Foundation of Sport Nutrition: Performance Nutrition

Jay R. Hoffman, Ph.D., FACSM, FNSCA
Department of Health and Exercise Science
The College of New Jersey

Performance Nutrition

- Pre-exercise/competition
- During exercise/competition
- Post-exercise/competition
- Nutrient timing

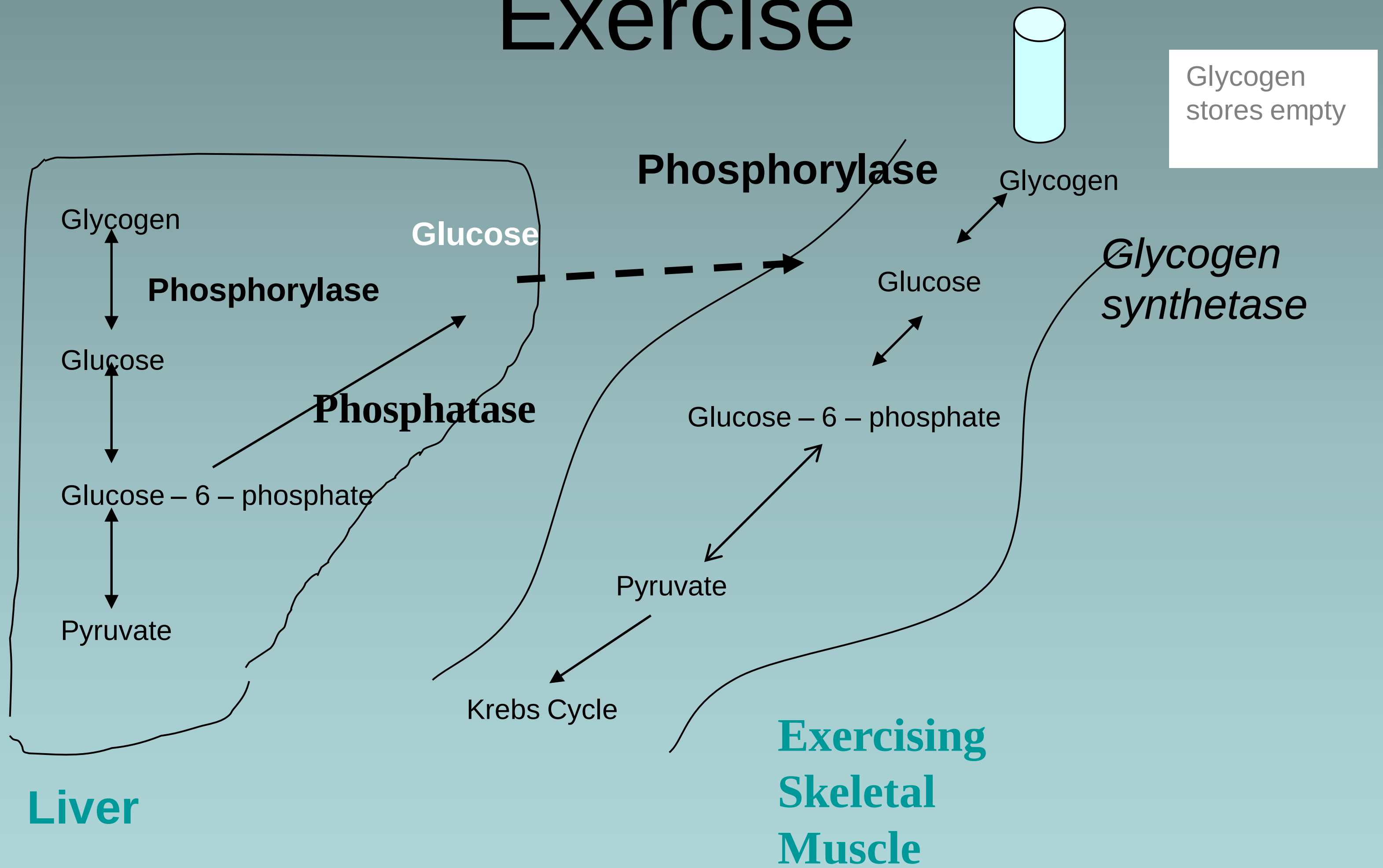
Carbohydrate Ingestion: Purpose

- **Muscle glycogen content important determinant of exercise performance!**
- Pre-exercise feedings
  - – Maximize (top-off) muscle glycogen stores
  - – Maintain blood glucose concentrations during exercise
- Feedings during exercise
  - – Maintain blood glucose
- Post-exercise feedings

How Much Carbohydrate Do We Store?

Source	Amount in Grams	Amount in Calories
Blood Glucose	5	20
Liver glycogen	75-100	300-400
Muscle glycogen	300-400	1200-1600

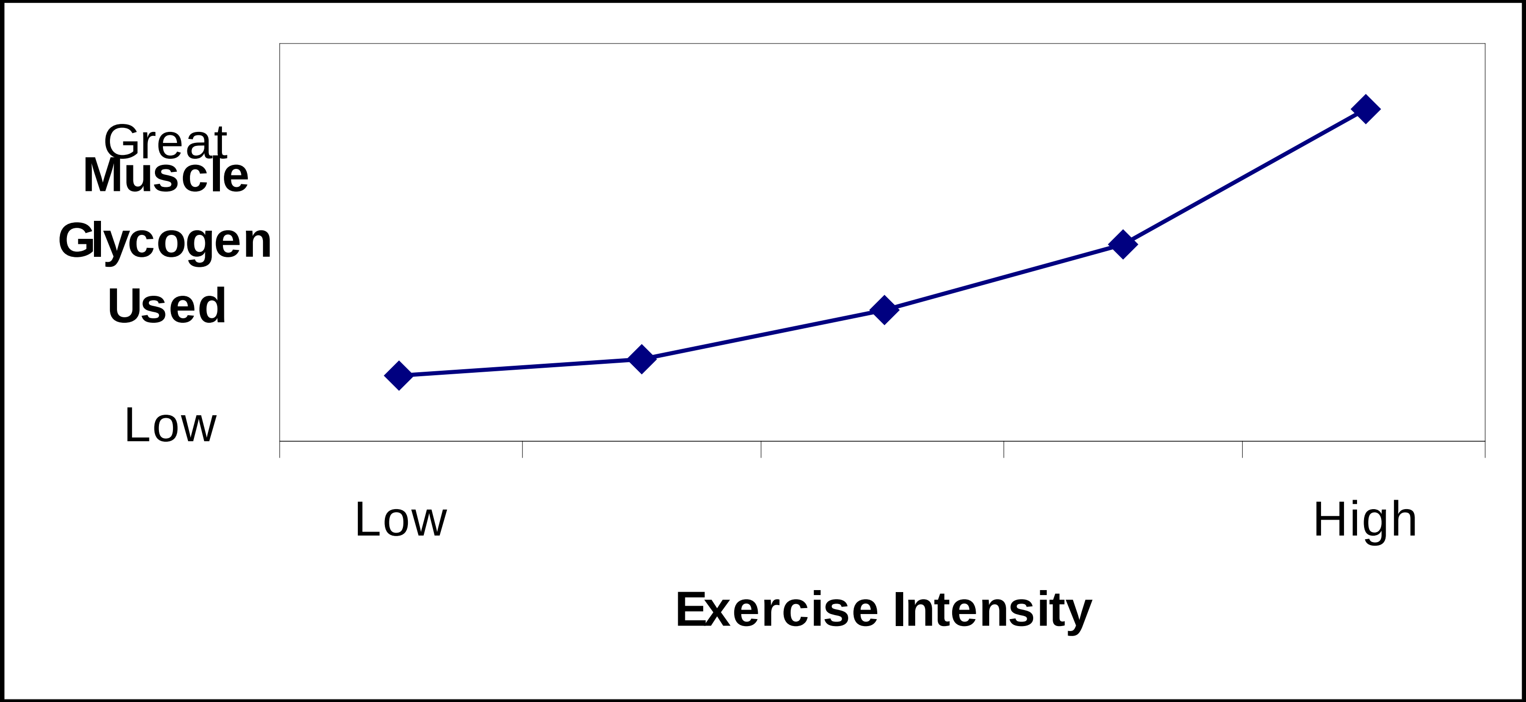
Carbohydrate Utilization During Exercise



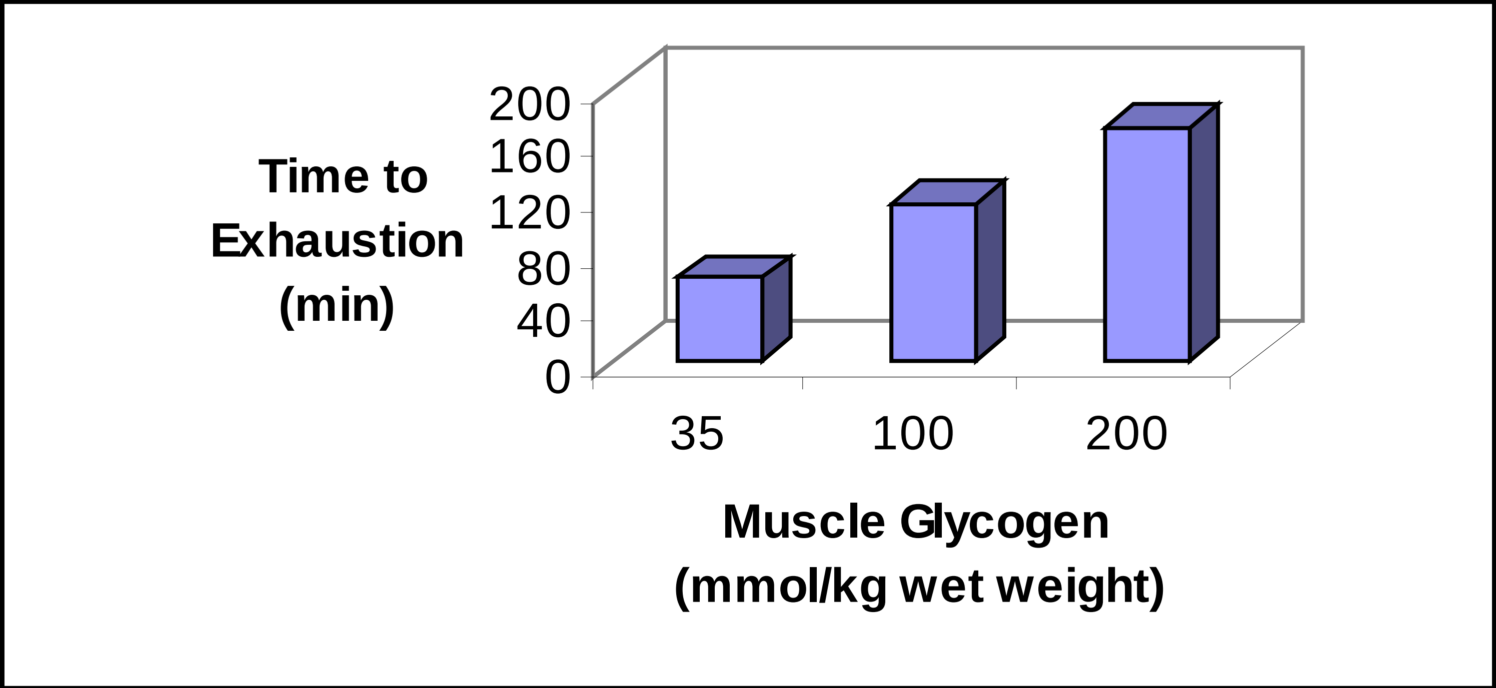
Carbohydrate Utilization During Exercise

- At onset of exercise, muscle glycogen is the primary source of CHO used for energy.
- Rate of muscle glycogen depends upon exercise intensity, physical condition, mode of exercise, environmental temperature and preexercise diet.

Carbohydrate Utilization During Exercise



Carbohydrate Utilization During Exercise



Relationship between muscle glycogen content and duration of exercise

Nutrient Timing

- **Carbohydrate**
  - Pre-exercise
  - Exercise feedings
  - Post-exercise recovery
  - Protein saving
- **Protein**
  - Amino acid – comparisons between pre and post feedings – protein synthesis
  - Whole protein
  - Comparisons
- Protein and Carbohydrate Ingestion
- Pre-event, pre-exercise meal

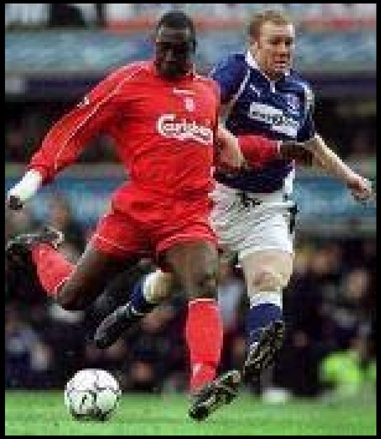
Glycogen Loading

- Idea arose during mid-60’s
- Maximize glycogen content within muscle
- Deplete glycogen stores one-week before event – through exhaustive exercise and consuming a low carbohydrate diet.
- Decrease glycogen stores → increase glycogen synthetase
- High carbohydrate intake then results in supercompensation and greater muscle glycogen content

Glycemic Index and Muscle Glycogen Recovery

- Glycemic index : *Incremental 2-hr area under the glucose response curve of 50 g of test food compared with the glucose response curve of either 50 g glucose solution or a white bread standard.*
- Low GI < 40 – slow absorption of glucose, delayed glycogen recovery, enhanced exercise performance from a pre-exercise feeding.
- Mod GI 40 – 70
- High GI > 70 – enhanced absorption, faster glycogen recovery

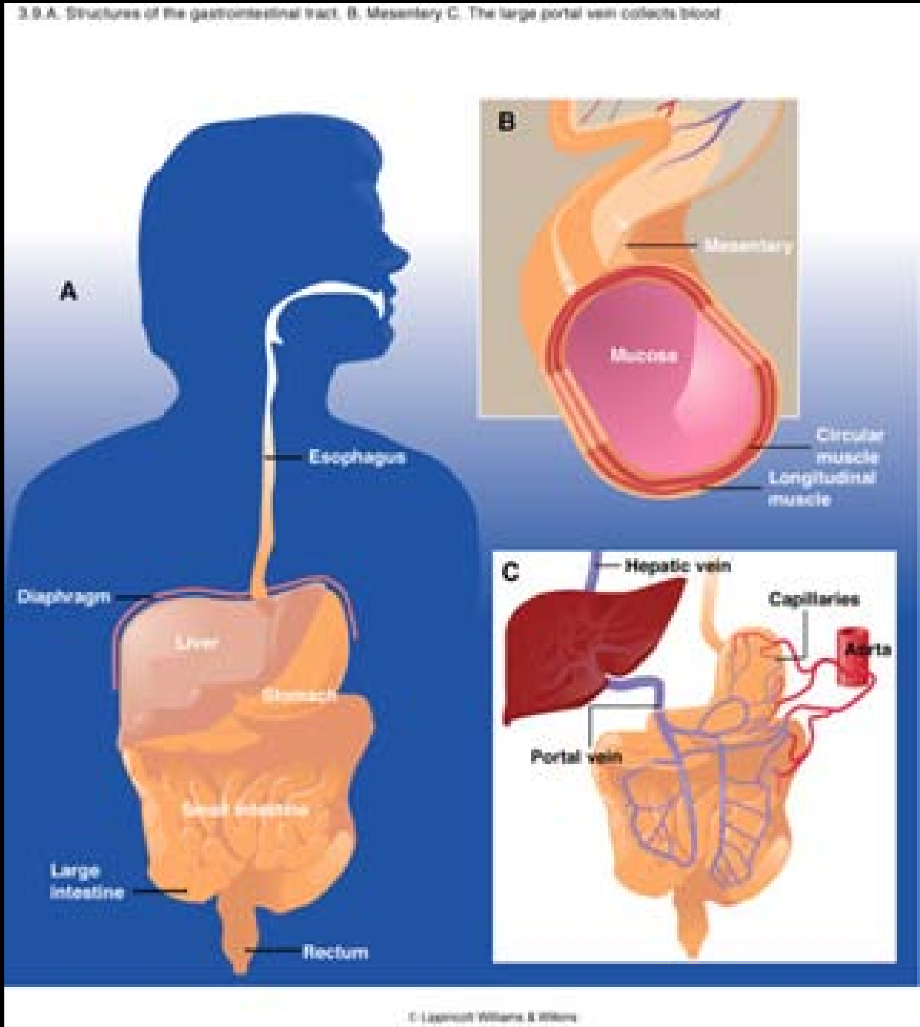
Glycemic Index and Sports



To speed glycogen replenishment after a hard bout of training or competition, one should consume high glycemic, carbohydrate-rich foods as soon as possible.

