and Negative Studies

• OVERALL STUDIES - show Increases in muscle endurance in rats and humans
• STUDY - double blind - 16 women - 135mg/day of zinc
• Increased muscle strength and endurance
• NEGATIVE STUDY - 33.6mg and 50mg for 1 month of exercise of 6 days/week -
• No effect on heart rate or lactate or time to exhaustion during 75% VO2 max run

Problem??

• > 50mg/day may be immunosuppressive – (more likely at >100mg)
• Large zinc supplements (150mg/day) will decrease HDL cholesterol and leukocyte and lymphocyte activity
• Copper absorption inhibited when zinc is >50mg/day

VITAMINS
POLLING QUESTION

- Appears that vitamin supplements are not necessary unless a deficiency state exists
- No increased requirement from exercise
- Exception - Exercise may increase the requirements for riboflavin and vitamin B-6 - Maybe Niacin and choline?
- High CHO diets - increase need of B vitamins

Multi-Vitamins

- In General -
- At or near RDA - No benefit
- Moderate to high - Positive effects
- Increased strength
- Increased race times
- Faster recovery
- Decreased infections and injuries
- Feelings of well-being
B2 (Riboflavin)

- Metabolism of fats, CHO, CHON for energy
- Cell growth/respiration
- Protects against free radical damage in people who exercise (part of antioxidant chain)
- Sedentary people who begin exercising acquire a decreased B2 status - STUDY - 50-67 yr olds had decreased B2 after 4 weeks of exercise
- Heat exposure may increase need of B2

STUDY (2017)

- Double-blind, placebo-controlled
- 2016 161-km Western States Endurance Run
- 100mg riboflavin or placebo
- 32 people (18 riboflavin, 14 placebo)
- Muscle pain and soreness during and immediately after the race were found to be significantly lower for the riboflavin group
- 400-m run times were faster for the riboflavin group

B6 (Pyridoxine)

- Amino Acid metabolism
- Many athletes have low levels
- STUDY - (Guilland et al) - 66% of male college athletes consumed only 69% RDA
- Need extra B6 if on high CHO and Protein diet
- B6 appears to enhance GH release after maximal exercise - Possible benefit for short term anaerobic exercise - (weightlifting)
B3 (Niacin)

- Energy metabolism - nicotinamide is precursor to NAD and NADP
- Beneficial in lowering body core temperature
- No effects on performance - positive or negative - with nicotinic acid or niacin
- Bodybuilders use nicotinic acid - causes flushing reaction due to histamine release - enlarges surface blood vessels prior to competition - bodybuilder looks more “ripped”

Choline

- Precursor of acetylcholine and phosphatidylcholine (lecithin)
- Fat and Cholesterol metabolism
- No dietary requirement
- An amine - body can make it from methionine
- Hypothesis -
  - Affects nerve transmission
  - Increases strength and reduces body fat

- Levels can decrease after exercise
- STUDY - Running 20 miles or swimming 2 hours resulted in 40%-50% decreased levels
- STUDY - (Spector et al)
- 2g of free choline before exercise prevented a decrease in choline levels (25%-40%)
- Running times improved (next slide)
- A timed swim test improved (next slide)
### 2 Positive Studies

- **STUDY** - higher percentage of swimmers who took choline before their swim had **improved performance on a timed swim test** compared to a placebo
- **STUDY** - long distance runners improved **running times** by 5 minutes over a 20 mile course compared to placebo group
- 2 - 8 grams of choline

### Negative Studies

- **STUDY** - brief duration highly intense activities (2min) or submaximal exercise for 70min - *No decrease in plasma choline levels*
- **In General** -
  - No studies support choline increasing strength
  - No studies support the loss of body fat

### B5 - Inositol - Biotin - Folic Acid - B12

- **B12**
  - DNA and RBC formation - growth
  - *May improve endurance by enhancing oxygen carrying capacity of the RBC?*
  - No significant data showing increase of performance
- **B5** - Inositol - Biotin - Folic Acid
- Very little research - exercise
Vitamins A – D – K
No effects on exercise performance