What would affect glycemic index?

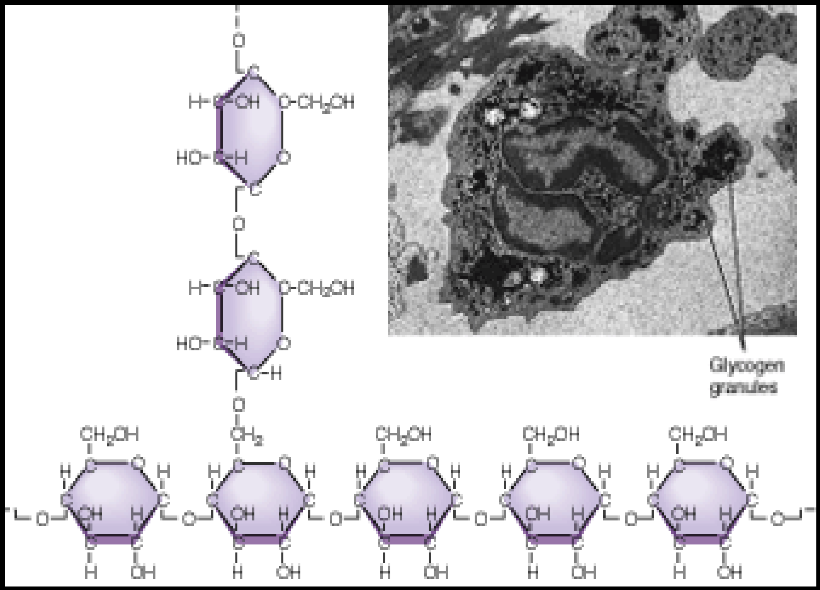
- Rate of ingestion
- Food form
- Fiber content
- Starch characteristics
- Fat and protein content
- Gastric emptying
- Gastrointestinal digestion



Examples of Glycemic Index (GI) of Various Foods

Food	GI	Food	GI
Soy bean	25	Bananas	82
Plums	30	Baked Potato	87
Grapes	43	Carrots	90
Rice	60	Instant Rice	120
Yam	60	French Bread	132
Spaghetti	65	Rice cakes	137

Glycogen synthesis is time-sensitive.



Immediately post exercise is the period when activities of glycogen synthesis are most active.

Pre-Exercise Glucose Consumption

- Two metabolically significant stages:
  - *2 – 4 hours pre-exercise*
    - Important for resynthesis of previously depleted hepatic and muscle glycogen stores
  - *30 – 60 min pre-exercise*
    - "*topping off*" liver glycogen stores to maintain blood glucose during exercise

Pre-Exercise Feedings

- Coyle et al., 1985: Cyclists provided a carbohydrate meal 4-hrs prior to a long ride (105 min) at 70% VO_2max.
  - **42% increase in muscle glycogen!**
  - **Greater levels of CHO oxidation and utilization of muscle glycogen.**

Pre-Exercise Carbohydrate Feedings

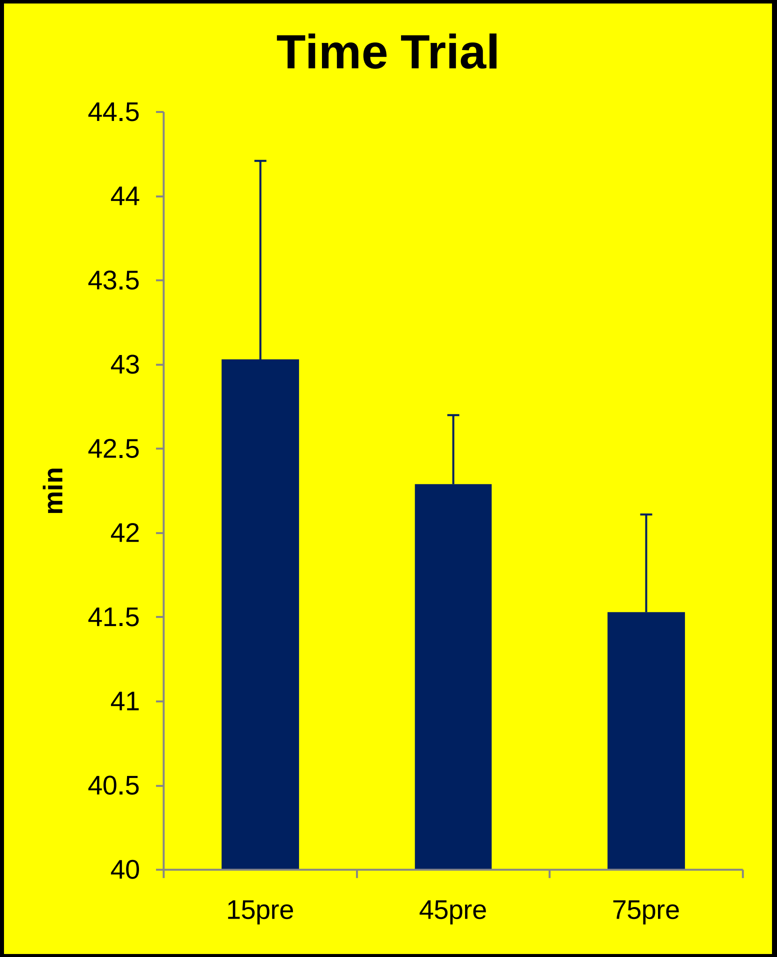
- Immediately before exercise:
  - Metabolic and performance effects similar to that seen during ingesting carbohydrates during exercise.
  - Smaller amounts (~50 g) ingested before exercise shown to improve performance
  - Prefer low GI carbohydrate

Pre-Exercise Glucose Ingestion: Research Examining Timing of Ingestion

- Trained triathletes consuming 5 ml·kg^{-1} of a 10% glucose solution 60-min prior to a 4000-m swim trial (Smith et al., 2002).
  - 2.5% improvement in time ($p > 0.05$), but 8/10 swam faster!

Comparison of 75 g Glucose feeding (15% solution) 15-, 45- and 75-min prior to Exercise

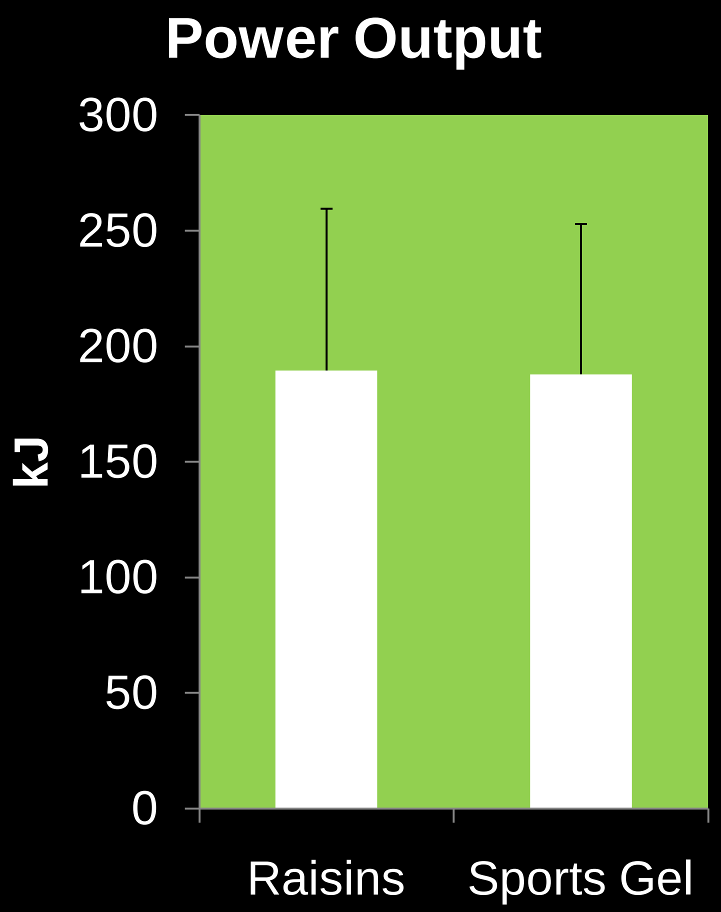
- Endurance trained men performing 60 min of exercise (20-min ride followed by a 40 min time trial at 80% W_{max}) on cycle ergometer exercise
  - Plasma glucose highest at 15pre.
  - No **significant** performance differences seen!
  - Timing of ingestion does not affect endurance performance
  - Hypoglycemia did not affect time trial performance after 20-min ride.



Moseley et al., 2003).

Differences in Whole Food vs. Sports Carbohydrate Gel on Performance

- 8 endurance trained cyclists consuming either a food (raisins) or sports gel ingested 45 min prior to a 60 min exercise session (45 min at 70% VO_2max and 15 min time trial).
- Both were mod and high GI foods (62 and 88, respectively).
- Results: no differences in glucose or insulin response during exercise



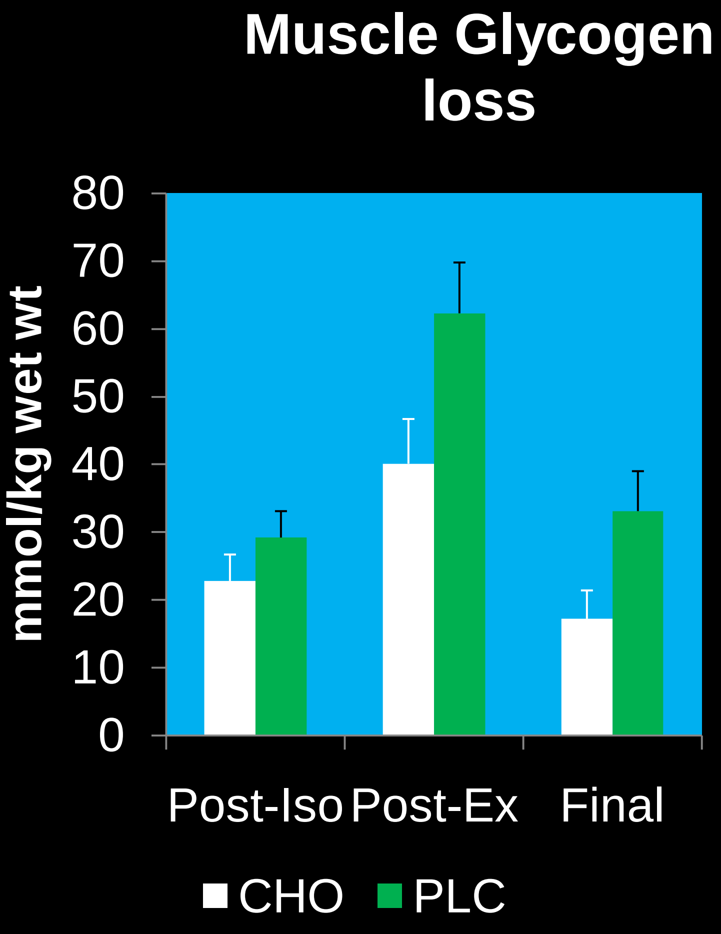
Kern et al., 2007

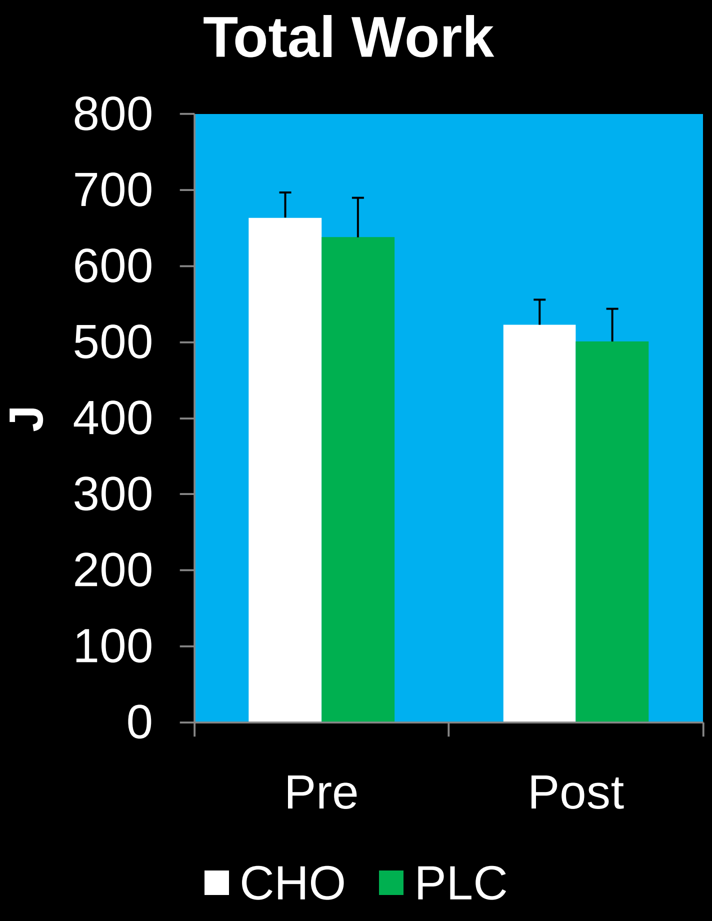
Pre-Exercise Carbohydrate Feedings and Resistance Exercise

- 8 experienced resistance trained subjects performed 1,3 sets of isokinetic knee extension/flexion exercise (3.14 and 2.09 rad·s^{-1} with 3-min rest.
- Ingested 1.0 g·kg^{-1} CHO 10-min prior to exercise and 0.3 g·kg^{-1} CHO every 10 min of exercise.
- Performed 3 sets of 10 repetitions of back squats (65% 1-RM), speed squats (45% of 1-RM) and 1-legged squats (10% of 1-RM) with 3-min rest between sets. Repeated isokinetic protocol.

Haff et al., 2000

Carbohydrates and Resistance Exercise





Haff et al., 2000

Carbohydrates and Resistance Exercise

- Carbohydrate supplementation can attenuate muscle glycogen loss.
- Does not appear to improve isokinetic knee extension/flexion performance

CARBOHYDRATE INGESTION DURING EXERCISE

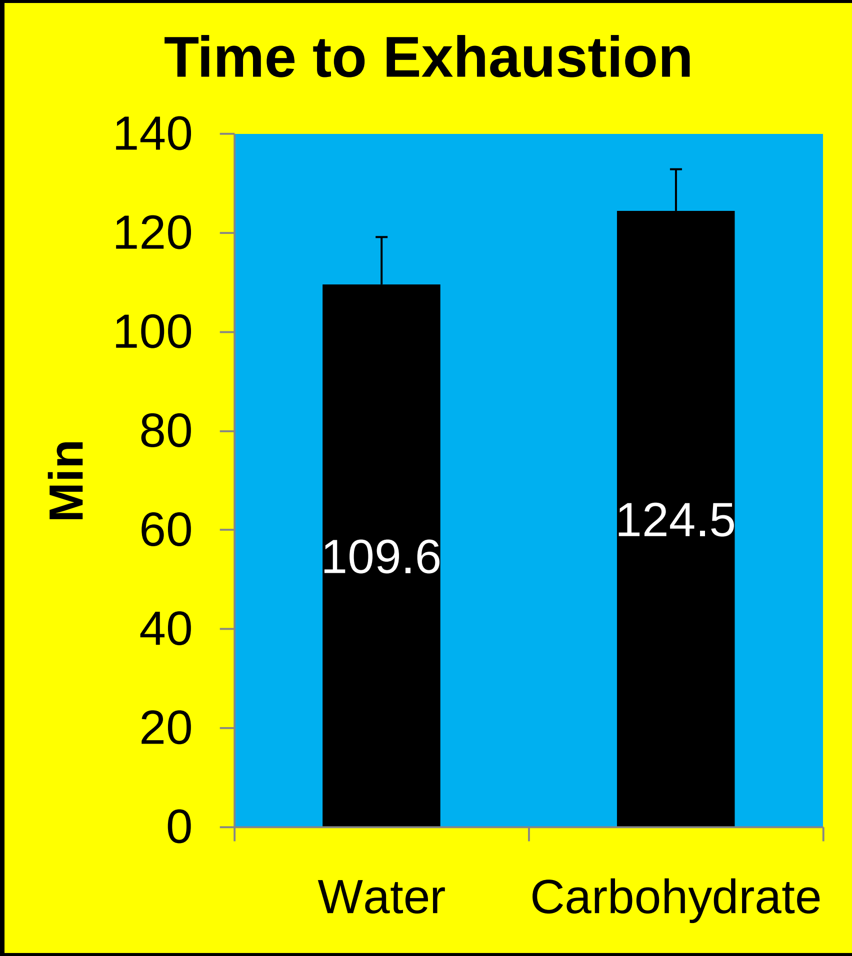
Carbohydrate Ingestion During Exercise

- 8% CHO solution provided every 15 min during exercise associated with 30% increase in time to exhaustion (47 min longer time to exhuastion) (McConell et al., 1999).

- ~5% CHO solution (10.75 g in 200 ml of water) at 30 min intervals enhances time to exhaustion greater than CHO intake of longer intervals (60 min) (Fielding et al., 1985).

Glucose Ingestion During Exercise

- Improved time to exhaustion (Tsintzas et al., 1997)
- Carbohydrate consumption for first hour of exercise, water there after.
- Delay in onset of fatigue
  - ↑ blood glucose
  - ↑ Insulin
  - ↓ FFA



Recommendations of Pre-Exercise and During Exercise Carbohydrate Feedings

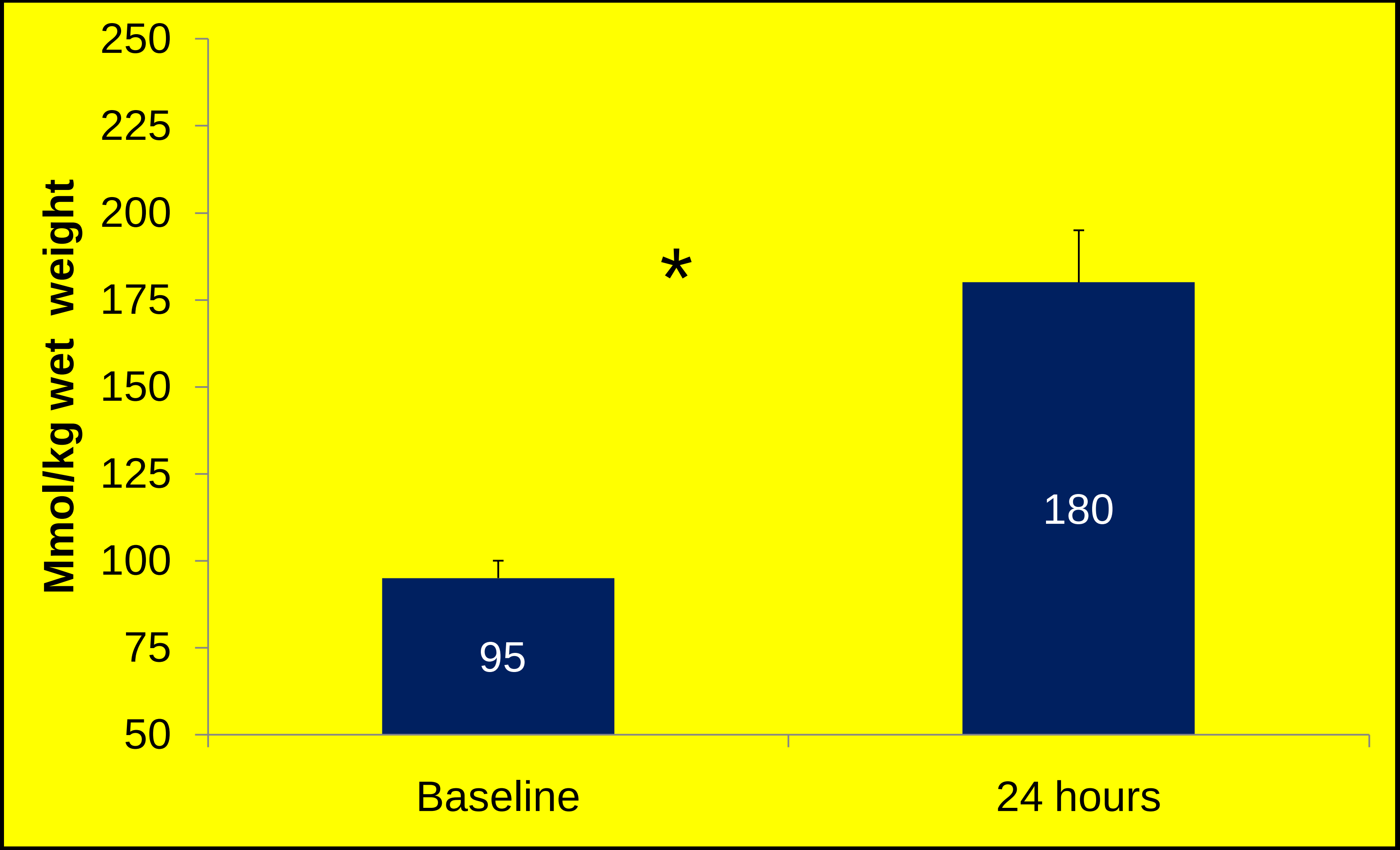
- **Pre-Exercise**
  - Low glycemic carbohydrate (close to exercise)
  - General guidelines 1 -2 g/kg bw 3 – 4 hours before practice or competition.
- **Exercise Feedings**
  - May use a high glycemic carbohydrate (catecholamines blocking the insulin response)
  - May become important during exercise durations > 60 min (6-8% solution (8- 16 ounces) every 10 – 15 min (Jeukendrup et al., 2005).

POST-EXERCISE CARBOHYDRATE FEEDINGS

Post-Exercise Carbohydrate Feedings

- Greater insulin sensitivity post-exercise maximizes the utilization of high glycemic carbohydrates!
- Heightened insulin sensitivity suggests a window of adaptation!
- Benefit of continued post-exercise feedings is seen to maximize muscle glycogen stores.
- Delay in carbohydrate ingestion by 2 hrs may reduce glycogen resynthesis by ~50% (Ivy, 1998).
- Needs are dependent on muscle glycogen depletion!

Effect of High Glycemic Feeding Post-Exercise (10 g/kg bw)



Bussau et al., 2002

Effect of Timing of Ingestion: High Glycemic Index Food

(Parkin et al., 1997)

- 6 endurance trained men provided a high glycemic meal (2.5 g/kg bw) immediately after or delayed 2 hours following 2 hours of cycle ergometer exercise followed by 4 – 30 s sprints.
- Results: No difference in muscle glycogen storage at 8- and 24-hr post-exercise!
  - Within 2 hour window

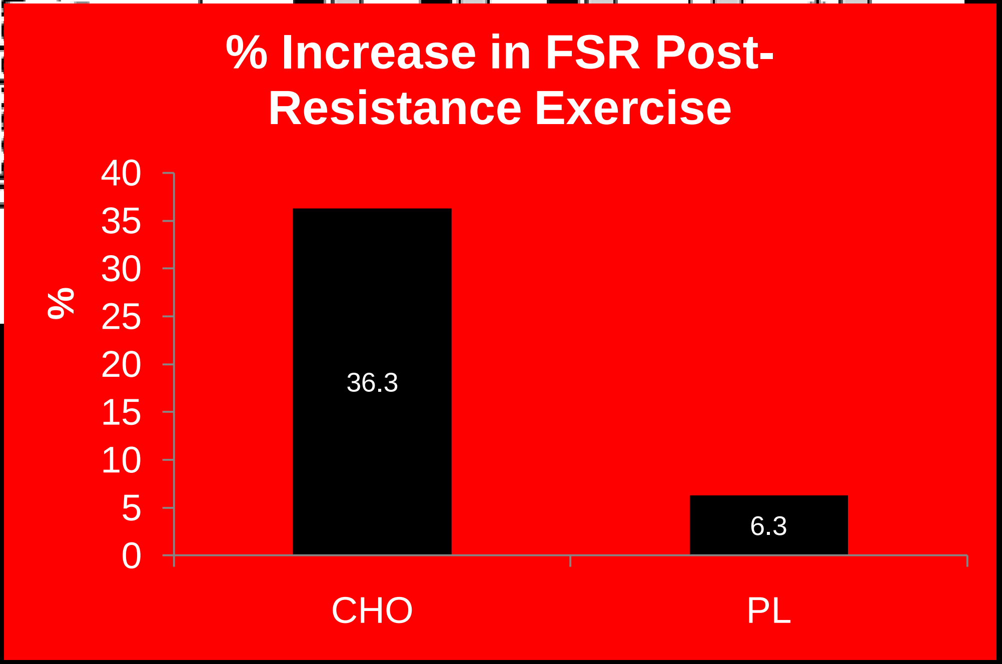
Carbohydrates Effect on Protein Synthesis During Recovery

Roy et al., (1997) showed that carbohydrate ingestion 60-min following resistance exercise can reduce protein breakdown.

let phenylalanine (PHE)

exercise

- 100 mg of carbohydrate provided 1hr post-ex
- Minor effect compared to amino acids.



Recommendations of Post-Exercise Carbohydrate Ingestion

- If muscle glycogen depleted: 0.6 – 1.0 g/kg/hr first 30’ and every 2 hours for 4 – 6 hours (Jentjens et al., 2001; Jentjens and Jeukendrup, 2003).
  - Maximal glycogen resynthesis rates seen at 1.2 g/kg/hr consumed every 15 – 30 min (Jentjens and Jeukendrup, 2003; Van Loon et al., 2000).
  - 9-10 g/kg/day for days of consecutive exercise (Nichoas et al., 1997).

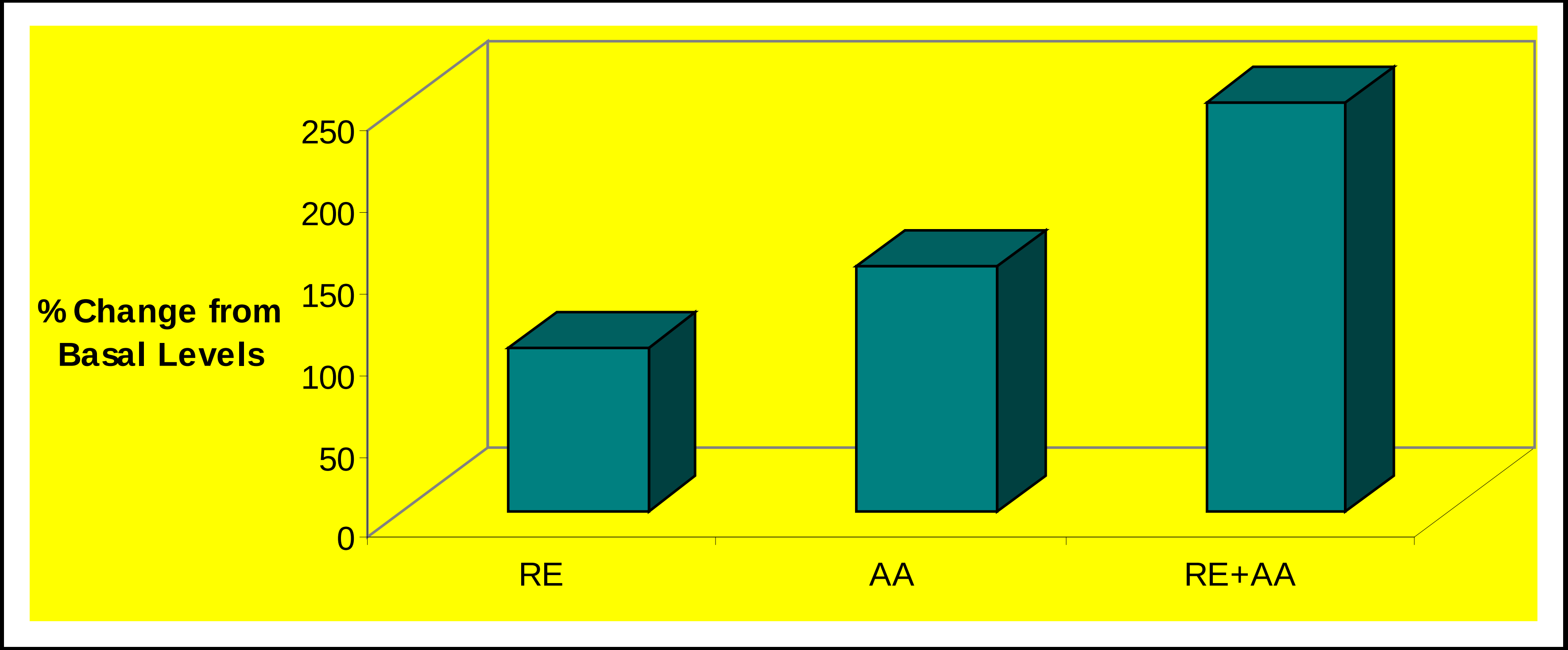
Protein

- Nitrogen containing substances formed by amino acids.
- Major structural component of muscle and other tissues of body.
- To be used by body, must be broken down in its simplest form: amino acids.