Antioxidants

POLLING QUESTION
Free Radicals

- Single e- in outer shell
- Highly reactive - Very unstable
- Every part of the cell and almost every molecule is subjected to free radical attack including DNA, Proteins and PUFA residues of phospholipid cell membranes
- Excess exercise can lead to free radical formation

- Exercise causes the rate of whole body consumption of oxygen to increase 10-15x
- Oxygen flux in active skeletal muscle may increase 100x
- Significant increase in free radical production with exercise over the resting state

- High intensity anaerobic work and weight training can lead to -
  - Transient tissue hypoxia
  - Can lead to increased H+ ions and react with superoxide anions - producing free radicals
  - Freeing of transitional metals (Iron and Copper) - involved in Fenton reaction - which increases formation of the very destructive hydroxyl radical
Other Ways Exercise Produces Free Radicals

• Increases catecholamines
• Increases lactic acid production
• Increases core temperature
• All are associated with exercise and all can increase generation of free radicals

In Addition

• Exercise causes
• Tissue injury
• Chemical mediators release
• Phagocytic migration
• Free radical formation and Inflammation

Antioxidant System

• Antioxidant enzyme activity increases in subjects who are trained
• Appears to be a protective adaptation to exercise stress
• However - An intense bout of exercise may overwhelm the capacity of the endogenous antioxidant system -
• Particularly in a person who does not habitually exercise
Vitamin E

- Great free radical scavenging ability
- Improves insulin action and glucose tolerance
- Helps in recovery from exercise
- Athletes may have low levels - Diets high in CHO are often low in Vit E - Thus - high CHO and low fat diets - may cause deficiency

2 Positive Animal Studies - Muscle Damage

- Animal (rat) STUDIES
- Vitamin E deficiency promotes decline in endurance performance
- Vitamin E deficient animals were more susceptible to tissue damage than controls
- STUDY - (Jackson et al)
- Rats - vitamin E 240mg/day - 42-45 days
- Less severe muscle damage in exercised rats and mice compared to control

3 Positive Human Studies - Muscle Damage

- 2 STUDIES - (Sumida et al) and (Cannon et al)
- Post exercise serum enzymes - indicative of muscle damage - were decreased in subjects who consumed 300-800IU of Vitamin E for 4-8 weeks
- STUDY - (Hartman et al)
- Vitamin E 800mg -
- Reduced DNA damage in peripheral WBCs after exhaustive exercise
- (1 IU = 0.67mg d-alpha-tocopherol)
2 More Positive Human Studies

- STUDY - (Meydani et al)
- 800IU/day - 7 weeks
- Exercise induced lipid peroxidation was significantly reduced with Vitamin E

- STUDY - (Kanter et al)
- 1,000IU/day - 1 week prior to exercise - A Diminished LDL Oxidation rate was observed

Vitamin E Conclusions

- When a deficiency exists -
- Multiple studies demonstrate a decrease in physical performance

- Otherwise - Vitamin E only decreases free radical damage and muscle damage induced by exercise - probably does not directly improve performance

Vitamin C

- Free radical scavenger
- May reduce muscle damage and lipid peroxidation after exercise
- May reduce infections in athletes
- STUDY - (Peters et al) - 600mg/day for 3 weeks before a 42-km road race
- Fewer cases of upper respiratory infections in runners who took Vitamin C
Positive Human Studies

- STUDY - (Jakeman/Maxwell) - 400mg - 3 weeks
- More rapid recovery of maximal contraction
- Less fatigue and Less muscle damage
- STUDY - (Kaminski and Boals)
- 3 grams for 3 days before exercise - and 4 days after strenuous calf exercises
- Less muscle soreness of the calf

Conclusion

- Vitamin C has shown improvements in exercise physiology measurements -
  - Increased peak work capacity
  - Increased muscular strength
  - Improved sub-maximal work loads
  - Improved recovery time
  - Less illness
  - No improvements in exercise performance

Selenium

- Co-factor in glutathione peroxidase
- Training decreases levels by a small amount
- Limited studies exist
- Reduces oxidative damage during exercise
- STUDY - 100-240 mcg/day
- Decreased oxidative damage after exercise
- Time to exhaustion on treadmill was unchanged
2015 Rat Study

- 32 male rats
- Group 1 (control), Group 2 (selenium), Group 3 (swimming), and Group 4 (selenium and swimming)
- Results - swimming exercise causes lipid peroxidation in liver and lung tissues - while selenium prevents free radical formation by increasing antioxidant activity

Free Form Amino Acids

POLLING QUESTION
• Some single amino acids may improve exercise performance -
  • Arginine
  • Ornithine
  • BCAA
  • L-Carnitine (discussed in part II)
  • Glutamine (discussed in part II)

Arginine
• Made in the body naturally - Deficiencies are rare
• Foods - red meat, fish, poultry, wheat germ, grains, nuts/seeds, dairy products
• Arginine converted to nitric oxide (NO)
• NO - a powerful neurotransmitter that helps blood vessels relax and improves circulation

Functions
• Relaxes blood vessels (vasodilator) - cardiovascular benefit
• Wound healing
• Helps kidneys remove waste products and ammonia from the body
• Maintains immune function
• Promotes Glucagon, Insulin, GH secretion
Positive Studies

- L-arginine infusion at rest increases plasma insulin, growth hormone, glucagon, catecholamines
- L-arginine infusion increases nitric oxide (NO) and alters skeletal-muscle metabolism during exercise
- L-arginine augments the effects of exercise training on insulin sensitivity and capillary growth in muscles

- At very high intakes - 250mg per 2.2 pounds of body weight (10-30 grams)
  - GH levels increase
- At lower amounts - exp - 5 grams taken 30 minutes before exercise
  - GH levels do not increase
- There are great individual differences in the effectiveness of arginine as a growth hormone releaser

GH release effect is reduced by -

- Increasing Age - minimal after 40
- Taking it continuously - Breaks are needed (perhaps 4 weeks of continuous use followed by a two week break)
- Taking it with food - other amino acids and insulin can reduce effect - Needs to be taken on an empty stomach (one hour before or three hours after a meal)
DOSE

- No recommended daily amount - Because body normally makes enough
- Studies have used different amounts
- Common dosage is 2 to 3 grams three times a day

Side Effects and Safety

- 2016 STUDY - safe and generally well-tolerated
- Oral intake safe level - 20 g/day - higher levels, short-term, no serious adverse effects
- Safe up to three months - No long term studies for safety
- Minor side effects - Abdominal pain, nausea, cramps, bloating, diarrhea
- May aggravate gout and asthma
- May lead to liver and kidney disease

Nitric Oxide

- Regulates vasodilatation, blood flow, platelet function, mitochondrial respiration - may increase exercise capacity
- Certain foods promote NO production from the reduction of nitrate to nitrite to NO
- NO production is hampered by free radicals - antioxidants may be helpful
- Production is reduced as we age
Nitric Oxide Synthesis

- At least two physiological pathways
- NOS synthase dependent
- NOS synthase independent
- NOS dependent - L-arginine is oxidized to NO by the action of the NOS enzymes
- L-citrulline can be converted to L-arginine and is a secondary NO donor in the NOS-dependent pathway

NOS-independent pathway -
- Nitrate and nitrite are the main substrates
- Are reduced to NO and other bioactive nitrogen oxides
- Nitrate sources - 80% of dietary nitrates are derived from vegetable consumption
- Nitrite sources - vegetables, fruit, and processed meats

Other molecules -
- Glycine propionyl-L-carnitine (GPLC), has been suggested to increase NO levels
- Unclear
- Negative study - placebo controlled, randomized, double blind - 8-wk aerobic-training program
- Conclusion - up to 3 g/d for 8 weeks has no significant effects on aerobic or anaerobic exercise performance
**NO Theory with Exercise**

- NO may enhance oxygen and nutrient delivery to active muscles
- Thus improve tolerance to physical exercise
- Improve recovery mechanisms
- Mixed study results

**Positive Sport Study - 2010**

- 16 male cyclists aged 50 to 73
- 5.2 grams of L-arginine, L-citrulline and antioxidants
- 16.7% increase in anaerobic threshold
- Placebo group - no increase in thresholds
- Anaerobic threshold = a predictor of performance in aerobic exercise - point at which lactic acid starts to accumulate in the muscles