Importance of Protein Intake as it Relates to Athletic Performance

- Maintain positive nitrogen balance.
  - Protein accretion > protein degradation
- Enhance muscle growth and strength development.
- Enhance recovery from exercise.

Importance of Protein Intake and Resistance Training



Biolo et al., 1995, 1997

Amino Acids

- Total of 20 amino acids identified that are needed for normal growth and metabolism
  - Nonessential (11)
  - Essential (9)
- Absence of amino acids compromises ability to grow.

Complete and Incomplete Proteins

- Meat, fish, eggs and milk best sources of complete proteins
- Protein from plant and grain sources do not supply all essential amino acids.
- Vegetarians?

Type of Protein to Consume

- Protein consumption from food intake.
- Protein drinks
- Protein bars
- Amino Acids

Does timing of protein ingestion influence the anabolic response to resistance exercise?

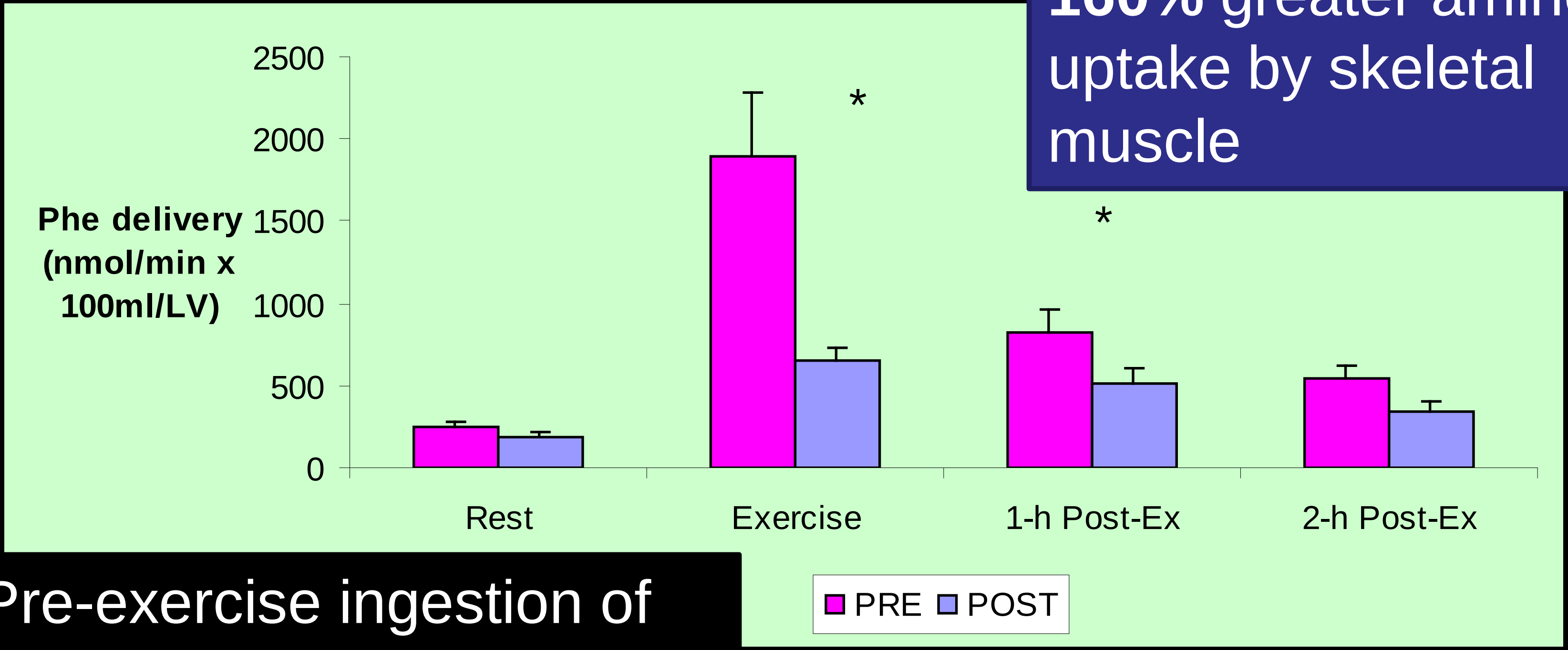
- **EAA provided 1 and 3 hr post-exercise**
  - Increases in muscle protein synthesis seen,
  - No difference between ingestion times in net muscle protein synthesis.

Rasmussen et al., 2000

- **When EAA provided before exercise.**
  - 46% ↑ in [aa] within muscle at end of exercise.
  - 86% ↑ in [aa] within muscle after 1-hr post-exercise.
  - 65% ↑ in [aa] within muscle at 3-hr post-exercise.
- Significantly greater compared post-exercise

Tipton et al., 2001

Comparison of pre vs post exercise EAA + CHO intake



Pre-exercise EAA ingestion resulted in **160%** greater amino acid uptake by skeletal muscle

Pre-exercise ingestion of EAA: Increased rate of delivery and subsequent uptake by skeletal muscle

Tipton et al., 2001

Type of Amino Acid: Essential versus Nonessential

- Only essential amino acids necessary for stimulation of protein synthesis
- Leucine and Isoleucine appear to have the greatest effect on muscle protein synthesis.
- Increases in protein synthesis occurs with greater amounts of EAA ingestion.
- Is there a ceiling effect?

Essential Amino Acid Ingestion

- Proportional availability of EAA in muscle from EAA ingestion does not occur.
- Differences in clearance rates of individual amino acids following ingestion.
- Differential uptake by skeletal muscle.
- Leucine and Isoleucine appear to have the greatest effect on muscle protein synthesis.

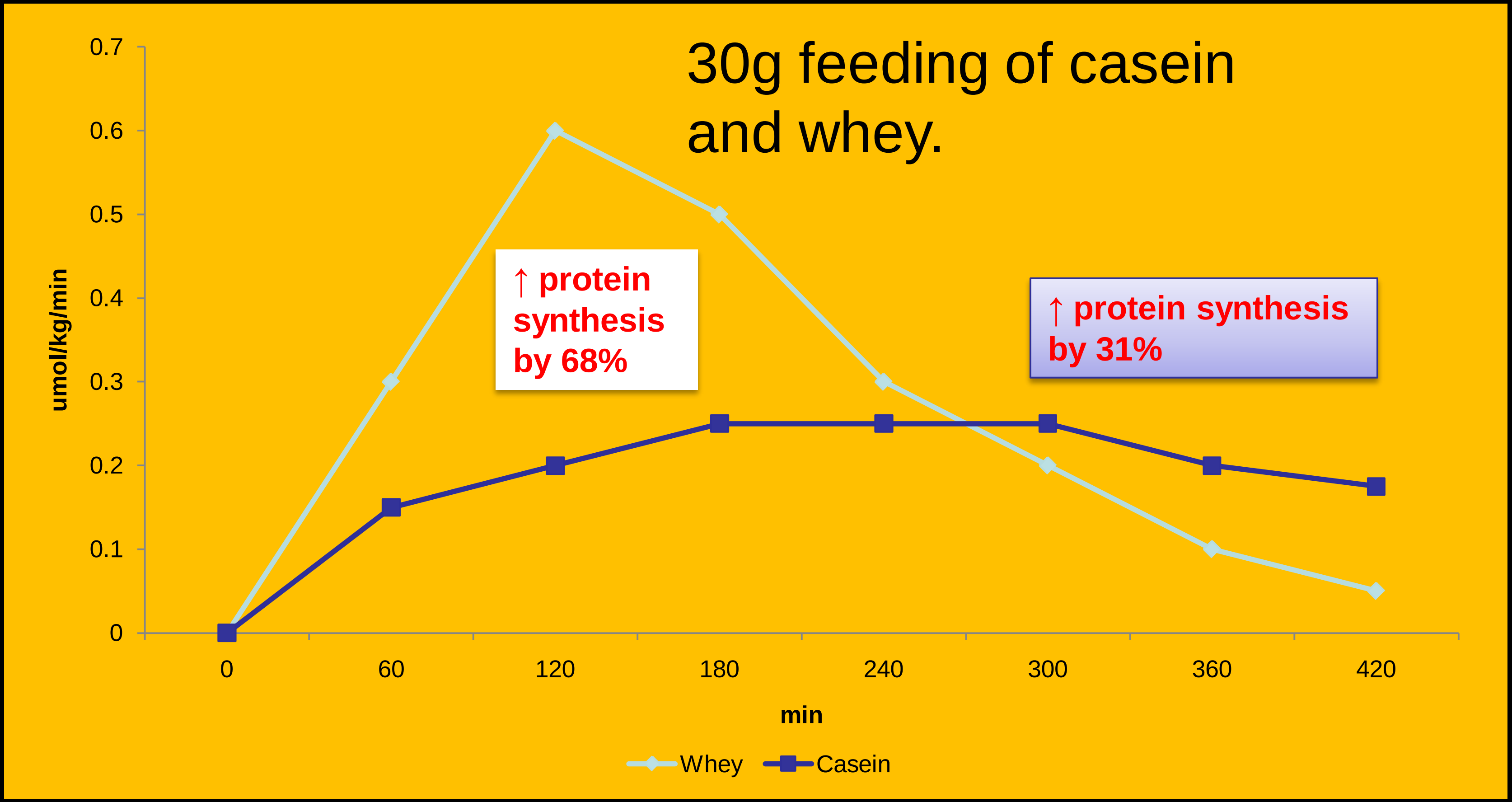
Protein Intake: Whole Protein

- Comparisons of casein and whey proteins
- From bovine milk with different digestive properties.
- Casein; predominant milk protein, exists in the form of a micelle (large colloidal particle)
  - Slow to digest
  - Provides a slow, but sustained release of amino acids into blood
- Whey: translucent part of bovine milk (~20%), with high concentration of BCAA and EAA.
  - Absorption rate much faster than casein.

Casein vs. Whey

- Casein and whey are both effective in stimulating muscle protein synthesis.
  - Casein and whey are complete proteins with different amino acid composition.
  - Leucine is higher in whey than casein.
  - Differences in digestive properties also contribute to differences in rates of muscle protein synthesis
- Whey provides a greater acute response.
- A greater window of opportunity following exercise for enhanced recovery and muscle remodeling.

Total Leucine Oxidation



7 hrs post: casein intake resulted in higher ($p<0.05$) leucine balance

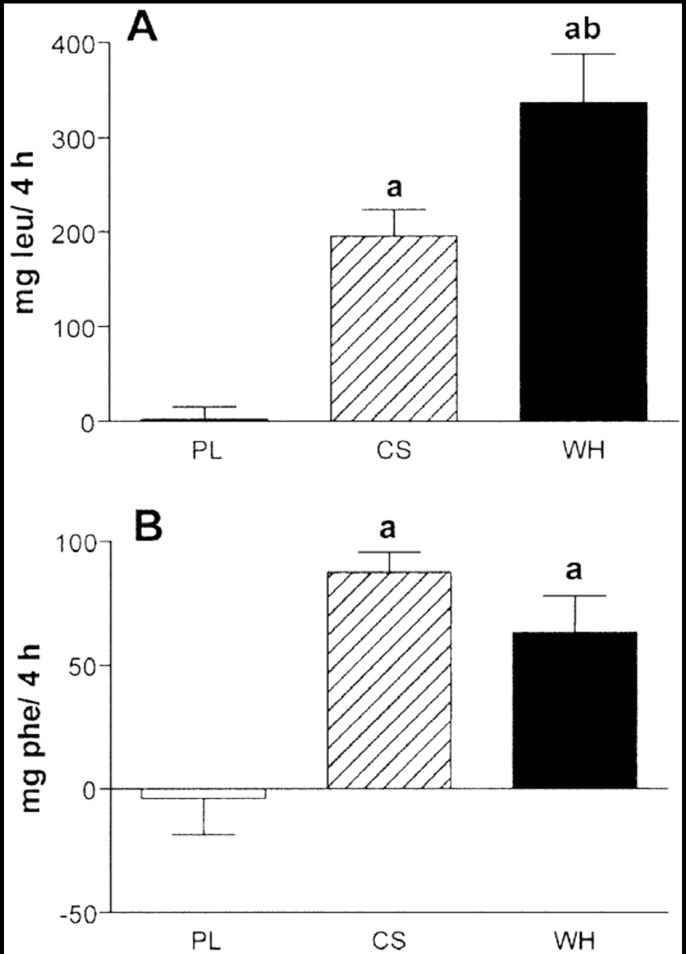
Boirie et al., (1997)

Comparison of Casein and Whey Protein Ingestion

- 23 male and female subjects (5yrs resistance training)
- 3 supplemental groups (given 1 hr after exercise)
  - Flavored water
  - 20g of Casein
  - 20g of Whey
- Exercise Protocol : 10 sets – 8 reps leg extension at 80% of 1RM
- Measured net muscle protein balance (Leu, Phen) and insulin

Tipton et al., 2004

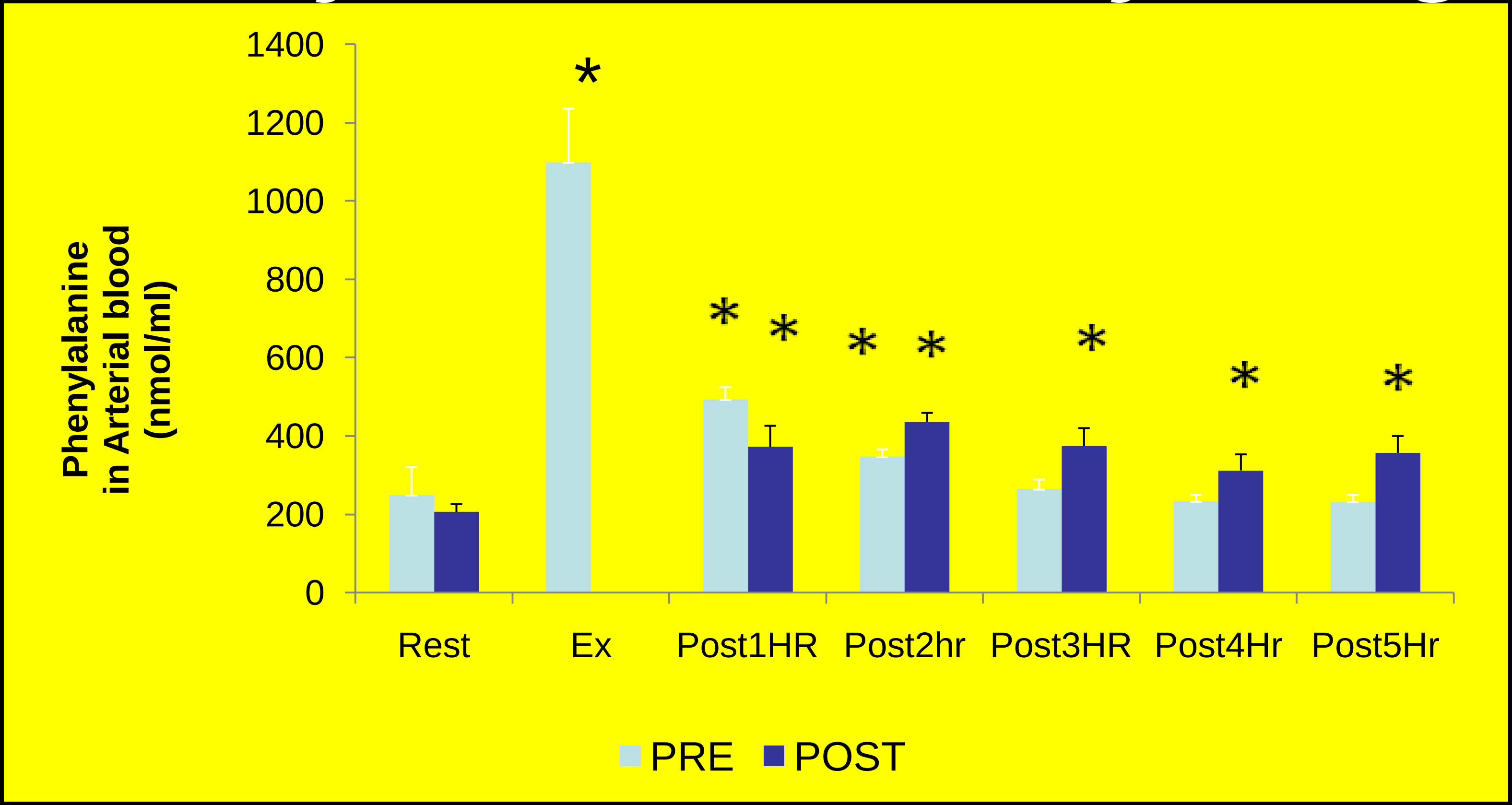
Net Protein Balance.