**Trained or Untrained?**

- (Bescos, R et al, 2012)
- Training status of subjects is important
- Studies - NO donors could improve tolerance to aerobic and anaerobic exercise of untrained or moderately trained healthy subjects -
- Highly trained subjects - no positive effect
- Also - positive results is from mostly young male population
Citrulline

- Either synthetic or in watermelon, walnuts, meats, milk, fish, legumes, onions and garlic
- L-citrulline ingestion increases plasma L-arginine
- Improves vascular function through increased L-arginine bioavailability and nitric oxide synthesis
- Recent studies - L-citrulline increases NO synthesis and peripheral blood flow, decreases blood pressure, improves skeletal muscle oxygenation and performance during endurance exercise

May improve exercise performance

- May help detoxify ammonia via the urea cycle and inhibit additional glycolysis
- STUDY - (Takeda, 2011) - Mice
  - Increased swimming time until exhaustion
  - Exercise-induced blood ammonia elevation and blood lactate was repressed/lowered

2016 Study

- Double-blind, randomized, placebo-controlled
- 22 trained males - 2.4 g/day of L-citrulline or placebo for 7 days - On Day 8 they took 2.4 g of L-citrulline or placebo 1 h before a 4-km cycling time trial
- L-Citrulline increased plasma L-arginine levels and reduced time taken to complete cycle ergometer exercise by 1.5 % compared to placebo
- Improved feelings of muscle fatigue and concentration immediately after exercise
2015 and 2017 STUDIES

- 2017 - Watermelon is a rich source of l-citrulline
- Watermelon juice (l-citrulline 500ml) or placebo
- Randomized, double blind - male runners performed two half-marathon races
- WJ - Lower muscle soreness and plasma lactate
- 2015 - Cit (6 g/day) 10 men - randomized, placebo controlled - moderate and severe intensity cycling
- Improved blood pressure and exercise performance

2 Negative Studies

- 2016 - 8 recreationally-active adult males - 300 mL/day watermelon juice (3.4g citrulline) or placebo
- Did not improve time-to-exhaustion or endurance exercise performance
- 2015 - randomized double-blind - 22 subjects
- Single pre-exercise dose of l-citrulline or watermelon juice did not improve exercise performance

- Some believe - oral l-arginine does not increase circulating nitric oxide or blood flow
- New molecule (2-[nitrooxy]ethyl 2-amino-3-methylbutanoate) marketed as “real nitric oxide”
- STUDY 2010 - 10 resistance trained men
- (2-[nitrooxy]ethyl 2-amino-3-methylbutanoate) or placebo
- Had a small effect on increasing circulating nitrate/nitrite (6.7%)
2012 STUDY - 2-nitrooxy ethyl 2-amino 3-methylbutanoate topical gel
• Fourteen resistance trained men (aged 24)
• Exercise testing (arm curl isometric force and muscular endurance)
• 2-nitrooxy ethyl 2-amino 3-methylbutanoate gel had a modest (6.2%), non-statistically significant effect on exercise performance

Arginine Works with Ornithine in the Synthesis of Growth Hormone

2 Positive Studies
• STUDY - Middle aged males - Weight training 5x/week - 500mg (bid) of each (double blind)
  • Decreased body fat
  • Increased total strength
  • Increased lean body mass
  • Results in only 5 weeks
• STUDY - Rats
  • Improved endurance exercise in rats
Ornithine

• Made in the body when arginine is metabolized during production of urea
• Foods = meat - dairy - eggs - fish
• Western diets supply 5 grams/day
• Increases Insulin
• May increase GH

Positive Studies

• STUDY - (Sugino 2008) - L-ornithine hydrochloride
  Decreased fatigue
• STUDY - Ornithine hydrochloride - 170 mg/kg - 12 bodybuilders - 4x increase in serum somatotropin levels
• STUDY - 13 grams/day - Increased GH
• STUDY - (2011) - 0.1 g/kg, body mass or placebo - maximal cycling exercise - maximal anaerobic performance may be improved