- **Both Casein and/or Whey Proteins can boost the anabolic effect of resistance exercise.**
- **Window of Adaptation??**

Pre vs. Post Whey Protein Ingestion

Phenylalanine delivery to leg



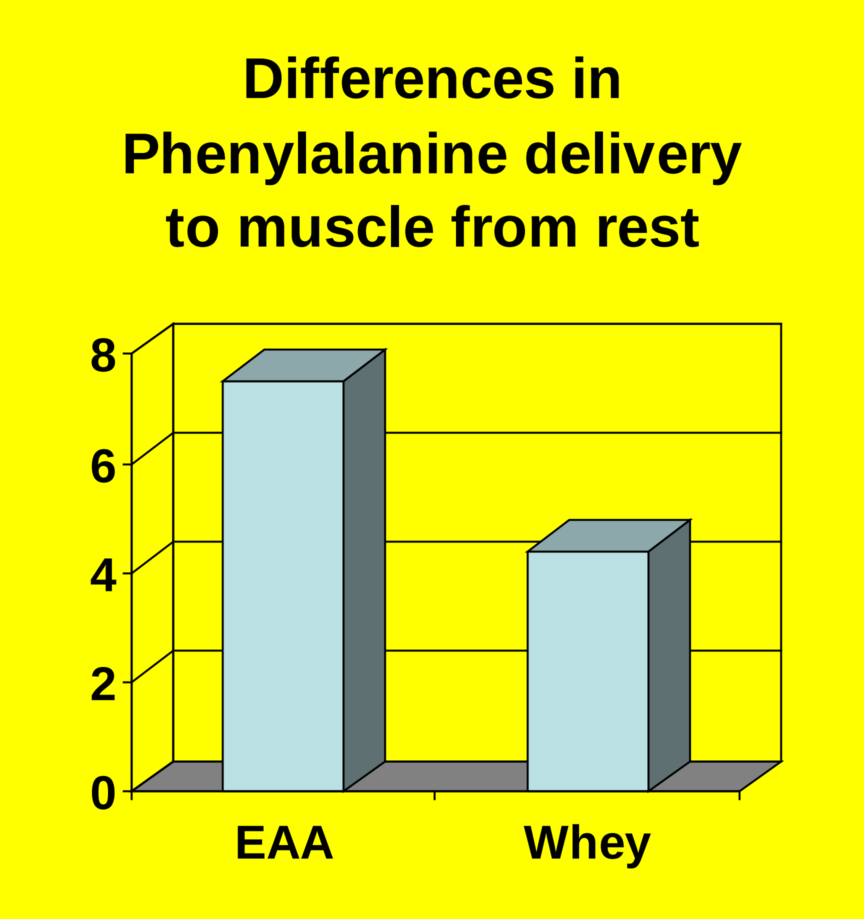
Tipton et al., 2007

IS THERE A DIFFERENCE BETWEEN AMINO ACID AND WHOLE PROTEIN INGESTION ON MUSCLE PROTEIN SYNTHESIS?

Comparisons between Amino Acid and Whey Ingestion

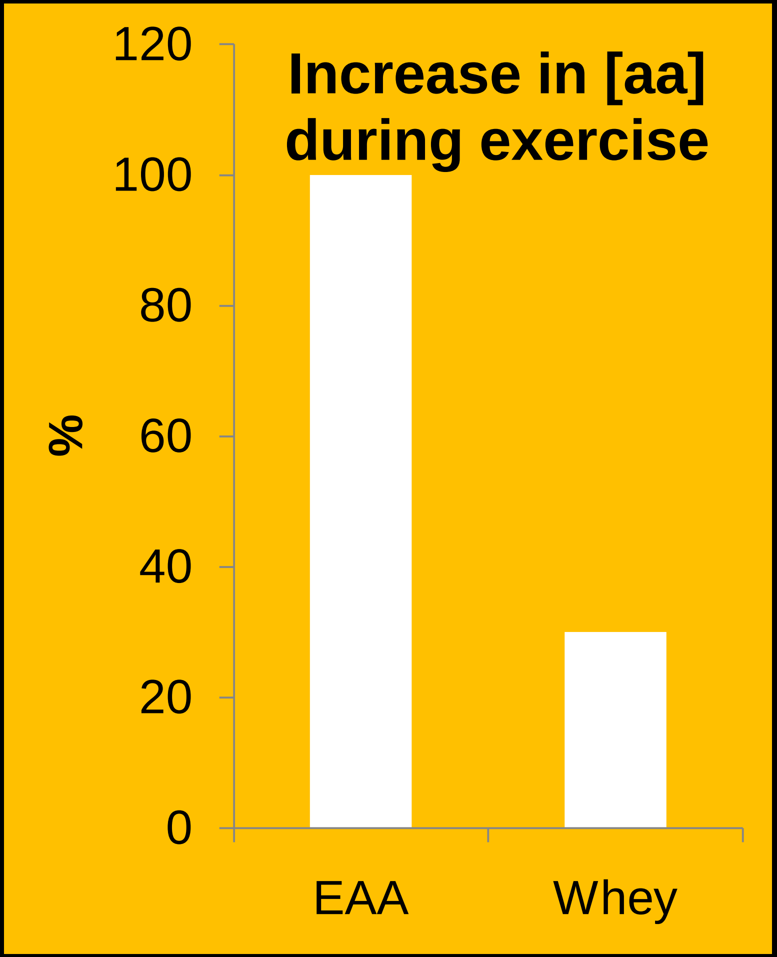
- ↑ in arterial AA 100% after EAA ingestion, but only 30% after whey ingestion

Tipton et al., 2007



Pre-Exercise Feedings of Amino Acids versus Whey

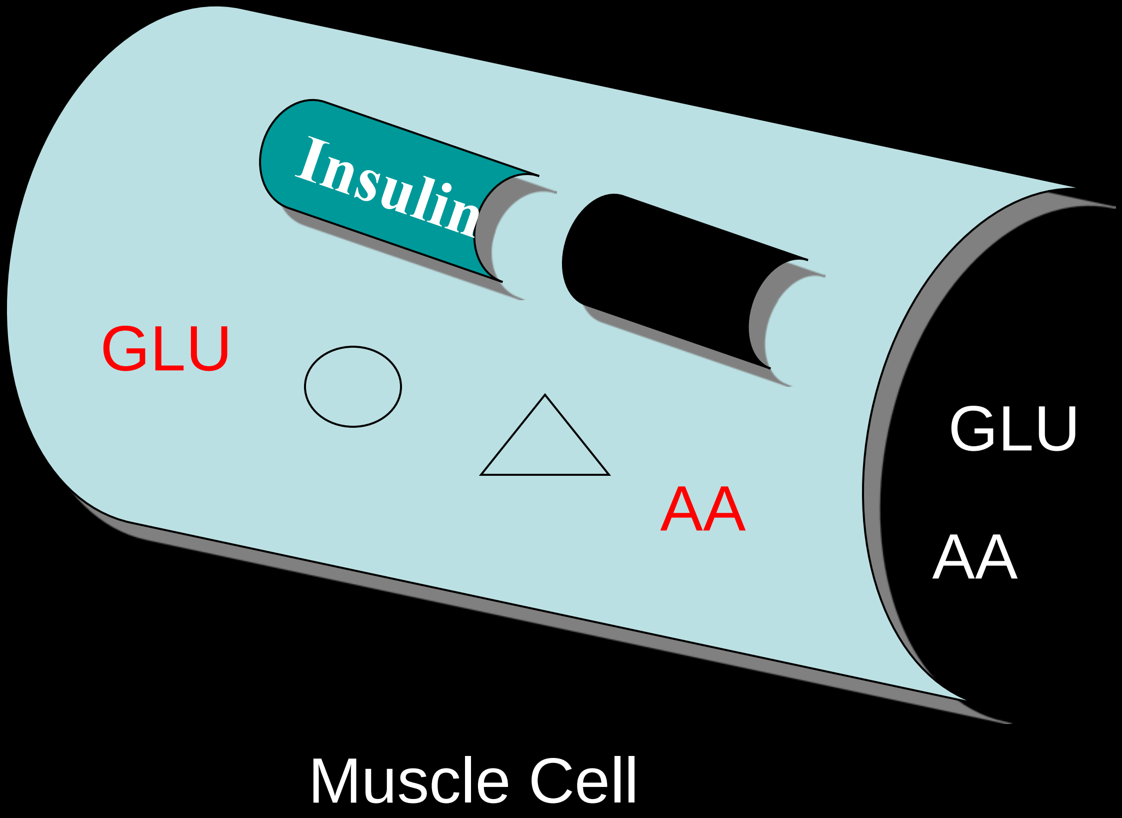
- Amino acid consumption prior to exercise leads to greater protein synthesis than whey
- Carbohydrate
  - Insulin response
- Timing of post-ex ingestion (IP vs 1 hr).



Tipton et al., 2001; 2007

Differences in EAA and Whey

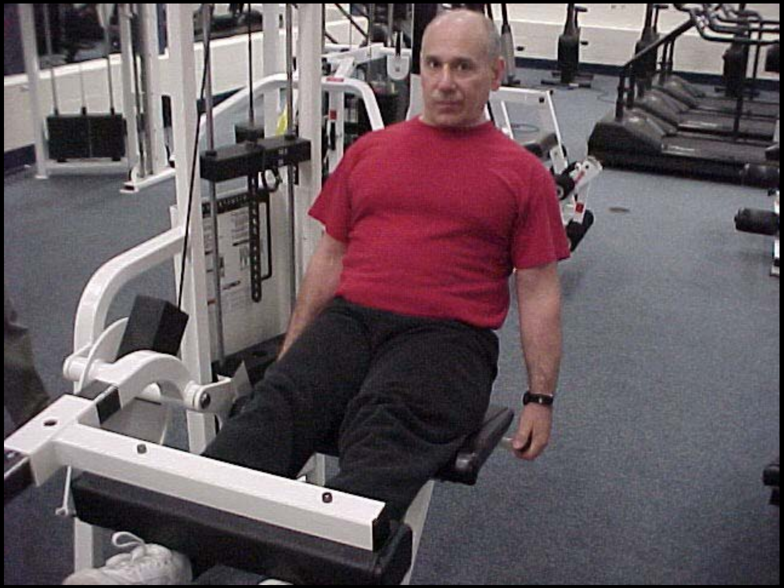
- May be related to addition of carbohydrate to EAA supplement.
- Importance of carbohydrate on stimulating greater insulin response.




TRAINING STUDIES

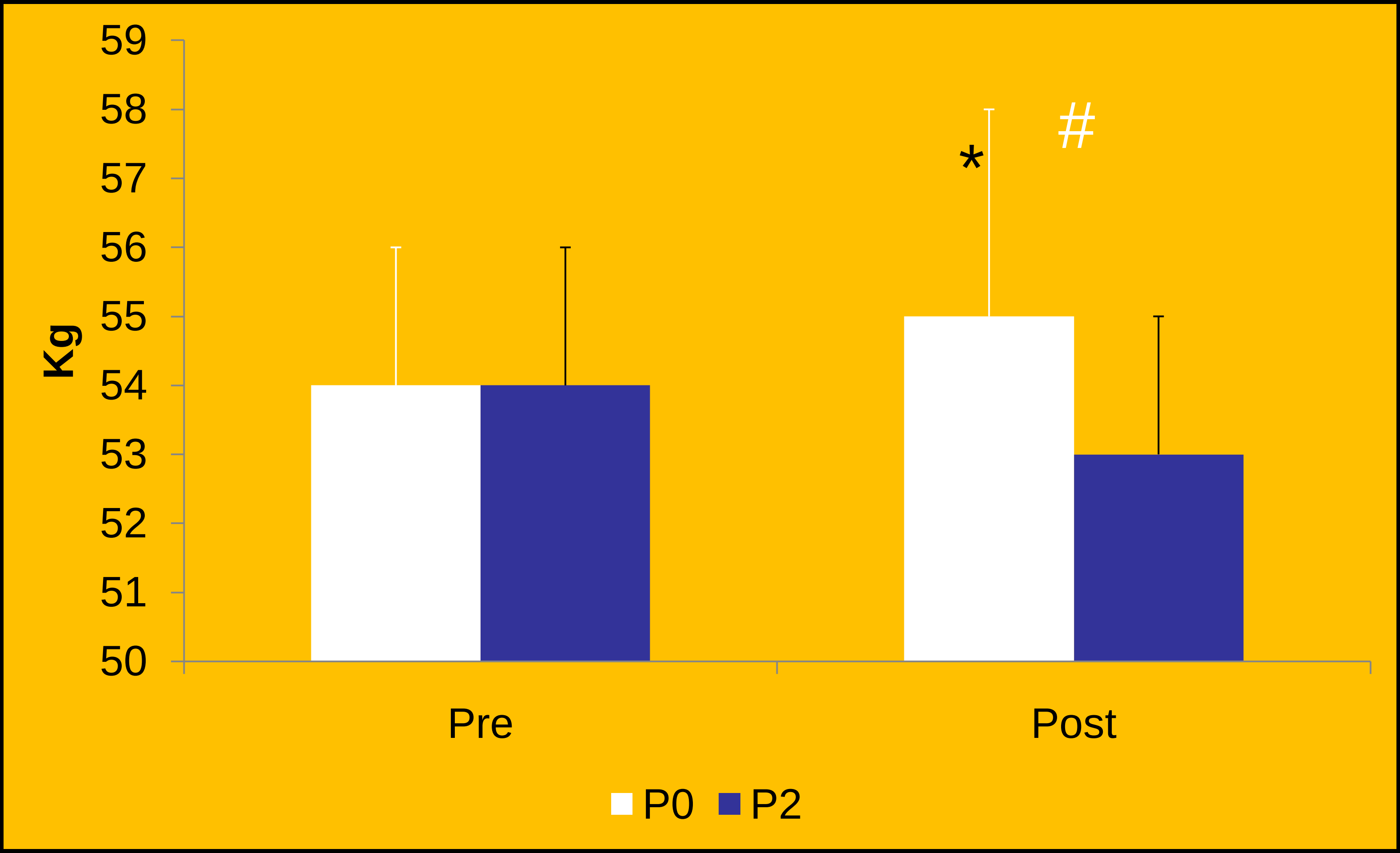
Protein Timing in Elderly Men

- 12 week training study in older (74 ± 1 y)
- 3 days per week
- 10 g of protein 5’ post workout (P0) or 2 hr post exercise (P2).
- Daily protein intake for each group 1.0 $g \cdot kg^{-1}$ and 1.1 $g \cdot kg^{-1}$ in P0 and P2, respectively.