Dose and Safety

• No known interactions
• Safety??
• Not pregnancy/lactating
• Dose - unknown range (many supplements contain 6 grams or so)
• 30 grams is used for burn patients
Branched Chain Amino Acids

- Leucine - Isoleucine - Valine
- 3 of the 8 essential amino acids
- Combo of 3 makes up 33% of skeletal muscle
- **Exercising muscle can increase uptake of BCAA fourfold**
- Exercise, Trauma, starvation - BCAA are oxidized for energy in the skeletal muscles

Functions of BCAA

- Enhances energy
- Increases endurance
- Increases Insulin secretion
- Aids in GH production
- Helps heal and repair muscle tissue
- Improve post exercise mood and cognitive performance during initial hour of recovery

- When energy is needed -
  - Body can break down muscle to get BCAAs
  - Supplements taken during or after a workout -
  - Muscles and other tissues are spared from breakdown
2 Positive Studies

- **STUDY** - healthy subjects
- One intravenous infusion of BCAAs
- Tissue breakdown that normally occurs overnight decreased by 50%
- **STUDY** - marathoners and cross-country runners
- Muscles were spared completely with a daily dose of BCAAS

2 Additional Positive Studies

- **STUDY** - (Shimomura and Murakami, 2004)
  - BCAA taken before and after exercise
  - Decreases exercise-induced muscle damage and promotes muscle protein synthesis
- **STUDY** - (Anthony, 1999)
  - Rats - Leucine stimulates muscle protein synthesis following exercise

Another Positive Study (2010)

- Eight previously resistance trained males
- Received either BCAA or placebo
- High-intensity total-body resistance training
- Serum testosterone levels were significantly higher and cortisol levels were significantly lower in the BCAA group during and following resistance training
2016 Power Study

- 11 resistance-trained males performed a seated shot-put throw (SSPT) and a countermovement jump (CMJ) (basically a vertical jump)
- 20 g of BCAA or a placebo
- Following training there were significant decrements in CMJ and SSPT
- However - BCAA was shown to attenuate the decrements in CMJ and SSPT performance

Conclusion - BCAA attenuate a decrease in power-producing ability

Ornithine and BCAA

- 2015 - randomized, double-blind
- 16 g BCAA and 12 g OA or placebo
- Eleven endurance-trained men
- Performed cycloergometer exercise for 90 minutes at 60% of maximal oxygen uptake followed by graded exercise until exhaustion
- Decreases in plasma ammonia during recovery were significantly higher in BCAA + OA
- Improvement in reaction time during high-intensity exercise and increased elimination of ammonia

BCAA Negative Studies

- STUDY - (Areces, 2014) - 5g/day
  - Did not increase running performance
  - Did not prevent muscle power loss, muscle damage or pain during a marathon race
- Other Studies - 10 to 20 grams/day
  - Did not change body composition
  - Did not improve exercise performance
  - Did not enhance physical training
Summary of BCAA

- **Effective** - reducing muscle breakdown during exercise
- **Ineffective** - enhancing athletic performance
- **Special Uses** - prevents muscle loss at high altitudes and prolongs endurance in heat

Dose

- Estimated average requirement - 68 mg/kg/day up to 75 (leucine 34 mg, isoleucine 15 mg, valine 19 mg) for adults
- **Newer thoughts** - 144 mg/kg/day
- Need balance between the 3 amino acids
- 2mg of leucine and valine for each milligram of isoleucine

Safety and Side Effects

- Safe for most people up to 6 months
- Fatigue
- Loss of coordination - (be careful driving)
- High valine - crawling sensation in the skin - possible hallucinations
- High leucine - lead to pellagra (niacin def) and may increase ammonia in the body
Contraindications

- Avoid during pregnancy/lactation - unknown
- ALS - lung failure and higher death rates
- Branched chain ketoaciduria
- Alcoholism - increases liver damage
- Do not use 2 weeks prior to surgery
- Decreases absorption of levodopa - do not take together
- Decreases blood sugar - combo of diabetic medications may decrease too much

Creatine

POLLING QUESTION
Creatine

• 95% is located in skeletal muscles
• Made by the body - synthesized from amino acids - arginine, glycine, methionine
• Primarily produced in the kidney - but also by the liver and pancreas
• Dietary intake - meats and fish in quantities of 5g Cr/kg of meat
• Allowed by IOC, NCAA and professional sports