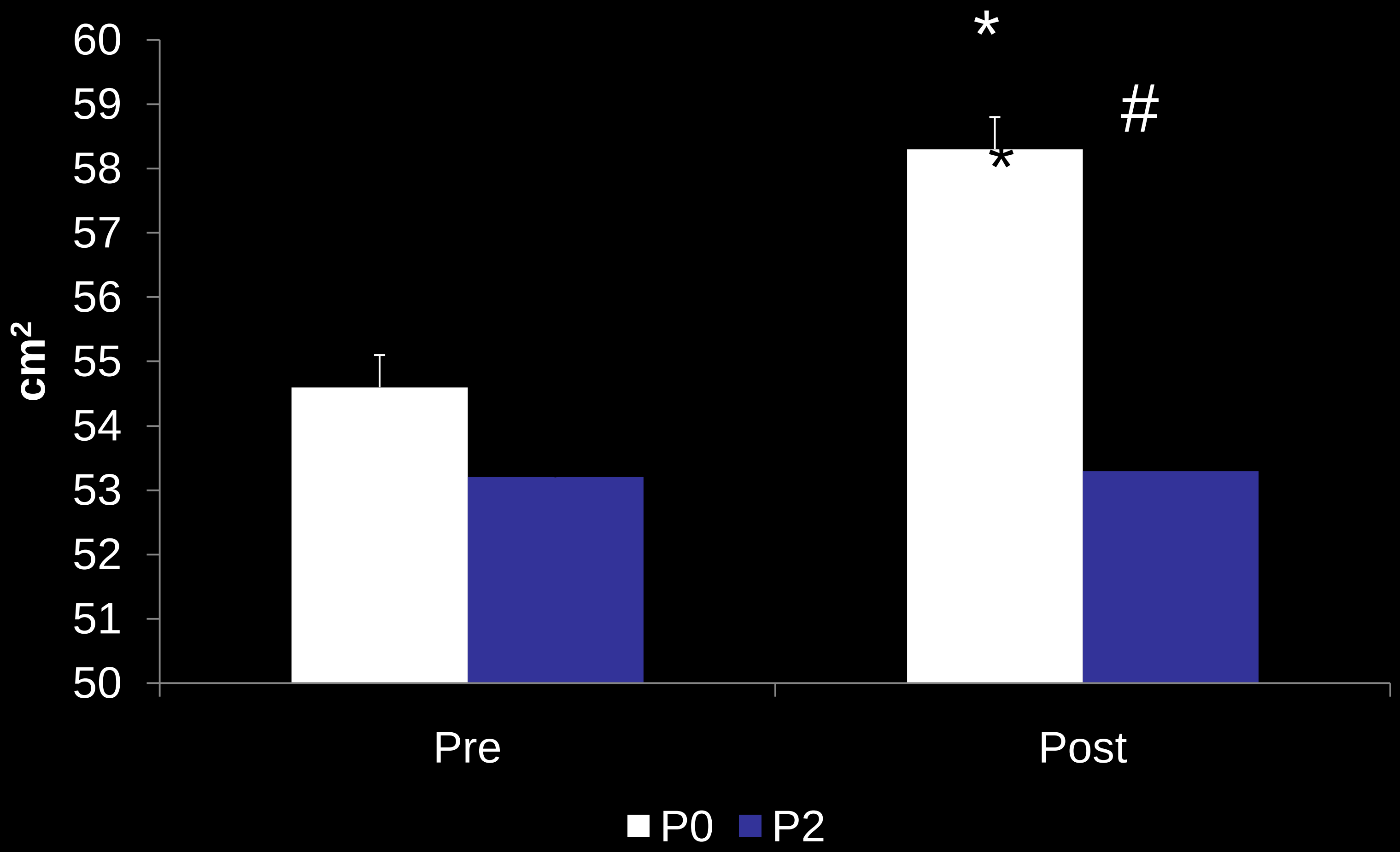
Esmarck et al., 2001

Lean Body Mass



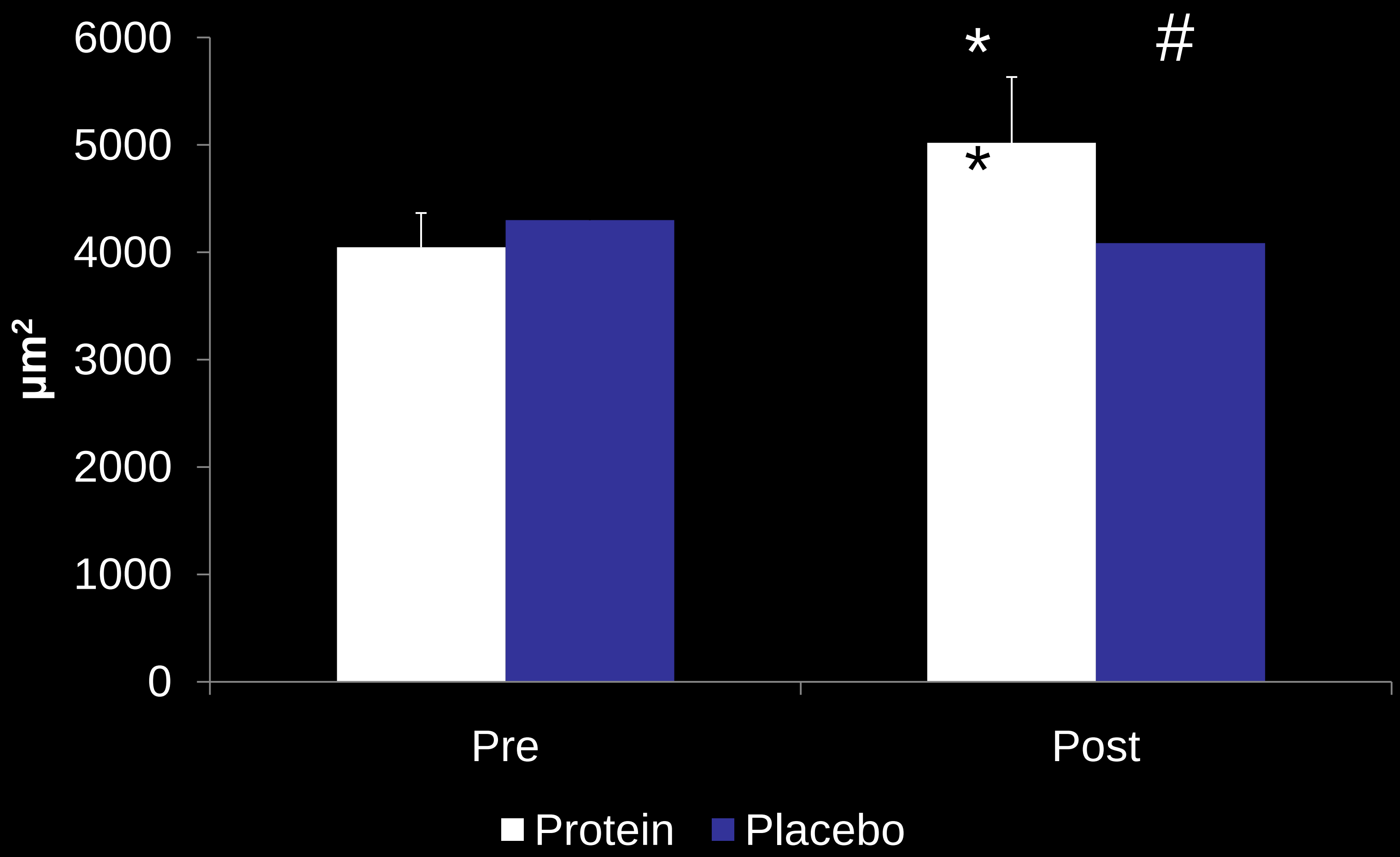
Esmarck et al., 2001

Muscle Cross-Sectional Area Quadriceps



Esmarck et al., 2001

Mean Fiber Area



Esmarck et al., 2001

Strength Performance

- Significant improvements in peak torque seen in 60°·sec^{-1} and 180°·sec^{-1} in P0 and no increases observed in P2.
- Both groups saw increases in dynamic strength (5-RM) in knee extensions. No differences between groups.

Summary

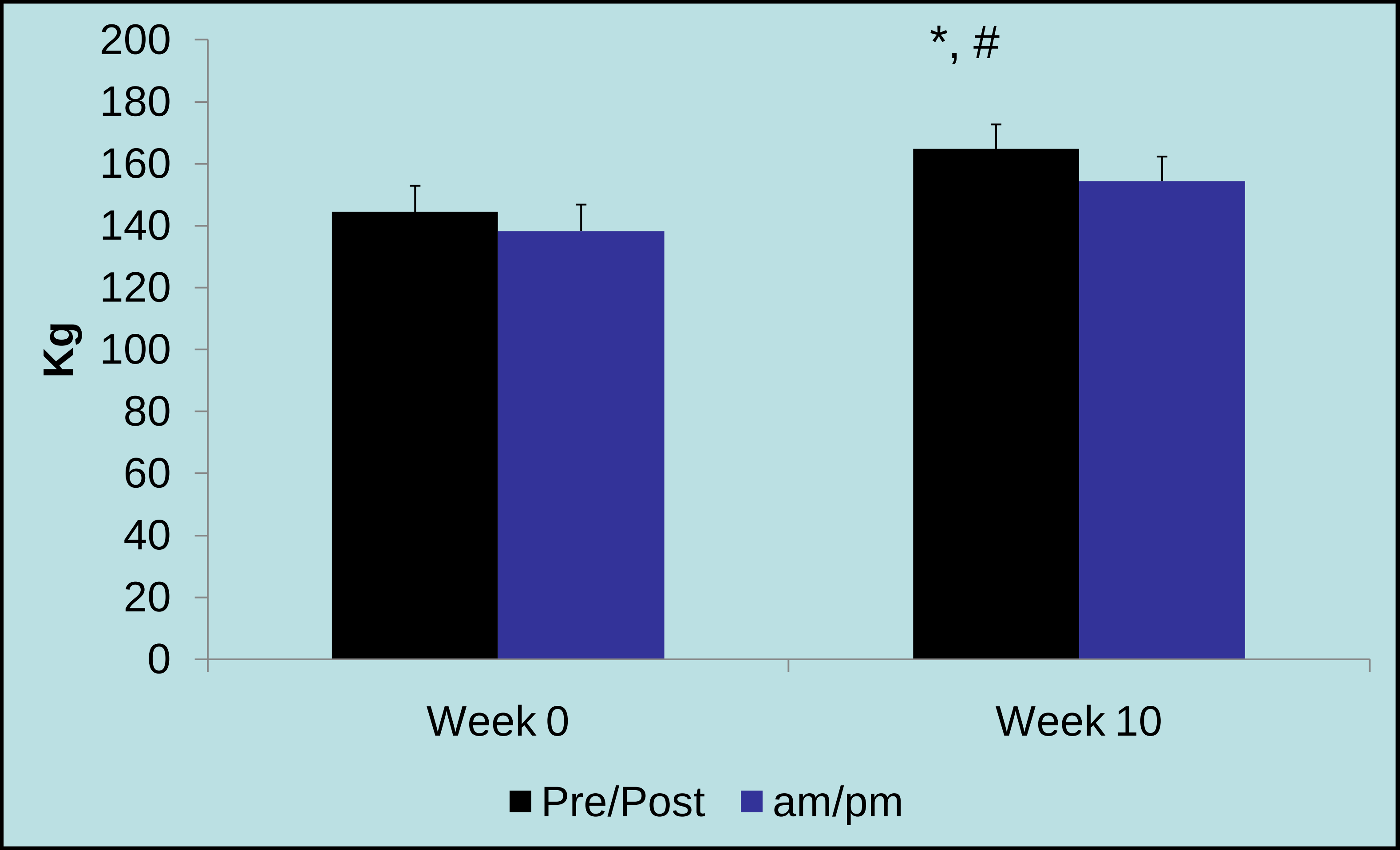
- First study to show that timing of protein intake after resistance exercise can significantly increase protein synthesis, muscle CSA, and muscle fiber area in elderly subjects.

Protein Timing in Recreational Bodybuilders

- Young recreationally trained bodybuilders (~21 – 24 y).
- Whey (40 g) + CHO (43 g Glucose) in consumed immediately before and after (Pre/Post) vs. Morning/Evening (am/pm)
- 10 week study.
- Daily protein intake 1.92 $g \cdot kg^{-1}$ and 2.11 $g \cdot kg^{-1}$ in Pre/Post and am/pm, respectively.

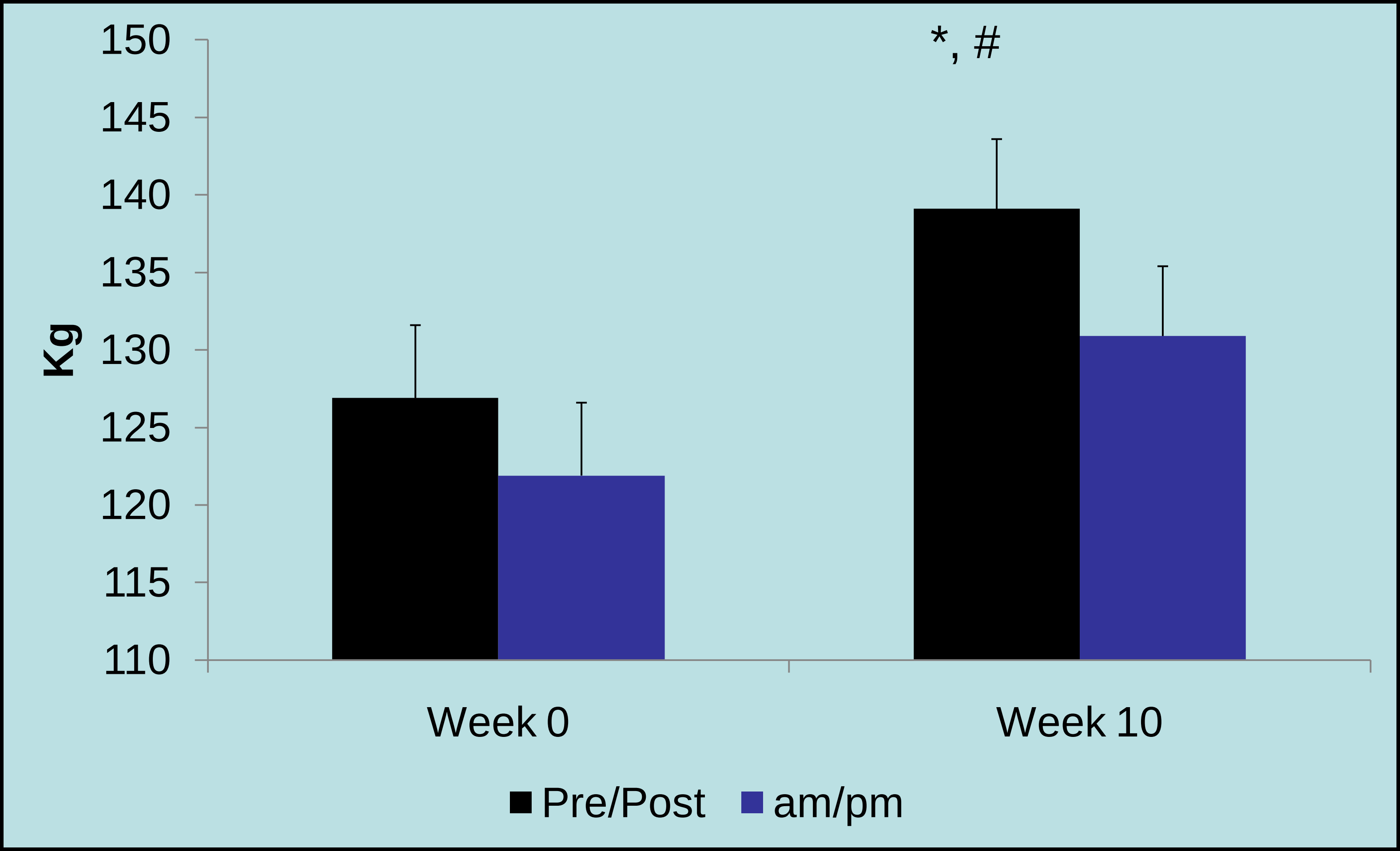
Cribbs and Hayes, 2006

1-RM Squat



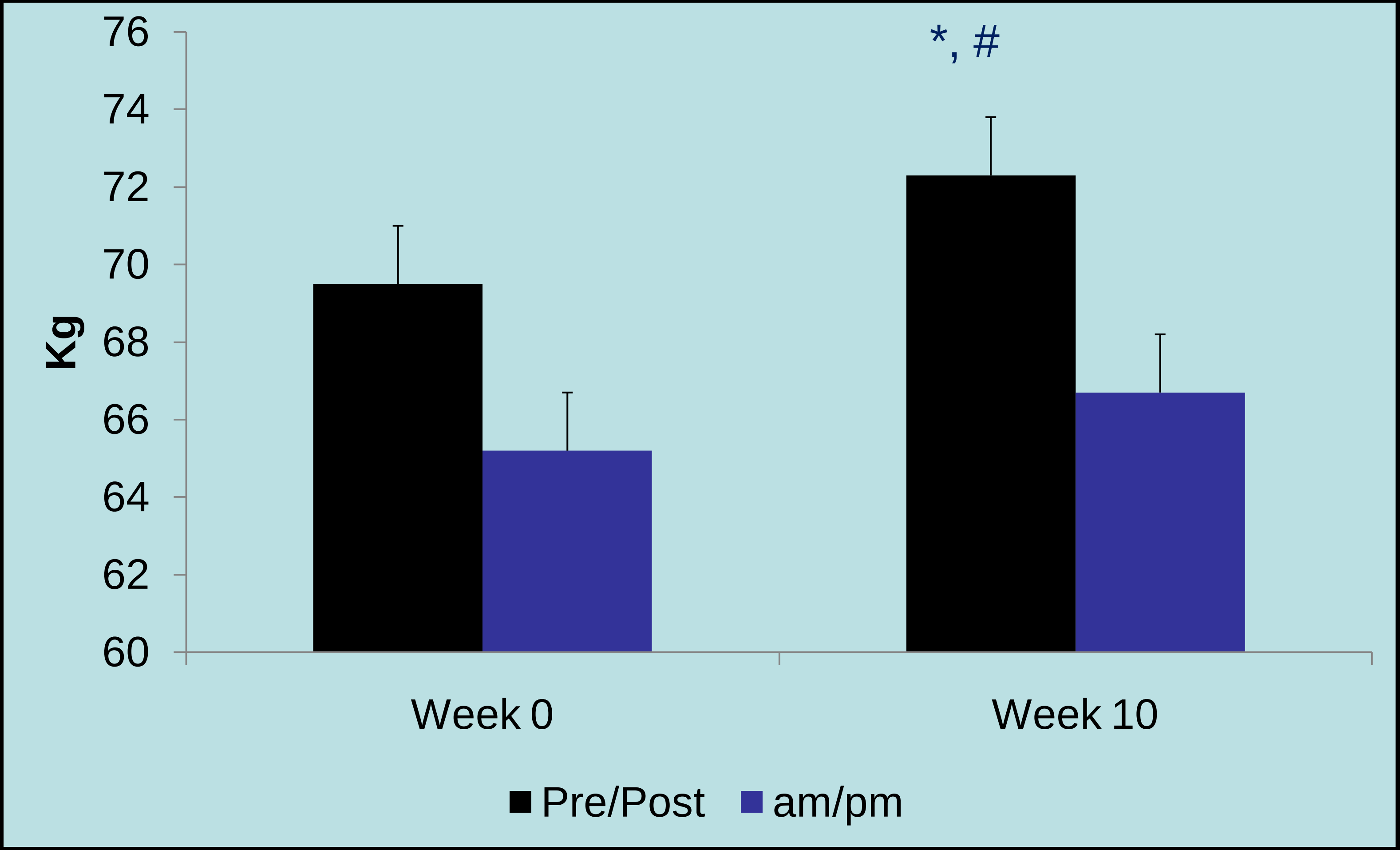
Cribbs and Hayes, 2006

1-RM Bench Press



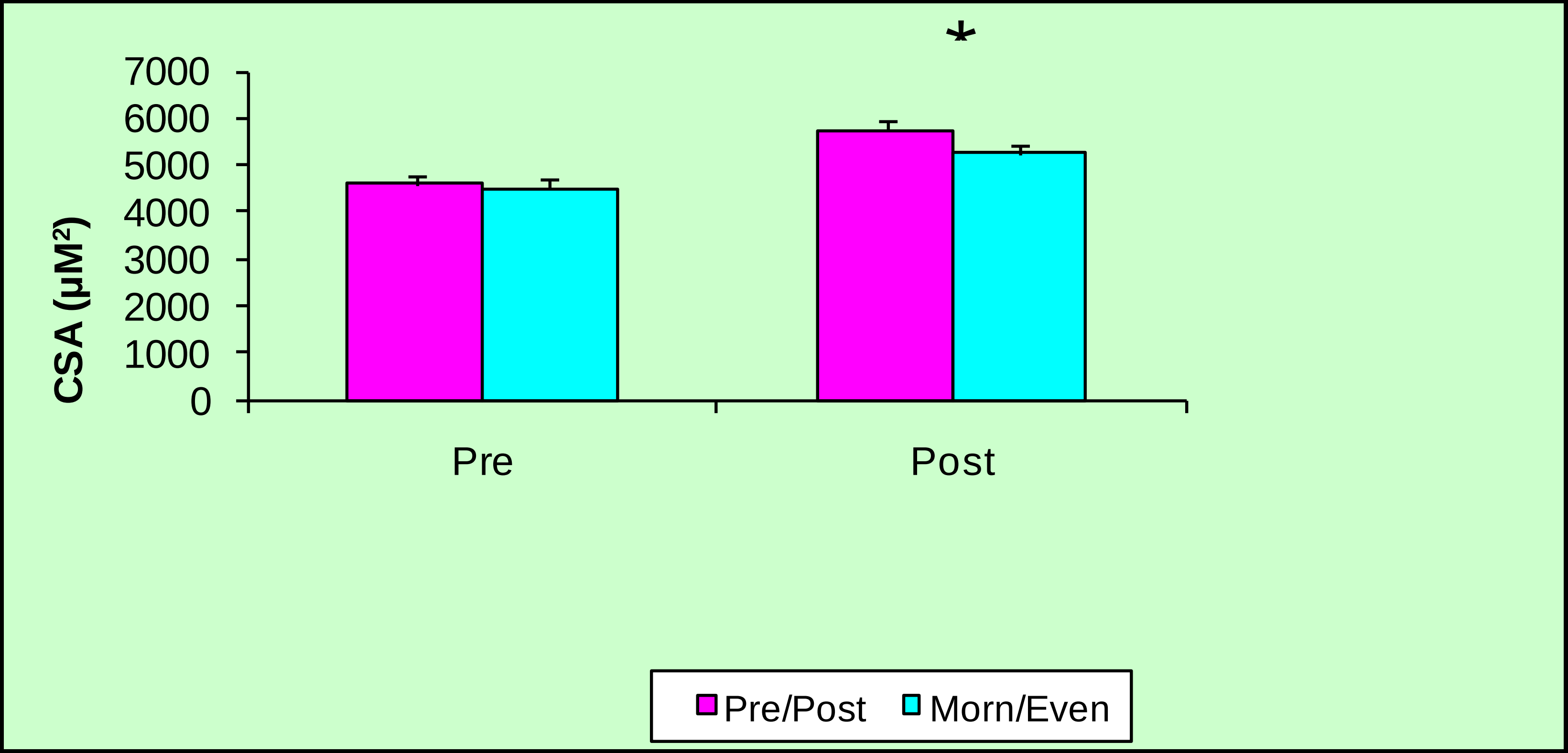
Cribbs and Hayes, 2006

Lean Body Mass



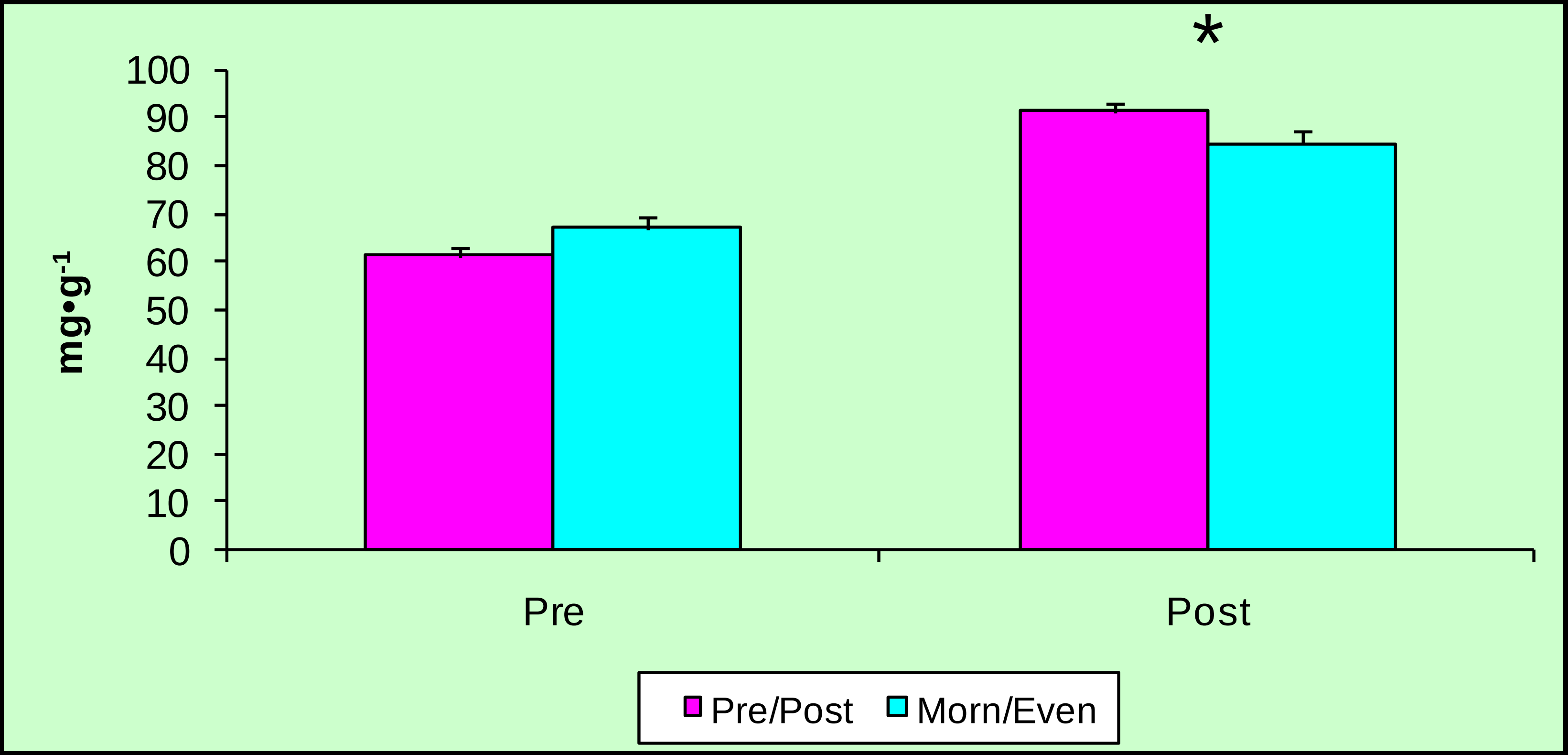
Cribbs and Hayes, 2006

Cross-sectional area of Type IIa fibers



* = significant difference between pre/post and morn/even. Data adapted from Cribbs and Hayes, 2006

Contractile protein content



* = Significant difference between pre/post and morn/even. Data adapted from Cribbs and Hayes, 2006

Summary

- First study to show benefit of protein timing on both muscle hypertrophy and strength gains in young, athletic population.