Benefits of PCr

• May delay fatigue
• Improves muscle performance in high intensity work
• Enhances strength in weightlifters
• Increases lean body mass
• Improves muscle protein synthesis

Best for High Intensity Sports

• Short term exhaustive anaerobic exercise with minimal recovery periods
• Sprinting - Field events - Throwing
• Weight lifting
• Does not improve performance in aerobic exercises - older people (>60) - highly trained athletes
Two Direct Functions

- Energy source to replenish ATP
- Buffer to maintain muscle pH
- \( \text{PCr} + \text{ADP} + \text{H}^+ \rightarrow \text{Cr} + \text{ATP} \)
- Enzyme is Creatine Kinase
- Once ATP is generated - Cr is re-synthesized into PCr
- Most likely by oxidation in the mitochondria

During high intensity exercise - muscle stores of ATP are quickly used up
- Rapid re-synthesis is needed
- Impaired PCr re-synthesis has been linked to impaired performance
- Studies - Depletion of PCr can occur within 5-7 seconds after sprints of 40, 60, 80, and 100 meters

STUDY - PCr Re-synthesis

- (Greenhaff et al) - unilateral knee extension
- at 0, 20, 60, 120 seconds
- During first 40 seconds - rate of recovery was identical between placebo and Cr group
- After that - PCr re-synthesis was greater in the supplemented group
- Muscle concentration of Cr at end of recovery was 30% higher in supplemented group
Study - Absorption

- Biopsy studies have shown increases of muscle PCr and total Creatine with Cr monohydrate supplementation
- By as much as 33%
- However - ATP stores were unaffected
- There appears to be no nutritional or training programs that will increase amount of ATP to be stored (unless increase size of muscle)

Ribose?

2017 Study

- double blind, placebo-controlled
- 19 youth male soccer players
- low dose, short-term Creatine monohydrate 0.03 g/kg/day
- Before and after supplementation - performed a 30s Wingate Anaerobic Test
- Cr group - significant increases in both peak power output and mean power output - but not the placebo

Loading DOSE

- Results in a 20%-40% increase of PCr stores
- Different ways to LOAD -
  1. Load with 20 - 30 grams/day (or 0.3 grams per kg) for 5 days followed by a maintenance dose of 2 or more grams (0.03 grams per kg) daily - Two days of loading has also been used
  2. Load dose of 9 grams/day for 6 days
Is Loading Necessary?

- Similar results can be obtained with 3 grams per day for 28 days - no loading necessary
- STUDY - (Swedish Karolinska Institute) - group that loaded and group that did not
- No difference was observed
- 20% increase in muscle Cr
- Loading phase probably unnecessary
- 3g/day was effective

Creatine and CHO

- STUDY - (Green, et al)
- Ingestion of carbohydrate with Cr augments Cr accumulation in the muscle tissue
- 60% greater when 5g Cr was followed by 93g simple CHO (qid)
- Decreased urinary excretion of Cr
- Elevated serum insulin
- Increase in body mass - from 0.9-3.2kg

Safety/Side Effects

- Safe at recommended doses
- Stomach pain, diarrhea, nausea and muscle cramping
- May cause skin pigmented purpuric dermatosis
- High doses > 5g per day - may damage kidney, liver or heart
• **Need extra water** - 64 ounces per day
• **Cr** causes muscles to draw water from the rest of the body - **dehydration**
• Be careful in the heat
• **Weight gain** - due to muscles holding water
• **Long term effects** - **unknown**

**Risks/Contraindications**

• **Do not use** if you have diabetes, kidney disease or are pregnant/breast feeding
• **Do not take** with meds that can harm the kidneys
  NSAIDS - ibuprofen (advil, motrin, nuprin, others), indomethacin (indocin), naproxen (aleve, anaprox, etc), piroxicam (feldene) cyclosporine (neoral, sandimmune); aminoglycosides (amikacin (amikin), gentamicin (garamycin, gentak, etc), and tobramycin (nebcin, etc)

THE END