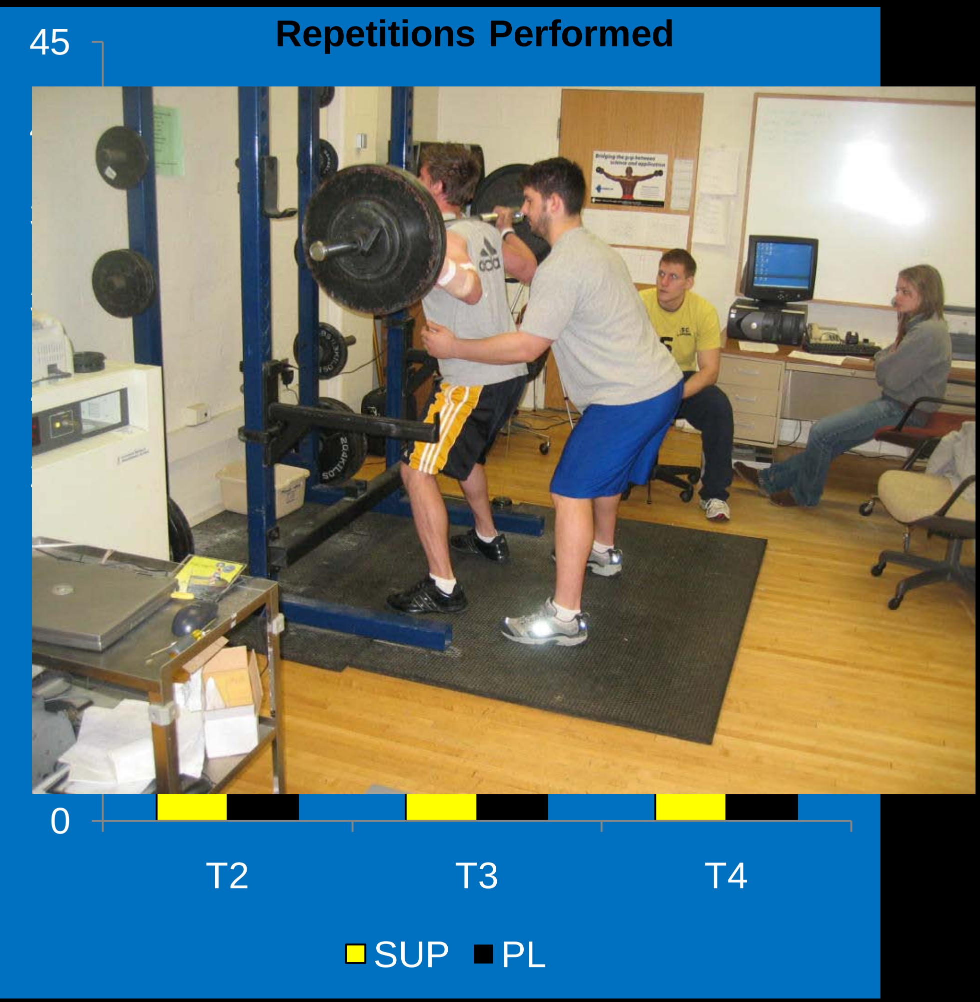
Protein Timing in Competitive Strength Power Athletes

- Protein Timing
  - **Effect of Protein Supplement Timing on Strength, Power and Body Compositional Changes in Resistance-Trained Men.** *International Journal of Sport Nutrition and Exercise Metabolism 2009*
  - **Effect of Protein Ingestion on Recovery Indices Following a Resistance Training Protocol in Strength/Power Athletes. Amino Acids, 2009**

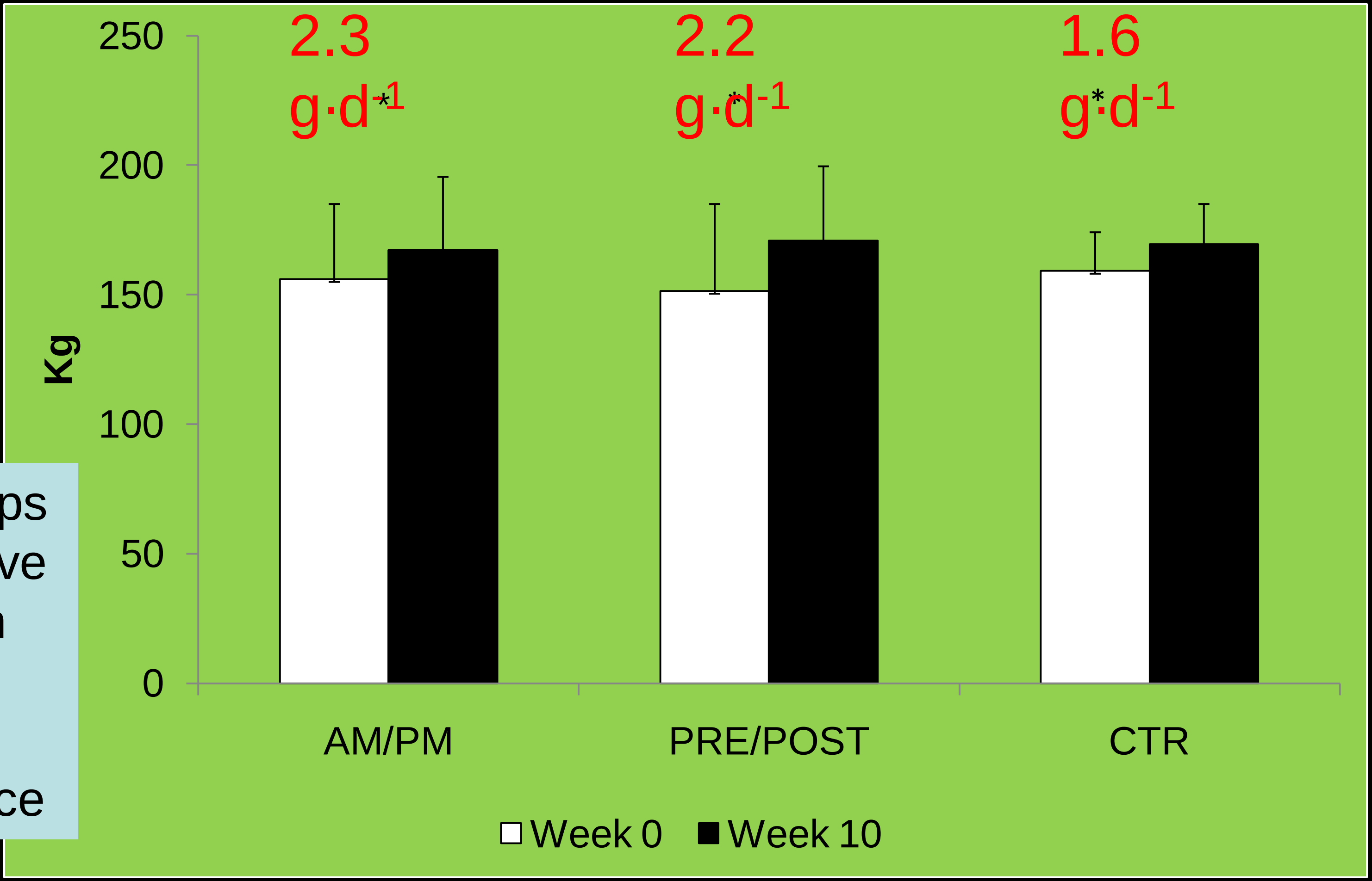
Proprietary Blend With BCAA On Muscle Recovery In Strength/Power Athletes

- 15 male strength/power athletes divided into protein and BCAA blend consumed 10 min prior to and 15 min following the workout.
- Subjects 4 sets of 80% of 1-RM the squat, dead lift and barbell lunge exercises. 90-s rest interval between each set.
- Subjects performed 4 sets of the squat exercise, using the same loading pattern and rest interval 24- and 48 h post.

Hoffman et al., Amino Acids, 2009


Repetitions Performed
45
0
T2
T3
T4
SUP
PL

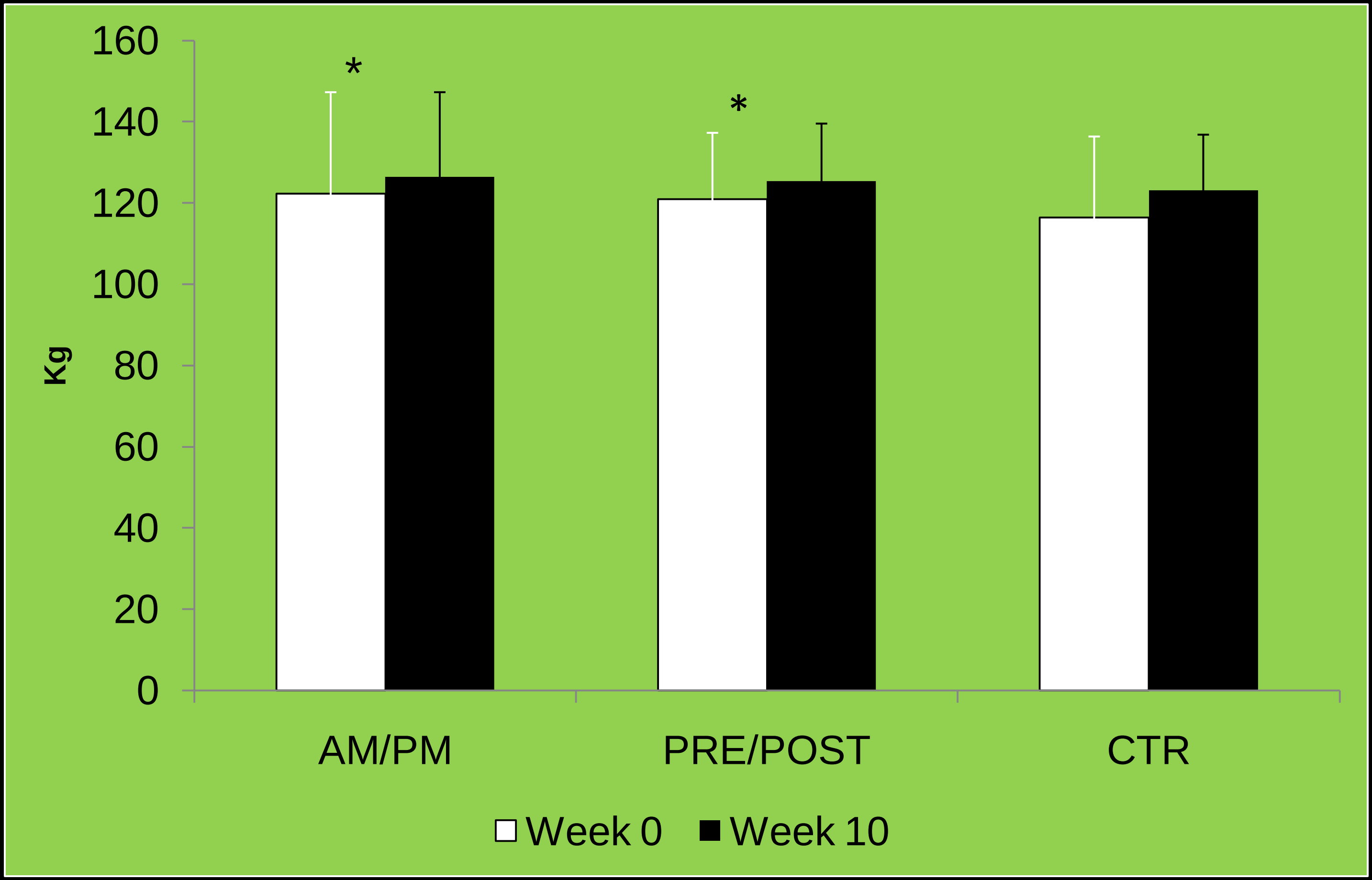
Experienced Strength/Power Athletes: 1RM Squat



All groups in positive nitrogen balance with no difference

Hoffman et al., Int. J Sport Nutr. Exerc. Metab., 2009

Experienced Strength/Power Athletes: 1RM Bench Press



Anthropometric Measures

Variable	Group	Week 0	Week 10
Body Mass (kg)	AM/PM	102.3 ± 18.9	102.0 ± 18.5
	PRE/POST	95.1 ± 14.4	96.3 ± 14.1
	CTR	100.1 ± 27.2	100.4 ± 27.7
Body Fat (%)	AM/PM	24.9 ± 10.2	23.0 ± 8.5
	PRE/POST	18.4 ± 6.3	18.0 ± 6.6
	CTR	21.7 ± 9.7	21.7 ± 8.2
Lean Body Mass (kg)	AM/PM	75.1 ± 5.8	77.2 ± 6.4
	PRE/POST	77.1 ± 8.7	78.3 ± 8.2
	CTR	76.6 ± 13.3	77.0 ± 14.3
Fat Mass (kg)	AM/PM	27.2 ± 16.2	24.8 ± 13.3
	PRE/POST	18.0 ± 8.5	18.0 ± 8.9
	CTR	23.5 ± 17.0	23.4 ± 14.8

Dietary Recommendations for Protein

- **Athletes need more protein and may benefit from up to 1.5 - 2.0 g·kg^{-1} each day.**
- **Strong consideration to the timing of protein, pre and post exercise**
- **Suggested Foods:**
  - Two to three servings of meat, poultry, fish, eggs, beans and peas, nuts;
  - Three servings of low-fat milk, yogurt, cheese;

Effect of Food Source on Muscle Protein

- Milk ingestion stimulated a net uptake amino acids indicating an increase in net muscle protein synthesis.
- Milk may be a suitable post-exercise drink.
- Chocolate milk may be even better

Elliot et al., 2006

Water

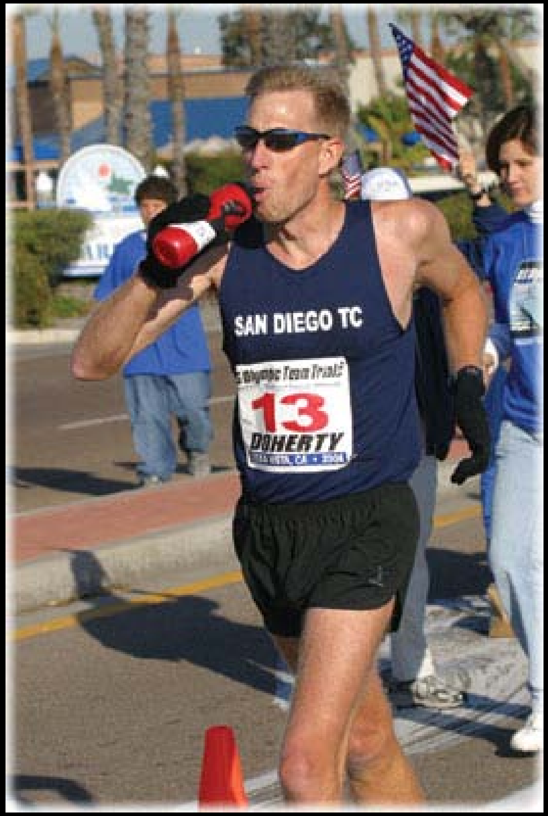
- Critical for dissipating body heat, transporting nutrients and removing metabolic waste.
- Critical for maintaining athletic performance
  - Levels of dehydrations of only 2% of BW can have detrimental effects on performance.

Pre-Exercise/Competition Nutrition

- **Individual tastes must be satisfied first**
  - 1 hour or less before activity (depending on the type of exercise), low GI carbohydrate and perhaps low dose protein.
  - 2-4 hours before activity low GI carbohydrate, lean protein, and healthy fats.
    - Limit high fat foods and processed meats. You'll taste them later!

During Exercise/Competition

- Primary need – Hydration
  - Fluid, fluid, fluid!!!!!
    - Do not wait until thirsty!!
    - Water vs sports drink
  - Add a touch of protein to the sports drink?
- Prolonged Exercise: High GI carbohydrate, energy bars or drinks



Post-Exercise/Competition Nutrition

- Liquid – ease of consumption and rapid replenishment of fluids.
- Contain electrolytes which may accelerate rehydration (primarily in heat, and following prolonged exercise) by speeding intestinal reabsorption of fluids and improve fluid retention (alanine/glutamine).
- Contain rapidly digesting, high glycemic carbohydrates.
- Contain rapidly digesting protein with (i.e. whey protein, essential amino acids)

Post-Exercise/Competition Nutrition

- Recovery
  - Rehydrate
  - Repair Muscle
  - Replenish Energy (stored glycogen)
- Timing is critical
  - Consume a combination of fast-acting protein and high GI carbohydrate.

Thank you